Surgical Correction of

Facial Deformities

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Editor

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Surgical Correction of Facial Deformities

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To
The memory of
My parents
Mr MV Mani and Mrs Achamma Mani
who have been my leading lights

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Foreword

During the past three decades, the pioneering work of Dr Varghese Mani has greatly enhanced and inspired the work of other maxillofacial and plastic surgeons in India.

In 1806, Sir Charles Bell wrote a series of essays under the title of "The Anatomy of Expression" which in truth was a detailed study of the muscles of the face and its bearing on facial expression and the shades of human emotion. Bell's work fascinated both artists and surgeons but most of all the surgical artists who called themselves plastic or reconstructive surgeons. In their enthusiasm many of these men forgot that behind the complex play of muscle and soft tissue, there lay the bony foundations of the face. Great artists like Leonardo da Vinci realized this before we surgeons did.

These artists talked about a face with a good bony structure and taught that only a face with a good bony structure stood the ravages of time. The so-called pretty face without a good bony foundation disappears like the mist, with the first flush of youth.

Years ago, Dr Varghese Mani came to see me work on clefts. Working with him, I began to understand the foundations of the face, I realized how much the soft tissues depended upon a sound foundation and how important it was to build from the bottom that my results began to improve by leaps and bounds. As a result, and for the first time, very late in life, I matured into a true cleft surgeon.

You can imagine then how thrilled I was when Dr Varghese Mani asked me to write a foreword to his book. It gives me an opportunity to acknowledge his influence in teaching me that a good face lies in its bony structure.

To work adequately on the face, a plastic surgeon must be something of a maxillofacial surgeon and vice versa, am I suggesting that in the near future these two disciplines will merge? I would not be too surprised if they do.

Surgical Correction of Facial Deformities is not just another textbook of Maxillofacial Surgery. The first chapter "Evolution of Face and Beauty Through Time" sets the tone to this remarkable volume wherein has gone a life-time of single-minded devotion to the healing of all the internal scars that external deformities can cause. In the chapter on "Surgical Treatment" the author has poured out his vast experience on the correction of these complex deformities of the face giving it a very personal touch. In the second chapter, "Etiology of Facial Deformities" the author touches on the psychological aspects of deformities, an important feature of this sort of work he says, "It has been observed that good looking and attractive people are more successful, intelligent and skilled than unattractive people". This on its face value seems absurd, but if you go to the next line the author says "An unattractive person is usually seen as less intelligent and socially awkward by his peers and associates. They gradually consider themselves as thus and become so". This is exceptional insight into human psychology—shows how people become what they think they are. The chapter on "Troubleshooting in Orthognathic Surgery" is not only meant for the novice surgeon. It stresses the need for sound knowledge of the anatomy of the area, good planning, careful execution and meticulous postoperative care. It touches on the fundamentals of all good surgery, never forgetting that any operation is an insult to the system and the advantages must always outweigh the price that is paid.

This book is a labor of love and I am told by the author that it has taken 3 years in gestation. It has the touch of a master which the author truly is.

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Preface

The importance of face is eloquently expressed in the maxim 'Face is the index of the mind'. Great philosophers, artists, scientists and architects of the past like Plato, da Vinci, Michelangelo, Phidias and others, have realized the importance of beauty and its relation to function. Recent researches indicate that beautiful people are often more successful in life (may be due to the higher level of self confidence); though this is not always true. A study by the author, on the proportion of the facial structures in lieu of evolution, indicates that, by each advancement, the hominid species, gets closer to the 'Golden / Divine proportion'. To reach perfection in proportion (beauty), we, *Homo sapiens*, may take another one million years of evolution through two more advanced species, provided, we do not face the wrath of nature, leading to our extinction.

Surgical correction of facial deformities has achieved a status of its own as a specialty of Maxillofacial and Plastic Surgery. Conceived as a textbook for residents and aspiring young surgeons, this could be useful to the practicing surgeons as well, who would like to hone their skills in orthognathic and facial esthetic surgery.

I am delighted and privileged that Dr HS Adenwalla, a world renowned cleft lip and palate surgeon, has contributed two chapters on cleft lip and palate, in this book. He being my mentor, philosopher and guide, has penned the foreword as well. My gratitude to him is boundless.

The predecessor to this book, 'Orthognathic Surgery- Esthetic Surgery of the Face', published by Jaypee Brothers Medical Publishers in 1995, was well received by practitioners, faculty and students. However, the fast and ever-expanding technological and scientific advancements made this book a little vapid, and demanded something more than a mere revised edition of it. This conviction, along with nudging from fellow surgeons, pressure from students and request from the publisher, made me venture into the writing of this new textbook, *Surgical Correction of Facial Deformities*.

The first chapter of this book, "Evolution of Face and Beauty Through Time", is the result of a pet research project of mine. I am grateful to my co-authors, Dr Eldho T Paul and Mr KS Harish Kumar, for their invaluable help in preparing this chapter.

I express my sincere gratitude to all the contributors. No effort has been spared in making this book as informative and up-to-date as possible.

May I present this book to the fraternity.

Varghese Mani

Acknowledgments

I am immensely grateful to Dr HS Adenwalla, a world renowned cleft lip and palate surgeon, who is my mentor, philosopher, guide and friend. He has not only contributed two chapters, but also written the foreword, which has added value to this book.

The contributors were magnanimous to respond positively to my request to author some of the chapters. I place on record my sincere gratitude to them.

Dr George Eipe, a senior colleague has reviewed the entire text and has given timely advice. My gratitude to him is beyond words. My thanks are due to my beloved wife, Mini, for giving me moral support and helping me in this project.

My confidential assistant Mr KP Vinod, and office staff Mr Jerry Jose, Mr Ebin Elias and Mr Basil T Varghese were helpful in typewriting the text and drawing the diagrams. I acknowledge the help rendered by my colleagues, Dr Bobby John, Dr Vinod Sankar, Dr Arun George, Dr Tojan Chacko, Dr Ranjith Kumar P, Dr Anthony George, Dr Giju George, Dr Eldho T Paul and Dr Sajad Salam, and my students, Dr Abie Paulose, Dr Mathew James, Dr Chancy U, Dr Jalaja KP, Dr Manu Johns, Dr Roshna M Bava, Dr Remya Kareem and Mr Abin Varghese in preparing the case reports and compiling the references. I put on record my gratitude to the management of Mar Beselios Dental College and the Secretary, Mr Salim Cherian, and Administrator, Mr Mathew Varghese, for supporting me in this project. Many others have helped me directly and indirectly in the preparation of this book. My thanks are due to them as well.

Most important is my gratitude to Jaypee Brothers Medical Publishers, a leading firm of medical publishers in the continent, for publishing this book in a beautiful format.

Contents

Chapter 1

Varghese Mani, Eldho T Paul, KS Harish Kumar

Introduction

It is an accepted scientific fact evinced by paleo-biologic (fossil) findings that life has progressed by evolution from a strand of protein to the highly complex intelligent human being, through changes subjected to rejections and selections over a period of 2000 million plus years. During the progression of life, movements have changed from chemotactic to intentional; activities from instinctual to conscious and decisions from logically linear to intuitionally complex. From passive existence, awareness and conscience emerged. All these phenomena point to the premise that life is progressing towards perfection where all the positive qualities like function and beauty meet. This chapter is an effort to extrapolate and project the evolution of the human face and its beauty through the fourth dimension.

Ancestry of Humans

Life started in the water and a group of aquatic vertebrates migrated to the swamp to become amphibians. Slowly and consistently reptiles and mammals evolved. Later the arboreal apes came into being and a group climbed down from the trees to the terrain. The fore limbs were released and gradually the bipedal, erect, straight faced, intelligent humans came into existance.

An excellent parallel to the concept of evolution is seen in the Indian mythology as the ten incarnations of Lord Vishnu, the sustainer of the universe. The nine incarnations were in the following order. (1) The fish, an aquatic vertebrate. (2) The tortoise, an amphibian. (3) The pig, a mammal. (4) Narasimha, half man and half animal. (5) Vamana, the dwarf man (bushman). (6) Parasurama, the wood cutter having an axe as his armament. (7) Sreerama, the hunter having bow and arrow as his armament. (8) Balarama, the farmer having a plough as his tool, depicting the cultural evolution from a forest dweller to an agriculturalist. (9) Krishna, the glorified lover of all times and a modern statesman. The tenth incarnation is yet to come. He is Kalki the destroyer who comes for the final judgment. Most of the mythologies predict this plight to the human race **(Figure 1-1)**.

Climatic cooling during the late Miocene period (6.0 to 5.3 million years ago) might have triggered speciation of Hominin super family. This period is marked by the speciation of other mammalian families as well. The diversification of humans and chimpanzees took place somewhere during the late Miocene period. This period was marked by climatic changes compounded by simultaneous global cooling and drying trend. However the lack of sufficient fossil records during this period puts a question mark on the veracity of this generally accepted postulate.[5,23]

These geological events made the common ancestors of humans and the chimpanzees to split as rain forest dwellers of West Africa and open dry habitat dwellers of East and perhaps North Africa. The former evolved into arboreal modern chimpanzees and the latter to the modern humans.[2] The period of separation of the humans and the chimpanzees from their common ancestors is debatable. The late hypothesis theory based on molecular studies supports the date of separation as 4 to 5 million years ago. But some recent gene analysis suggests the date as 5 to 6 million years ago. Some authors put it to as 10.5 million years.[28]

In 1655 Isaac de la Payrere from France discovered stone tools used by primitive men. He claimed that these tools belonged to men who lived before Adam. His findings were condemned and books were burned by the church

Figure 1-1: Ten incarnations of Lord Vishnu, the sustainer of the universe according to Indian mythology. This is an excellent parallel to the concept of evolution.

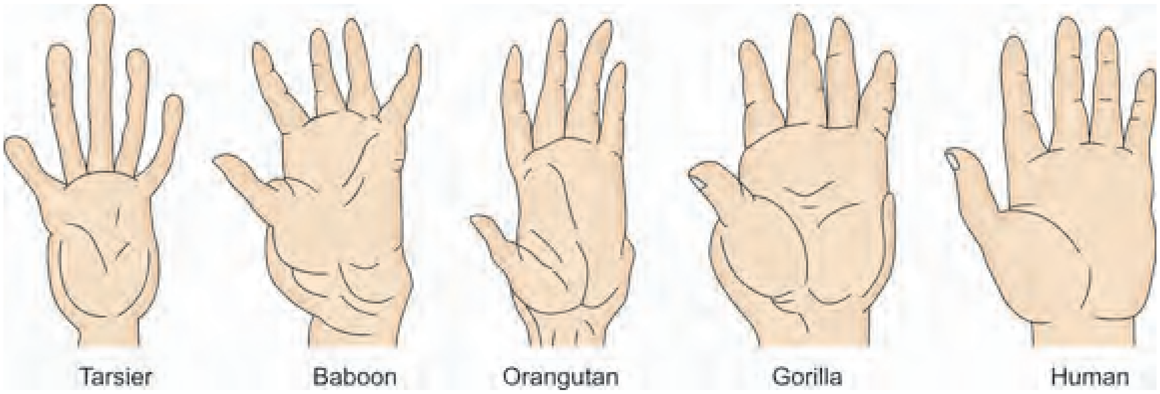


Figure 1-2: Opposable thumb gave more dexterity to the hand and helped in making and using the tools.

authorities. However by late 18th century Paleo-anthropology became a scientific discipline.

As the common ancestor of apes and humans climbed down from the tree and started walking on their hind limbs. Their forelimbs became free and took over many of the functions of the jaws, like fighting, carrying, holding, etc. Development of an apposable thumb facilitated tool making, which in turn helped the enhancement of intelligence, and vice versa **(Figure 1-2)**. Though modern humans and apes show stark differences in their posture, structure and morphology, the differences were less with the earliest hominins, and the subtle differences were mainly due to bipedalism (walking upright on two legs) which brought the foramen magnum forward. The pelvis became bowl shaped as it shortened and broadened **(Figure 1-3)**.[22] Many factors were responsible for the facial changes. Receding jaws and expanding skulls made anthropologists state that the "Brain case is expanding at the expense of the jaws". Several environmental, developmental and evolutionary factors played their roles in the changes that have taken place in the physical characteristics of the humans. This Chapter briefly deals with the evolution of the human face and its beauty.

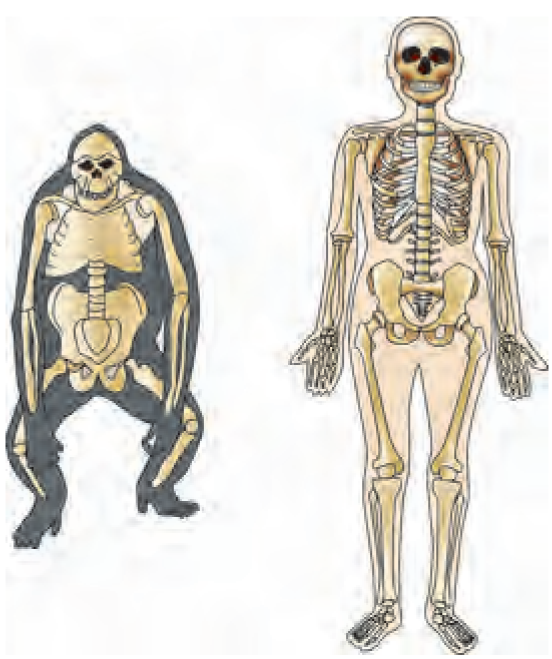


Figure 1-3: The straight posture of the humans made the face straight and the pelvis short and bowl shaped. The foramen magnum got shifted forward.

The modern man known scientifically as *Homo sapiens sapiens* belongs to the larger family 'Hominidae'. Living humans, all human ancestors and many extinct members of the Australopithecus belong to the 'Hominidae' family. Our immediate biological cousins are Cercopithecoidea (old world monkeys and apes) and Pongidae (chimpanzee, gorilla and orangutan). It is generally accepted that we are not the direct descendants of any of the existing monkeys or apes or even the old world monkeys. Instead, we had a common ancestor.

In 1856 a strange skull was discovered in the Neanderthal valley in Germany. The skull belonged to a hominid later named as Homo neanderthelensis. Ernst Heinrich, a German Scientist opined that the skull is half human and half ape. (Though Charles Darwin had completed his voyage of the Beagle, his book *'Origin of Species'* had not come out at that time. It was published on the 24th of Nov 1859).[7]

In the book '*The Descent of Man*' Charles Darwin wrote, "We must acknowledge, as it seems to me, that man with all his noble qualities, with sympathy which feels for the most debased, with benevolence which extends not only to other men but to the humblest living creature, with his god like intellect which had penetrated into the movements and constitution of the solar system – with all these exalted powers, man still bears in his bodily frame the indelible stamp of his lowly origin".[8] In 1890, a Dutch physician Eugene Dubois opined that the skull got from the banks of a river in Java is a link between man and ape. Johansson is credited with the finding of the fossil skeleton of 'Lucy' (Australopithecus afarensis) in Ethiopia the upright walking mother of all modern humans. Members of the family Hominidae are the bipedal primates.

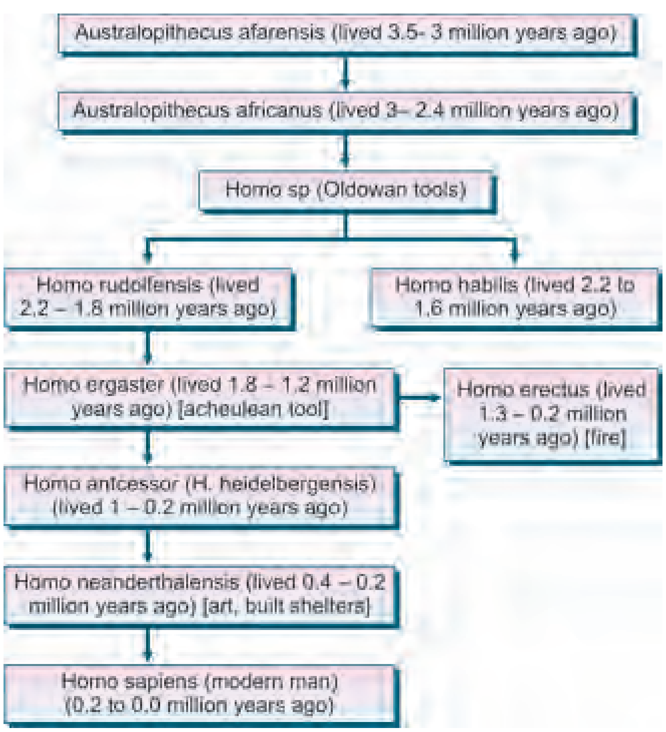
Ardipethecus Ramidus ('Ardi' means ground or floor, 'Ramid' means root) lived about 4.4 million years ago. A piece of the Foramen magnum indicated upright posture. The leg and pelvis indicated a semi-bipedal mode of locomotion. Fossils of these species were discovered by White, et al in 1994. This species is at present considered the ancestor of Australopithecines.[37]

From Australopithecus the evolution of humans took place at a breakneck speed. Reasons attributed are many:

- Early humans were a restless species
- They had a tendency to migrate and were subjected to varied climatic, geographical and environmental conditions which necessitated adaptation. This acted as an impetus for evolution through natural selection.

During the last 2 million years there was co-existence of different species of hominid species.

Important Hominid Evolution



Changes Through Time

A systematic analysis of the evolutionary trend in Hominin family shows that the physical and intellectual changes took place in humans, quite gradually and consistently directed towards betterment and perfection. It is to be noticed that nature is very conservative and economical. Body parts which lose their function/purpose, gradually become vestigial and disappear and as a response to the demand of nature new tissues emerge and take up new functions and specialize as new organs. As the importance of the evolution shifted from physical to intellectual, the evolution of the brain gained more importance.

The striking difference between humans and their closest living relatives (chimpanzees and Gorillas) is in the size of the brain and their lifespan. The brain is larger by a factor of 3 to 4 and the lifespan is larger by a factor of 2. According to Kettard S Kaplan and Arthur J Robson the larger human brain is an investment with initial costs and later rewards.[16]

Cranium of modern man is characterized by its globularity and facial retraction. According to Daniel E Lieberman and associates, the developmental changes that led to the modern cranial form were derived from a combination of shifts in cranial base angle, cranial fossa length and width, and facial length.[19]

Brain Case

Hominins were the first animals to 'grow' an extended limb outside of themselves (by making tools). Tools are considered as extra corporeal limbs. This has reduced the pressure on the body for frequent adaptations. But this increased the stress on the neural tissue to develop intelligence to use and modify the tools.[6] Absolute brain volume has more than tripled from A. afarensis (480 cc) to H. sapiens (1500 cc) and the relative brain size has increased more than double.[25,34,38] Full appreciation of objects and events in the external world was dependent upon the development of the brain cortex. According to Elliot Smith this occurred only when man became human.[38] Analysis of the prehuman and the modern human skulls, evidently shows tendency for increase in frontal bossing during evolution. This is due to the increase in the size of the frontal lobe which is considered to be the seat of intelligence. Thus slanting forehead has become straight.

An interesting study has been conducted by WP Rock et al in 2006. They have compared human skulls from the 14th, 16th and 20th centuries. They found that the horizontal measurements in the anterior cranial fossa and the maxillary complex were greater in the modern group. Cranial vault, especially anterior cranial fossa, was significantly higher in modern skull. They concluded that the medieval ancestors had more prominent faces and smaller cranial vaults than modern man. The angle SNA (S-Sella, N-Nasion, A-Deepest point of the maxilla in the anterior part below the anterior nasal spine) was lesser in modern man indicating the reduction in the size of the maxilla. The prefrontal area is accepted to be the seat of intelligence. Increased intracranial dimension and high forehead of the modern man are evidences of the increase in brain size over centuries.[26] This evidence is good enough to show that evolution is occurring in a much faster pace than generally thought.

Brain size in relation to the basicranial length is an important determinant of the basicranial angulations. Spoor et al (1999) and Liebermann (2000) opined that differences in cranial base angle are more likely to account for facial retraction in modern humans.[20,32]

Absolute brain volume has more than tripled from A. afarensis to H. sapiens and the relative brain size has more than doubled.[21] Despite the lack of fossil proof, biologists of early days who were proponents of evolution, like Lamarck, Thomas Huxley and Charles Darwin, speculated that bipedalism preceded encephalization. Their speculation was proved right later by archeological studies and fossil findings.[20] The frontal lobe and cerebrum are supposed to be the seat of intelligence. One of the striking features that delineates Homo sapiens (the wise man) from his ancestors is the prominence of the forehead by its steep rise. The modern human skull looks infantile compared to the Neanderthal skull with the cranium more round and delicate. Comparison of the brains of amphibians, reptiles, birds and mammals shows the increase of the brain size mainly due to the enlargement of the cerebrum **(Figure 1-4)**.

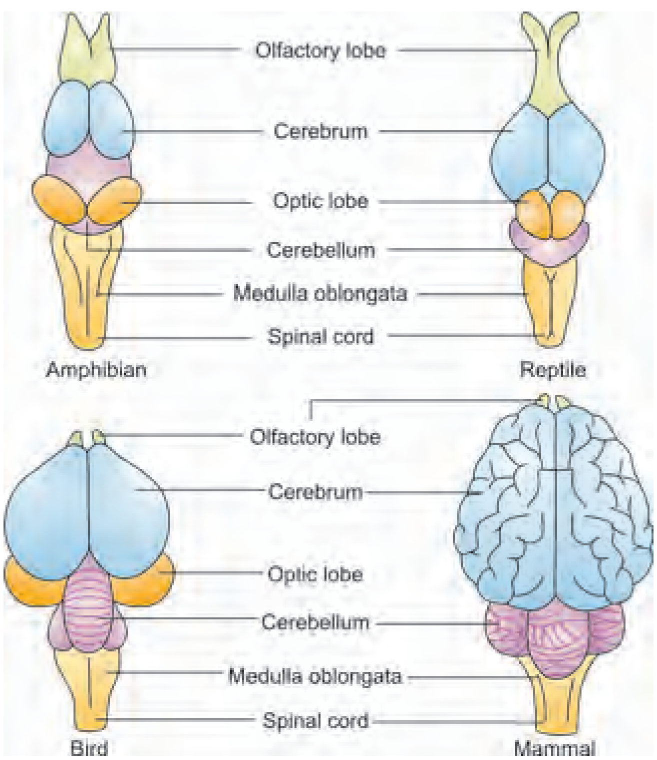


Figure 1-4: Cerebrum controls intelligence. Comparison of brains from Amphibian to Mammal.

Facial Changes

Reduction in the size of jaws and teeth could also be attributed to the development of tools and transfer of functions from the jaws to the forelimbs. In fish the breathing function is by the jaws. In mammals the jaws perform many functions like, carrying and fighting besides chewing food. The modification of the skull is a gradual adaptation and evolution when the arboreal ape climbed down from the tree and had to travel through the terrain. In the terrain he had to travel fast to escape the predators as well as to reach the prey or food faster. To be faster bipedal locomotion is superior than knuckle walking. For bipedal locomotion the protruding jaw was a hindrance as it blocked the vision of the immediate ground in front. This also necessitated reduction of the jaw size. The released fore limbs found better use and took over many of the functions of the jaws. For better dexterity and skillful use of the hand stereoscopic vision became necessary and eyes were pushed from sides to front. To support the skills cortical mechanism developed. As development of the tools (extra corporeal limbs) occurred, demand on physical evolution reduced and the demand on intellectual evolution increased resulting in increased volume of the brain.[31]

Certain other morphological adaptations occurred along with bipedalism. These include Valgus knee angle, anteriorly placed Foramen Magnum and short, broad, bowl shaped pelvis.[4] As the jaw size reduced the masticatory muscles also reduced in size. For the ape the jaw is broadest at the canine area. But in man it is broadest at the condyle region. This is because the skull has expanded in lieu of the enlarged brain, pushing the glenoid fossa laterally **(Figure 1-5)**.[5,18]

During the embryonic development the mandible develops as two halves which got joined in the midline. This area is subjected to great strain owing to the powerful muscles of the apes and the pre-humans. To contain the stress at the inner side of the anterior part of the jaw a shelf of bone called the 'Simian shelf' developed. In humans the muscle size reduced, the jaw size reduced and the simian shelf disappeared. The remnant of the shelf is the genial tubercles to which the genioglosses and

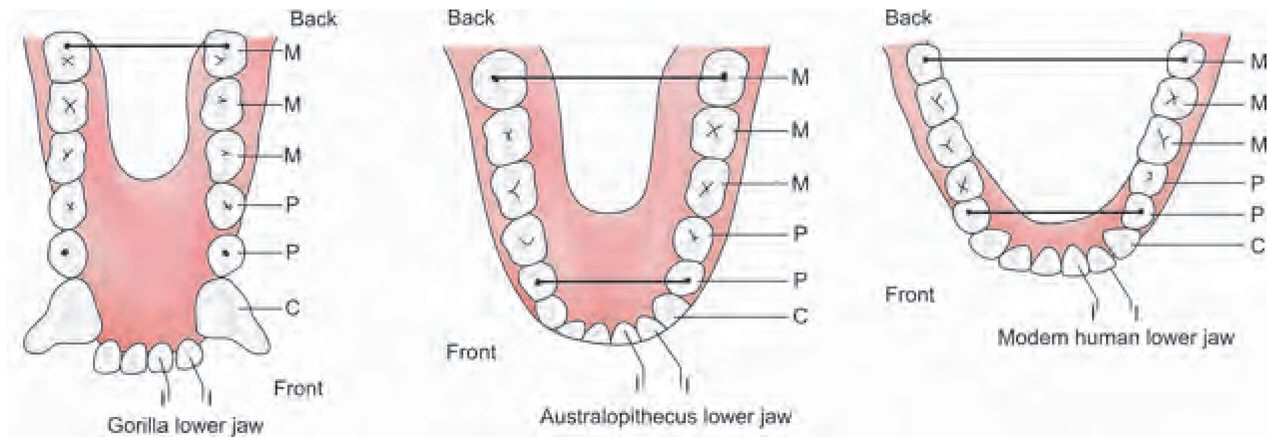


Figure 1-5: The lower jaw got widened at the condylar region as the skull enlarged.

geniohyoid muscles are attached. Genioglossus is an important muscle in the movement of the tongue. Chin has moved forward and the jaw got widened at the posterior region to give more space on the inner side providing more manoeuvrability to the tongue which helped in development of speech. Paul Broca, a great French anthropologist, discovered that the third inferior frontal convolution is the speech area, which was later named after him. Now it is understood that this is only one of the cortical areas associated with speech.

Among the Hominins, H. sapiens is the only species having a well developed chin. A protruded chin makes it vulnerable to injury in a fight or accident. In response to it the neck of the condyle has become thinner and the sigmoid notch became deeper. A direct force on the chin will be transmitted to the condyle. If the neck of the condyle is broad and strong the force could fracture the temporal bone and in turn injure the brain, killing the victim. Hence, a thin condylar neck was a favourable evolution for the protection of the brain.

According to Rebecca Rogus Ackermann genetic drift should be the primary cause for facial diversification. However selection also might have played a role in the changes in facial morphology during the evolutionary process.[1]

Reduction in the size of the jaws during human evolution is associated with its shift under the skull. This had an influence on human dentition. A beautiful regular smile is the result of a delicate balance among many different facial genes. And so a regular smile, the sign of good genes, some theorists claim, is the underlying sexual significance of physical beauty.[6]

The face, jaw and teeth of Mesolithic humans of 10,000 years ago were about 10% more robust than those of modern humans. 30,000 years ago (Paleolithic period) it was about 20 to 30% more robust. Relative to the body size the molars of A.afarensis are 1.7 times larger than expected compared to that seen in modern species of Hominins. An interesting finding to be noted is that the tooth size has increased in A. robustus and further evolution decreased the tooth size. This could be attributed to the food processing habits (using tools), which the later forms developed.[34, 35]

Orbit and Eye

Eyes owe their beginning to the sensitivity of protoplasm to injurious and beneficial effects of light. Early prevertebrates had directional organs which used light. True vision resulted as the brain enlarged and accessory organs developed to change the curvature of the lens for focusing light. The orbits moved forward and stereoscopic vision developed. Chimpanzees and humans have chromatic and non-chromatic vision. As the face reduced in length, the size of the orbit also reduced in height.

In earlier primates and hominins the brow ridge is very large like a penthouse protecting the eye. These large brow ridges act as buttresses to resist the stress exerted by the massive jaws while chewing. As the jaws and the muscles of mastication became smaller, the parietal bone became prominent. The brow ridges lost its function and got reduced in size.

Lips

The mouth of the archaic mammal the 'duckbill' is surrounded by a leathery skin which could be a remnant of a tough reptilian skin. In the spiny ant-eater the lip has muscles and is covered by hair. As evolution progressed to the great apes the lips got protrusive. The philtrum of the upper lip is peculiar to the hominins. As the jaws shrunk in size the alveolus too got reduced and the lips rolled outwards exposing the mucosa lined part of the lip. Another theory suggests that the protracted period of suckling could be the reason for eversion of the lip.

Nose

Jacobson's organ found in amphibians, reptiles and primitive mammals allows the food taken in the mouth to be smelt. It is absent or vestigial in the adults of higher primates and man, but is found in foetal life. Among the primates the nose of modern man is prominent by the elevation of the bridge and prolongation of the tip.

Compression of the lateral part of the maxilla and the movement of the orbits medially have narrowed, elevated and arched the nasal bone forming the bridge of the nose. Tip of the nose is not vestigial, but evolving. The shape of the nose in man is mainly due to the regression of the jaws. The rising bridge of the nose might have evolved to give resonance to the voice.

Following is a brief list of major facial and cranial changes that have taken place during evolution of the hominins.

Summary of Facial Changes (Figure 1-6)

1. Brain case enlarged and become rotund.
2. Frontal bossing has taken place making the forehead straight and higher.
3. Nose became prominent.
4. Chin became prominent and the simian shelf reduced to genial tubercles.
5. Jaw size and tooth size have reduced.
6. Sigmoid notch has become deeper.
7. The neck of the condyle became thinner.
8. Brow ridge reduced in size.
9. Face became more oval.
10. Neoteny has set in as the skull enlarged and became rotund.

Evolution of Facial Beauty

Concept of beauty varies from time to time, from place to place and from race to race. However there are certain inherent norms and universal concepts about beauty. Multitude of ideas about beauty is evident from the host of statements by many authors, thinkers and artists. The statement from Shakespeare 'Beauty lies in the eyes of the beholder',[29] suggests that beauty is subjective.

'A thing of beauty is a joy forever
Its loveliness increases; it will never
Pass into nothingness'.[17]

Above lines by poet John Keats shows the positive influence of beauty on emotional perception. He glorifies beauty. True beauty radiates vitality and happiness.

Opinions about the beauty of the face abound as it is more subjective than objective. Some consider attractiveness as having average ingredients. However Francis Bacon in his 'Essays on Beauty' opines that 'There is no excellent beauty that hath not some strangeness in the proportions'.[3] However symmetry has got a positive influence on facial beauty.[12,33] Attractiveness is related to positive physical qualities.

Theory of 'survival of the fittest' was proposed by Charles Darwin.[8] Survival could be by challenging the odds or by adapting to the periodical positive and negative changes taking place in nature. Fitness often is a harmonious and balanced blend of both. Simply getting adapted to the surroundings to exist doesn't mean progress; if so, the thrust of evolution is not to advance but to compromise and the result will be just survival or

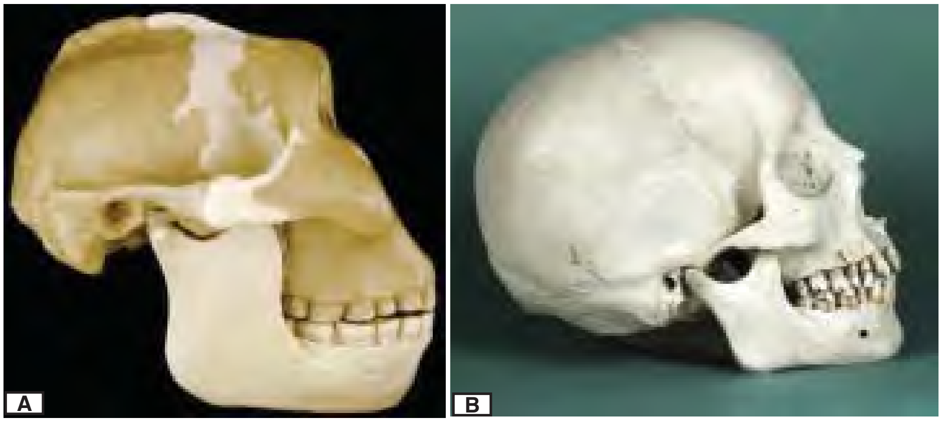


Figure 1-6: Comparison of the skulls of the Australopithecus (A) and the Homo sapiens (B).

passive existence. In nature we find not passive existence but a positive progression of life empowering the species to face the challenges and odds. Hence 'fit to survive' takes another dimension strengthening the species to progress through evolution. All round progression has taken place in metabolism, reproduction, form and function.

Anaerobic metabolism has been replaced by aerobic metabolism in higher forms of life since it is more efficient in the production of energy. One molecule of glucose can produce two ATPs in anaerobic metabolism, but the same molecule can produce 8 ATPs by aerobic metabolism. Efficiency in metabolism and production of energy had some compromise on existence reminding us that mere existence/survival is not the sole aim of life. As evolution progressed, organs got specialized and the regenerative capacity of the organism regressed.

A single celled organism never dies by aging, but multiplies, by binary fission. It dies only by injury or starvation. Next step, in the evolution of reproduction, was conjugation and division where genes were allowed to mix. Single celled organism by evolution became a multicelled organism with functional differentiation of parts and had to accept death by aging. In lower forms each cell is a stem cell; which had the property to grow into a full organism. Vegetative reproduction in plants is an extension of this phenomenon. Gradual evolution has seen sexual differentiation and sexual reproduction. This has improved and increased the pace of evolution by mixing of the genes and promoting selection.

Sexual reproduction paved the way for selection of a partner. Purpose of evolution, it appears, is to attain perfection, and hence it is important that the organism moves on to better fitness by each generation, and to a better species. During the progression of evolution, the stress shifted from physical to intellectual evolution by gradual refinement of the nervous system to a well formed controlling brain. This quantum shift might have happened in a reptile **(Figure 1-7)**.[27] (In the story of genesis in Bible, the fruit of knowledge is given to Eve by a reptile)

Sexual reproduction brought the need for the selection of a partner for reproduction. To produce a better offspring a better partner is important. Attractiveness became an important criterion for selecting a partner for reproduction. External features representing health, vitality, and intelligence, by default became attractive. During the cascade of mutations and selections during the evolutionary process attractive features got incorporated into fitness and the 'survival of the fittest' became akin to 'survival of the prettiest'. Thus prettiness came to represent brightness and fitness. True beauty evokes pleasure (a thing of beauty is a joy forever' John Keats) and pleasure is perceived in the subconscious limbic

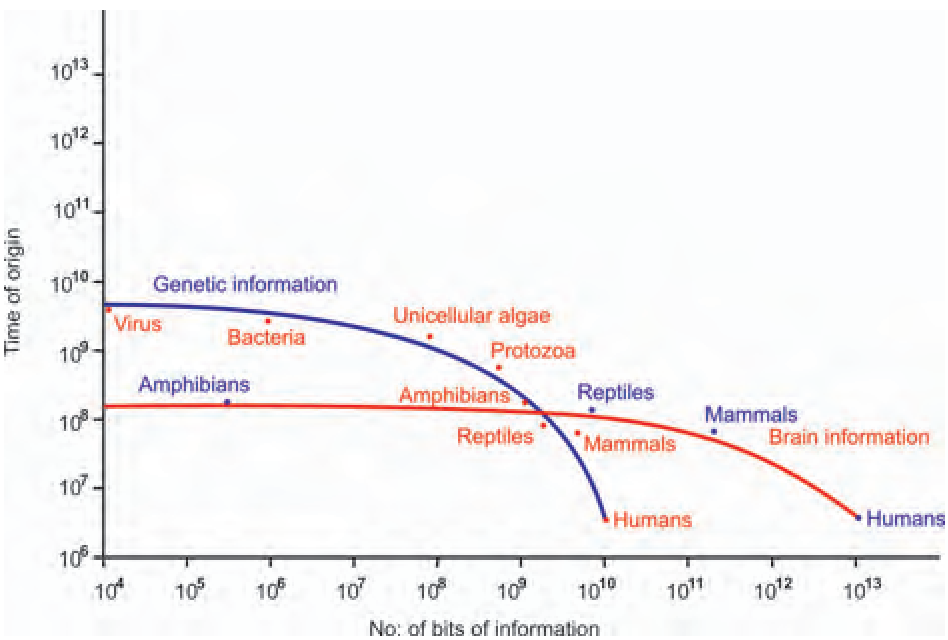


Figure 1-7: This is a very interesting observation of the comparison of bits of information in the genes and the brain.For amphibians the information in the gene is much more than the information in the brain. But it is opposite in mammals and maximum in humans. If we observe the graph we find that the transition took place in a reptile. (At this point you may remember that the fruit of knowledge was given to Eve by a snake). We can observe that from then on the focus of evolutionary thrust was more on the brain than on the body (Idea taken and modified from Carl Sagan) .

system, not in the cognitive neo cortex. This developed in response to pressures exerted on the brain throughout its evolution.[10]

Many studies have showed that baby face characteristics like large and round eyes, larger domed forehead and well defined chin are attractive features especially for females. It is to be noted that during the hominin evolution, tendency towards retention of childhood characteristics is evident. This tendency is called Neoteny.[15] Humans exhibit a number of neotenies compared to apes. In Chimpanzees adulthood starts by 2 to 3 years. In humans it is by 14 years only. Some of the features of the face that are attractive are brown skin, full lips, larger distance between the eyes, larger and darker eyelashes, darker eyebrows, high cheek bones, narrow nose, etc. People with more attractive features were assessed to be more successful, contended, pleasant, intelligent, sociable, exciting, creative and diligent.[11] This finding poses a question whether intelligence and other positive qualities cultivate attractiveness, or, the confidence imparted by attractiveness in turn makes people more intelligent and creative. Infact, these are interdependent and contributory. If attractiveness and intelligence are extrapolated in time, we can deduct that both are the two main factors in selection of a mate – survival of the prettiest and the brightest or in other words, survival of the fittest. This plays an important role in evolution.

Leonardo Da Vinci has drawn the 'Vitruvian man' relating divine proportion to the human anatomy. The body when in divine proportion is able to effect maximum efficiency with least effort and also imparts better aesthetics, reflects health and provides survival advantages. Perfection ensues where function and beauty meets. Attractiveness has been a lure since the evolution of sexual reproduction. The pretty and the bright ones stand a better chance in the competition for a partner. Proper proportion expresses fitness and prettiness. On the aspect of selection and propagation of genes and subsequent evolution, function always precedes form. Hence it can be postulated that prettiness is a manifestation of fitness and brightness.[14,24]

Attractive physical features provide external clues to health and fertility status, the two most important requirements for genetic success. "In civilized life, man is largely influenced in the choice of his wife by external appearance". Charles Darwin noted so, way back in 1871. Longitudinal data suggest that attractive women tend to marry men of high occupational positions. (Is the dough, the marker for men?). Baby like neotenous traits are considered attractive for females.

Testosterone, a male hormone, makes the person grow big and also causes lower jaw to grow longer. Estrogen a female hormone increases the lip volume.[36] Estrogen also increases the fat deposits on the buttocks and the thighs and increases the utilization of abdominal fat giving the woman an hour glass (gynoid) appearance which is associated with menarche.[30] Large breasts give an impression that there is plenty of milk for the child which is important for a healthy offspring, a fundamental prelude to propagation. Wide girdle bones can house a large head of the foetus which means a large brain volume (more intelligence). (High heeled foot wears worn by ladies give prominence to both hips and brests and make them more desirable as a partner.). Humans are considered to be the species having the maximum pain during labor and the highest maternal mortality rate. This could be due to the fast intellectual evolution (large head of the fetus) and not so fast physical evolution (pelvic bone). For taking the forbidden fruit of knowledge the woman is cursed by God that she will deliver her child in pain (Genesis, Old treatment, Bible).

Studies have shown that young babies are attracted by beautiful faces which suggests that humans have got an innate capacity to appreciate balance and harmony.

As face is the prime seat of expression it is the area of attention. Study of evolution of face and skull gives insight to the evolution of facial beauty. It is said that during the evolutionary process the brain case got expanded at the expense of the jaws. This statement simply means that brain volume is increasing and jaw size is reducing.

To analyze beauty and to analyze the proportion of expansion of brain case and reduction of the jaw size, a modified cephalometric analysis is applied.

MN Line: MN line is drawn from the junction of the frontal bone and the nasal bone *(fronto nasal junction - 'N')* to the base of the mastoid process (point M). This line virtually separates the brain case from the jaws.

Point 'I': Tip of the upper incisor is taken as point 'I'

Point 'B': A parallel line to the occlusal plane is drawn at the middle point from occlusal level to lower border of the mandible at 1st molar region. The point where the line meets the anterior border of mandible in the lateral picture of the skull is taken as point 'B'.

Point 'Ch': Point where anterior border and lower border of mandible meet is marked as point 'Ch'.

Point 'V': A perpendicular line to 'MN' line is drawn from point Ch to the top of the skull. This point is marked, as Point 'V', to mark the vertex.

Angle MNI: Gives projection of maxilla. This is found to be decreasing from Australopithecus afarensis to Homo sapiens in the order of evolution. This indicates the reduction of maxillary size.

Angle MNB: Angle MNB gives the anterior projection of the mandible. It is also found that this angle is decreasing and it indicates that the anteroposterior length of mandible is decreasing **(Figures 1-8 to 1-11).**

Angle of frontal bossing: This is calculated by drawing a tangent of the frontal bone at the anterior plane. A horizontal line parallel to the occlusal plane is drawn from point N. Angle formed between these two lines is the angle of frontal bossing. It is found that this is increasing during the evolutionary process due to the increasing size of the brain, especially the frontal lobe.

Figure 1-8: Gorilla. Gorilla has got a massive jaw and a small cranium. The crest of bone at the vertex is to support the large and powerful Temporalis muscle.

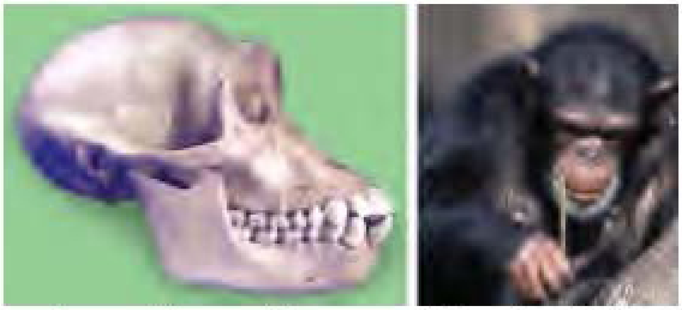


Figure 1-9: Chimpanzee's jaws are smaller than that of gorilla.

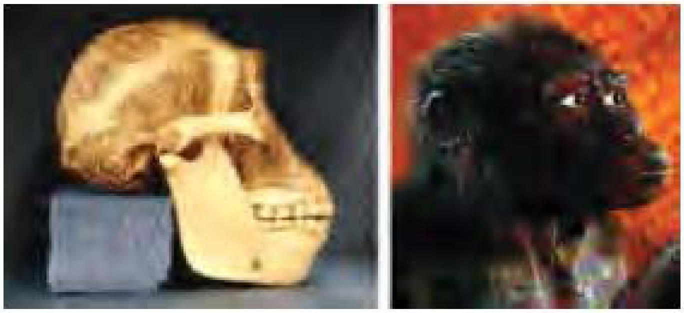


Figure 1-10A: Australopithecus africanus.

Figure 1-10B: Australopithecus boisei.

Figure 1-10C: Homo habilis, the skilful man.

Figure 1-10D: Homo erectus, the erect man.

Figure 1-10E: Homo neanderthalensis.

Skull Face Proportion

When we discuss the proportions for beauty it is imperative that we consider Phi (φ) the golden proportion which is 1:1.618.

Figure 1-10F: The skull of Homo sapiens. The term means 'wise man' (modern man).

(The pictures of the pre human skulls are taken from the web sites of various museums of natural history.)

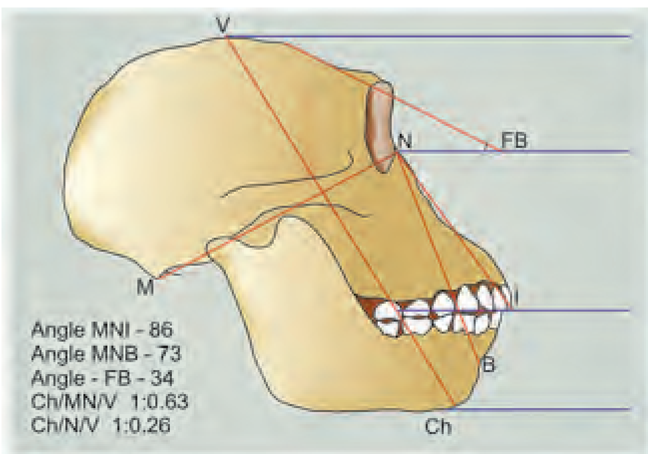


Figure 1-11A: Cephalometric analysis of Australopithecus africanus.

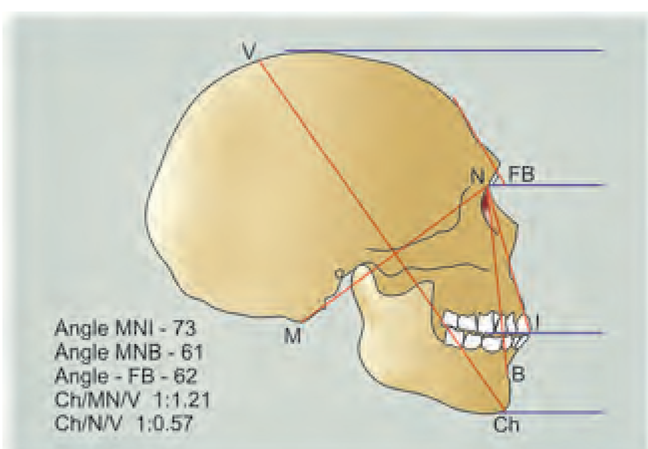
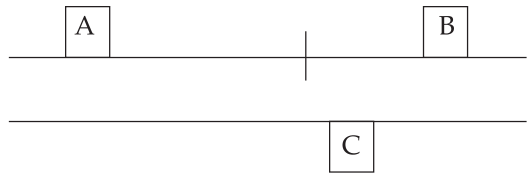


Figure 1-11B: Cephalometric analysis of Homo sapiens. Cephalometric analysis to assess and compare the following parameters of different species of the Hominidae family: (1) Maxillary projection (angle MNI), (2) Mandibular projection (angle MNB), (3) Frontal bossing (angle FB), (4) Cranium- facial proportion in two planes— frontal-lateral.

When a line is divided in such a way that the ratio of the shorter section to the larger section is equal to the ratio of the larger section to the whole line, this is supposed to be the most aesthetically pleasing point at which to divide a line. This is known as the golden proportion and is represented by the symbol φ (Phi). The name 'Phi' is derived from the Greek Sculptor Phidias who used golden proportion in his most famous work Pantheon.[9,13] This proportion is linked to many aspects of beauty that Kepler called it 'Divine proportion'.



A+B=C; A/B = C/A = 1.618

Phi is supposed to be the most pleasing proportion and is used in the construction of Greek temples and by Michelangelo and Da Vinci in their paintings. Michelangelo's famous painting 'Temptation and Expulsion from Eden' is a well known example of this proportion.[24] It appears that in nature this system of designing is abundantly observed in living and even non-living structures. Design of leaves, petals of flowers, shells, etc. use a series called 'Fibonacci series' (0, 1, 1, 2, 3, 5, 8, 13, 21,…….), where the adjacent two numbers are added to get the third number. It is interesting to note that the proportion between the adjacent two numbers is near about 1.618 which is known as the golden or divine proportion **(Figure 1-12)**.

Figure 1-12: Nautilus. Fibonacci series and the Phi proportion is abundantly seen in nature.

The proportion is calculated between the cranium and the face on two different planes – frontal and lateral. The distances between Vertex (V) and the nasion (N) and from the nasion (N) to lower border of the mandible are taken in a vertical plane. This proportion in the frontal plane appears to approach the golden proportion as the evolution progresses **(Table 1-1)**.

Table 1-1: During the last 3 million years about 7 important Hominin species evolved. During this evolutionary process, maxillary and mandibular projection has decreased. But the frontal bossing has increased. Cranium- face proportion has increased in favour of the cranium which enlarged and became globular (MYA-Million years ago; MNI- Projection of maxilla; MNB- Projection of mandible; FB-Frontal bossing; Ch/MN/V- Proportion of the dimension cranium and the face on the lateral plane; Ch/N/V- Proportion of cranium and face on the frontal plane)

Species	*Years (MYA)*	*Angle MNI*	*Angle MNB*	*Angle FB*	*Ch/MN/V*	*Ch/N/V*	*Brain vol.(cc)*
A. africanus	3	86	73	34	0.63	0.26	420-500
A. bosei	2.5	80	70	26	0.7	0.27	480
H. habilis	2	78	69	51	0.92	0.5	650
H. ergaster	1.5	76	65	43	1.06	0.5	850
H. erectus	1	75	65	46	1.06	0.5	800-1000
H. neanderthalensis	0.5	74	65	50	1.05	0.51	1400-1800
H. sapiens	0	73	61	62	1.21	0.57	1040-1600

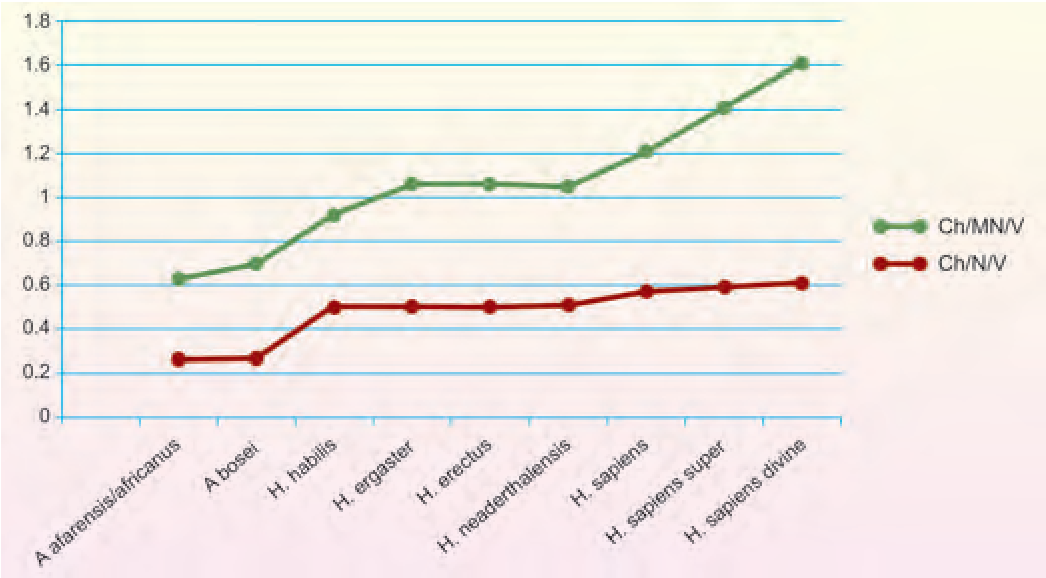


Figure 1-13: This graph of the proportion between the cranium and the face is projected in time to reach the golden proportion. To reach the golden proportion it may take another one million years and two more advanced species.

On the lateral plane MN plane, virtually divides the cranium and the face. As the brain case is expanding and the jaw size is reducing, this proportion approximate the divine proportion as evolution progressed. If the extrapolated graph (of the proportions from the pre-human to human face through different species) is projected to the future we can deduce that it will take another million years for the present proportion of skull and face to reach divine proportion **(Figure 1-13)**.

If we go through the archeological history of the Hominidae, branching of the humans took place about 7 million years ago and from then about 7 to 8 species have emerged to reach the present Homo sapiens. It is also to be noted that during the first 3 to 4 million years from the branching of the Hominid from his cousins, the apes, evolution was slow and took a faster pace during the latter half. So we can expect another two species of humans evolving during the next one million years. By then the adult face may look very similar to that of the present child with large head, large eyes, small jaws with an oval face. The children's face often exhibit the divine proportion.

The Superman concept of Nietzsche and the statement "Man is poised between the beasts and the gods" by Plotinus, points to the evolution of Homo sapiens to a more beautiful and intelligent being. Can we call the future two spices 'Homo sapiens super' and 'Homo sapiens divine' respectively? **(Figure 1-14)**.

Do We Ever Reach Perfection?

Perfection is at (the) infinity. It is like a mirage where function, beauty and such positive qualities meet and merge.

May I quote from the scriptures "God is sleeping in minerals, awake in plants, walking in animals and thinking in humans"

Figure 1-14: The future human may look like this cute angelic 'Barbie doll' with large head, large eyes, small jaws and oval face.

Life could be one of the properties of matter. Evolution is an innate quality of life, and may be the quest of nature/ matter for perfection, where trial and error/rejection and selection are the norms. By the wars between nations, the strife between religions and the fights between races, molesting nature with atomic wastes, suffocating her with pollution and hindering her plans by eugenics, are we on the path of self inflicted extinction? Are we, as Sir Winston Churchill said, on the verge of "a new dark age made more protracted and perhaps more sinister by the light of perverted science".

Are we misusing the self awareness and intelligence we have gained through evolution? If so, we may be subjected to nature's wrath-extinction and a future intelligent species (if any) may rename us 'Homo stupid'.

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Chapter

2

Varghese Mani, Antony George

Introduction

Receding jaws and expanding skull during the evolutionary process of the hominid face made anthropologists remark that 'the braincase is expanding at the expense of the jaws'. It is the shape of the face and the facial expressions that predominantly delineate human species from the rest of the primates . The concept of beauty of face varies with race, culture and region. Sharp, harmonious and balanced features are hallmarks of beauty.

Like elsewhere in the body, the basic framework of the face is the facial skeleton, and the facial features greatly depend on the skeletal architecture. Alignment of teeth also plays a major role in facial aesthetics.

Orthognathic surgery (ortho - straight, correct; gnathia - jaw) or surgical straightening/correcting of the jaw, is a well developed branch in Oral and Maxillofacial Surgery. Though challenging and intriguing, it is a remarkably gratifying field in facial aesthetic surgery.

Orthodontics is a branch which deals with correction of dentition. It intends to move the teeth to a better functional and aesthetic relationship and also to a stable position in the alveolus. Orthodontia has advanced from simple tooth movement to growth modification techniques. Understanding the changes in growth and development of the maxillofacial region has greatly contributed to the advancement in myofacial functional appliances and growth modification techniques.

The technological advancements and research in the field of aesthetic surgery, orthognathics, orthodontics and functional orthopedics have contributed a lot towards the progress and innovations in the branch of orthognathic surgery. The possibilities of orthognathic surgery are noteworthy. However there are limitations too. The same is true for orthodontics as well. It could be even said that orthognathic surgery developed to overcome the limitations of orthodontics. Orthognathic surgery in conjunction with orthodontics can do wonders on the face.

Etiological Factors

Growth pattern of the facial skeleton is genetically and developmentally modulated. The genetic factor is not easy to be manipulated, as it is imprinted in the genes. Facial syndromes and congenital defects are mostly genetically determined, and they are hence prenatal.

Congenital Defects

Common congenital deformities are Hemifacial microsomia **(Figures 2-1A and B)**. Treacher Collins syndrome **(Figures 2-2A and B),** Facial clefting syndromes **(Figure 2-3),** Cranial synostosis like – Crouzon's syndrome **(Figures 2-4A and B),** Apert's syndrome, Pierre Robin syndrome, etc.

Figures 2-1A and B: Hemifacial microsomia.

Figures 2-2A and B: Mandibulofacial dysostosis (Treacher Collins syndrome). It is a hereditary congenital deformity. Picture shows father and son, both affected by the same syndrome (Treacher Collins syndrome exhibits hypoplasia of the malar bones and receding chin. It is an autosomal dominant trait).

Figure 2-3: Facial clefting syndrome.

Hemifacial Microsomia

Gorlin and his associates were the first ones to use this term.[8b] This malformation of first and second branchial arches, consists of unilateral micro-otia, macrostomia and failure of formation of mandibular ramus and condyle. Although maxilla, zygoma, orbit and temporal bones are affected, the distinctive feature is the mandibular deficiency. Asymmetric mandibular growth plays a pivotal role in the development of facial asymmetry.[13b] Soft tissue affliction varies from minimal to severe with deficiency of muscles and macrostomia. Morphology of the external ear may vary from normal to total absence.

Treacher Collins Syndrome

This autosomal dominant syndrome is also referred to as Berry syndrome and Mandibulofacial dysostosis. The main characteristic is the near total absence of zygoma and its arch and the resultant ocular malformation. Maxillary dental arch is narrow and the palate is high. Both zygomatic arches are missing and the masseteric muscles are attached to the temporal fascia. Coronoid and condylar processes are often hypoplastic. Ramus is short with a prominent antegonial notch. Chin is retrusive.

Figures 2-4A and B: Frontal bossing, proptosis and maxillary deficiency with Cl III occlusion are the classical features of Crouzon's syndrome.

Crouzon's Syndrome

This syndrome was reported in 1912 as hereditary craniofacial synostosis by Crouzon MS.

The triad of symptoms are craniosynostosis, midfacial hypoplasia and exophthalmos.

The deformity ranges from very mild to severe.[5b] The cranial vault is frequently brachycephalic or oxycephalic.[5c] Mid-facial retrusion results in Cl III malocclusion and contributes to exophthalmos **(Figure 2-4A).** In severe cases, eyelid closure may be impaired. Often intracranial pressure is increased, and frequent monitoring may become necessary.

Apert Syndrome

This syndrome was described by Apert in 1906 as teratologic type, compatible with life and well charecterized by the coexistence of following peculiarities. High cranial vault flattened posteriorly and sometimes also on the sides, bulging in an exaggerated fashion in the upper frontal region, syndactyly of all the four limbs, brachycephalic calvaria, shortened cranial base and protruded supraorbital margins, creating a concavity at the middle of the frontal bone.[4b] Midfacial hypoplasia is a distinctive feature, but exophthalmos is not as pronounced as in Crouzons. Maxilla is deficient and the teeth are crowded and /or impacted. Incidence of cleft palate ranges from 10% to 30%.[5a] Low set hairline, hypertrichosis of eyebrows and mild ptosis of the eyelids may be present. Symmetric syndactyly of all four limbs is a characteristic feature.

Plagiocephaly

Asymmetry of the cranium is often referred to as plagiocephaly and could be frontal, occipital or hemicoronal. Frontal plagiocephaly is usually due to premature closure of the ipsilateral half of the coronal and frontosphenoidal sutures. This affects the facial skeleton as well. However the deformity is less pronounced at the midface and still less in the mandibular region.

Others

Heredity has a profound influence in the morphology of the face. Some facial characteristics run in the family. 'Hapsburg Jaw' (mandibular prognathism) seen in the German royal family is a typical example. Growth too plays an important role in the facial development and characteristics.

Gene therapy and stem cell research are advancing at a fast pace. In the near future genetic modulation may become a routine procedure.

Environmental Factors

Environmental, external and developmental factors play important roles in shaping the face. Shape of the facial skeleton depends on the forces acting on the skeleton, by facial muscles, tongue, breathing, function, nutrition, etc. However, growth is closely related to the rate of maturation.[37] Peak velocity of facial growth is achieved a few months after the peak velocity of height.[22] Skeletal age as assessed from a hand wrist radiograph is an efficient, effective and widely accepted indicator of developmental age.[9, 36] There are varied opinions regarding the age at which the sutures of facial bones get ossified. Sicher opines that it starts at the mid thirties. Wright is also of a similar view. But Persson found union of bony sutures at 17 years. Letham and Burston found no evidence of synostosis at the age of 18 years.[17,25,34, 41] Thus we find that there is no consensus on the time of ossification of the facial skeleton, among the scholars. Studies using experimental animals have conclusively shown that appliances can cause alterations in the development of T.M joint and other areas.[5a] Functional appliances are widely used in clinical practice to modify the growth in children with remarkable results.

Nasal Block

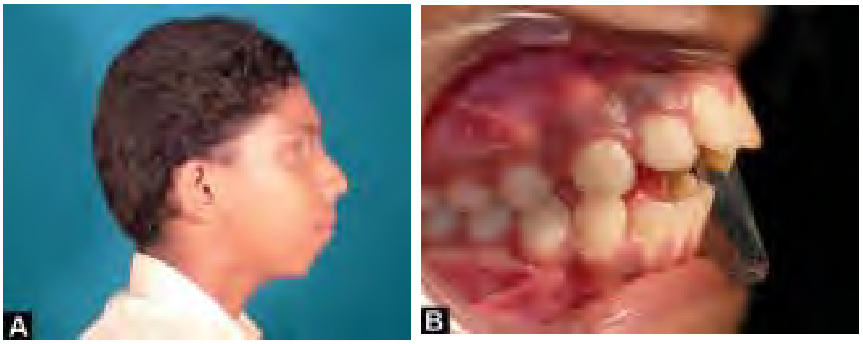
Children having block in the nasopharyngeal airway due to adenoids, enlarged tonsils, deviated nasal septum, etc. develop a peculiar facial appearance called "adenoid facies". Such patients have narrow arch, high palate, narrow bird beaked face, mouth breathing habit, open bite, speech defects and long face. Though the term 'Adenoid facies' is used for long face syndrome, in many instances, it need not be due to nasal obstruction.[39] Weakness of mandibular elevator muscles reduces the biting force, resulting in over eruption of posterior teeth, leading to a long face.

Tongue Thrust Habit

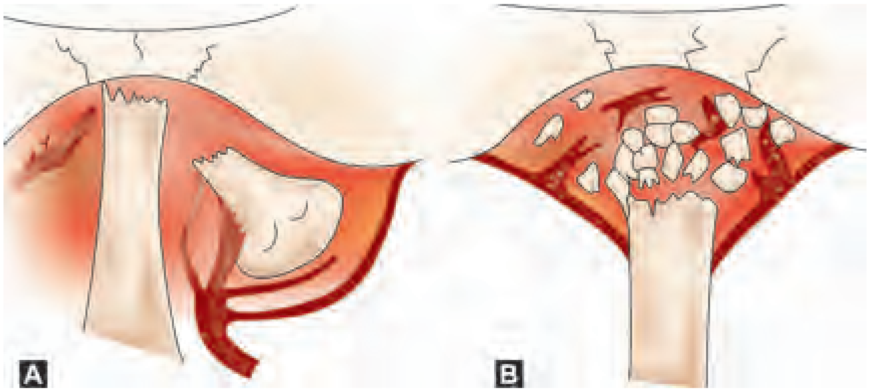
Whether open bite develops due to tongue thrust or vice versa is controversial. Surgical correction of open bite often alleviates the tongue thrust habit **(Figures 2-5A and B).**

Trauma

The most important postnatal reason for facial deformity is trauma. Injury to the nasal septum at a young age reduces the forward and downward growth of the maxilla.[32] Septum, though not a major factor, does contribute to the maxillary growth. Experimental studies in animals have provided substantial evidence to the importance of nasal cartilage in the growth of mid-face.[4,13a, 33] Soft tissue and muscles surrounding the facial skeleton contribute to normal growth of the underlying bone. Severe scarring of the soft tissue could adversely affect facial growth.



Figures 2-5A and B: Anterior open bite. (A) Facial profile, (B) Occlusion.



Figures 2-6A and B: (A) Fracture displacement of the condyle. (B) Injury to condyle. Children are more susceptible to ankylosis due to injury to condyle.

Mandibular growth takes place primarily through three pathways: (a) Primary growth, an important factor, takes place at the condyle, underneath the fibrocartilaginous layer by the proliferation of cartilage which later changes to bone, (b) Enlargement of the jaw takes place on the surface of the ramus by apposition and resorption of the outer and inner surfaces respectively, (c) As teeth erupt, new bone is added to the alveolus. Moreover, remodeling of bone takes place in the rest of the region. Functional matrix theory proposes that the major contributing factor for development of the orofacial region is function.[20, 21] However it has to be accepted that condylar growth and other remodeling activities too play an important role in the growth and development of the orofacial structures.[5,9,38] Injury to the condyle in children can cause asymmetry of the face **(Figures 2-6A to 2-8).** Tissue reaction to the injury can be varied. Trauma to TMJ could cause hemarthrosis followed by ankylosis. This will compromise both function and growth, resulting in severe deformity. Retarded growth and occasionally exaggerated growth of the condyle are observed subsequent to minor TMJ injuries. Some researchers consider that the main reason for retarded growth is scarring of the surrounding tissues, rather than the injury to the condyle.[18]

Figures 2-7A and B: Ankylosis of temporomandibular joint. Front and profile views. Bird face is a classical appearance of bilateral ankylosis, which occurs in childhood.

Muscle Disturbances

Muscles have an important role to play in facial appearance. Hollenshed divided the mimetic or facial muscles into five chief groups concerning mouth, nose, orbit, ear and face.[10] The muscles of mouth and nose are innervated at their posterior inferior aspects by the facial nerve. They get inserted to the skin and most arise from periosteum of the facial skeleton.[31]

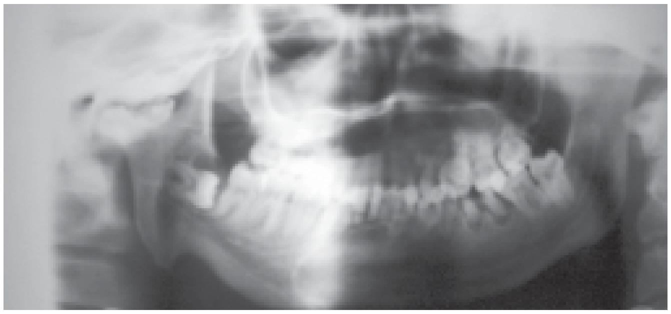


Figure 2-8: OPG showing ankylosis of the TMJ.The right condyle is flattened and united with the temporal bone, and the coronoid process is elongated.

Muscles and their activity have definitive influence on bone growth. Atrophy of the muscles due to denervation or other reasons can reduce bone growth at their area of attachment and cause asymmetry. Similarly, hypertrophy of a muscle can increase the growth of the bone to which it is attached. Masseteric hypertrophy causing excessive bone growth at the angle of the mandible is not very uncommon, resulting in a square face **(Figures 2-9A and B).**

Figure 2-9A: Bilateral masseteric hypertrophy.

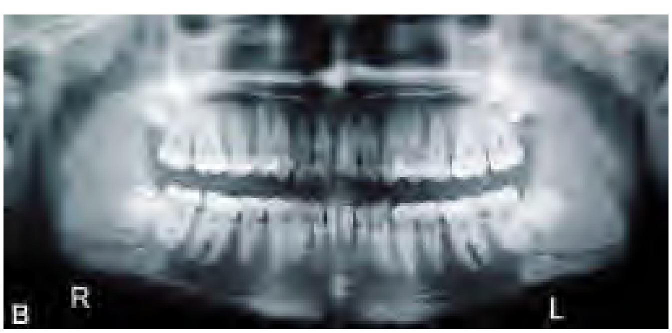


Figure 2-9B: Radiograph showing enlargement of angle of the mandible subsequent to masseteric hypertrophy.

Hormones

In Acromegaly, due to increased production of the growth hormone by the pituitary, there is an increase in the size of the mandible producing long jaw or mandibular prognathism (**Figures 2-10A and B)**.

Figures 2-10A and B: (A) Acromegaly photograph, (B) Lateral cephalogram.

Condyle

Condylar hyperplasia is another reason for mandibular asymmetry. Facial asymmetry could be due to excessive growth of ramus in both vertical and horizontal dimensions **(Figures 2-11A and B).**[23]

Figure 2-11: Condylar hyperplasia.

Influences of Posture and Other External Factors

Posture of the lip, cheek and tongue can influence the bone. More than the intensity, the duration of the force applied is important in causing remodeling and bone changes. Experiments have proved that continuous pressure against tooth should be of 4-6 hours duration to initiate remodeling of bone and tooth movement.[29]

Biting force has little effect on the development of the facial structures. In fact, biting force depends on the facial structure. It is often observed that there is an increase in the biting force after deformity correction. Our understanding of the reasons for development of facial deformity is not complete. It can be said that genetic factors are the major determinant for the development of facial features. The environmental and the external factors like airway, diseases, forces, habits, etc. play important roles in the development of the facial structures.

Adult shape of the facial skeleton can be reliably predicted in the early puberty. Functional and growth modulating appliance therapy started during earlier stages of growth can alter the growth pattern remarkably. The role of orthognathic surgery is mainly after growth is completed.

Indication for Orthognathic Surgery

Orthodontic treatment is in vogue and the number of people seeking orthodontic treatment is on the rise. As the name indicates orthodontic treatment is limited to the movements and alignment of teeth. Functional orthodontic treatment can to a great extent modulate the growth pattern, provided one 'catches them young'; i.e. during the beginning of growth spurt which is between 8 and 13 years of age. In gross facial deformity where the basal bone is also involved, correction has to be surgical.

Facial deformity can affect both physical and mental development, directly or indirectly. Some malformations can affect occlusion, mastication and speech adversely. It may not be possible to maintain proper oral hygiene if malocclusion is very severe. Moreover patients who resent their teeth, are less motivated to maintain proper oral hygiene, hence the incidence of dental caries and periodontal disease is high in them.[28]

Dentofacial deformities can be a cause for temporomandibular joint problems. It is often felt that psychological problems related to dentofacial deformities are more important than the physical problems.[12,19] Proffit et al are of the opinion that persons with mandibular deficiency are most likely ones to seek orthognathic surgery.[27,30] This varies from region to region and race to race. Evaluation of our case records mainly of South Indian population reveals that the most common reason for orthognathic surgery is maxillary prognathism.

Occlusion can be corrected orthodontically if the deformity is not very severe. Camouflaging of a jaw discrepancy can be done orthodontically to a limited extent. Dental compensation usually occurs naturally. If this compensation is very severe (e.g. Lingual tilting of lower anteriors in mandibular prognathism), surgery to obtain normal jaw relationship may induce severe malocclusion. Hence, during pre-surgical orthodontics, 'reverse orthodontics' is done to decompensate the natural compensation. Though this often makes the facial appearance worse initially, surgery makes the occlusion, appearance and jaw relationship normal.

In short the indication for orthognathic surgery is the facial deformities which cannot be corrected by orthodontic tooth movement, camouflage and dentofacial orthopedics. According to WR Proffit and RP White "Occlusion is important but satisfactory facial aesthetics must accompany it".[28]

Gummy smile is often an indication of the vertical excess of the maxilla. However, a short upper lip and hyperactivity of the levator muscles could be the reasons for gummy smile. These can be assessed with lip in repose and in animation. Normally the upper lip is expected to lie on the gingival margin while smiling. It is hard to lengthen the upper lip. V-Y procedure on the upper labial sulcus usually does not increase the length of the lip; but may avert the shortening of the lip due to scar contracture and help to increase the visibility of the Vermilion.

Patient, parent and doctor conferences have revealed that more than 80% of patients come for treatment due to aesthetic and psychological reasons. Functional reasons came only last on the list. Important functional reasons were speech, temporomandibular joint pain, difficulty in chewing, breathing, snoring, etc. The patient's chief complaints should be given due importance. The ultimate satisfaction of the patients depends on addressing their concerns and rectifying their complaints.[40]

Facial appearance is very important for social acceptance and self confidence. It has been observed that good looking and attractive people are more successful, intelligent and skilled than unattractive people.[2, 3,6-8] Studies show that attractive female workers perform better than unattractive workers.[16]

An unattractive person is usually seen as less intelligent and socially awkward, by their peers and associates.[16] They will gradually consider themselves thus and become thus. Many researchers are of the opinion that patients who underwent orthognathic surgery are happy due to the improvement in their personality and appearance, rather than the functional improvement.[11,35]

Studies conducted by Kiyak HA and Bell R indicate, that the patients who emphasize on functional problems were more satisfied than the ones who focus on aesthetic correction. So they advise that the importance of functional improvement also should be highlighted to the patient before surgery.[14]

Allowing the patients to interact with those who had undergone surgical treatment was found to be very helpful in developing confidence and a positive attitude in them. However the surgeon and the orthodontist should be cautious not to make their patients over optimistic. Unrealistic expectations often result in dissatisfaction and resentment.[15,24]

Proffit and colleagues have conducted a study on Cl II malocclusion patients and come out with certain guidelines as indications for surgery.[26]

1. Overjet greater than 10 mm
2. Pogonion to nasion perpendicular greater than 18 mm
3. Mandibular body length less than 70 mm
4. Face height greater than 125 mm.

Combined orthodontic and orthognathic surgery is the ideal method of treatment. Postsurgically a satisfactory occlusal relationship is essential for good stability. Occlusal stability is important to prevent relapse after surgery. Presurgical orthodontic treatment is planned in such a way as to attain a satisfactory interdigitation of the teeth immediately after surgery.

It is preferable to perform orthognathic surgery as early as possible during the treatment for the following reasons:

1. Orthodontic precision is greater than surgical precision. Hence, even if the arches are 'perfect' before surgery, a reasonable period of postsurgical orthodontics is invariably necessary.
2. Orthodontic tooth movement is much more rapid following surgery, because skeletal and soft tissue relations are normalized and the rate of bone remodeling is increased (as the result of surgery)
3. Patient's facial appearance is improved earlier in treatment which in turn improves both self esteem and cooperation of the patient.[1]

To plan the postsurgical occlusion, model surgery is very helpful. This gives an idea on how pre-surgical orthodontic movements are to be done. Splint fabrication is helpful to maintain proper occlusal relationship while fixing the osteotomised segments. Once rigid fixation is resorted to, postsurgical treatment is limited to the movement teeth alone. Hence discrepancy of bony movements is hard to correct after rigid fixation. In semi-rigid and wire fixation, stability is compromised. In such cases IMF may become necessary. Disadvantage of IMF is that the patient may have to resort to liquid diet, and nutrition may be compromised.

Bone healing usually takes around 2 to 3 months. Fibro-cartilaginous tissue is formed by about one and a half months. This tissue is amenable to forces, and this can be utilized for bony movements by using heavy elastics or orthodontic appliances. There is a tendency for the maxilla to attain a forward position after superior repositioning. During surgery, ensuring the condylar position without strain in the fossa and achieving occlusion are essential. If any discrepancy occurs, it is easier to tackle this problem, if a semi-rigid fixation was employed. The author prefers rigid fixation at the anterior region of the maxilla and wire fixation at the posterior region. If resorting to wire fixation, the surgeon should ensure a good bone apposition. After achieving a good jaw relationship and occlusion, if bony apposition is not satisfactory, rigid fixation using mini plates is advised, lest mobility of the fragments and non-union may occur.

Unnecessary prolongation of presurgical orthodontic treatment reduces patient cooperation and may even induce frustration. Generally, presurgical orthodontics takes around six months and postsurgical three to six months. We have observed that earlier the surgery performed, better is the patient compliance and satisfaction.

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Chapter

3

George Varghese

Introduction

"Ever since Leonardo da Vinci measured a series of embryos and fetuses of different ages, the story of development before birth has fascinated countless students. It is truly a remarkable tale of an orderly sequence of events, by which each human being blossoms out from a minute egg cell, one fifty-thousand-millionth of the weight of an adult man. Thus descriptive embryology can be studied for its own sake. We can, however, probe more deeply and ask: How do the changes occur? ……A knowledge of development is a precious key to a grasp of the anatomical finished products. Although this principle holds for all parts of the body, it is probably true to say that it is more valid for the head and neck.

(Professor P.V.Tobias)

'Growth and development' is a strictly controlled biological process. Clinicians can manipulate some of these signals that control growth. Changes in developmental balances often lead to relapse in orthodontics and orthognathic surgery. In other words, clinical treatment can disturb a state of structural and functional equilibrium, and a natural rebound can follow. The direct target for clinical intervention must be the control process regulating the biology of growth and development.

A fundamental principle of facial growth is that it involves an interrelationship between all component parts. No part is independent or self-contained. Growth works toward an ongoing state of composite functional and structural equilibrium.

There are two types of growth movement. They are: (a) remodelling and (b) displacement.

a. *Remodelling:* In remodelling, the bone surface moves (relocates) by deposition on the side facing the direction of growth movements. This brings about a change in size of each whole bone and sequentially relocate each of the component regions of the whole bone to allow for overall enlargement. Remodelling also progressively reshape the bone to accommodate itself to its various functions and to the contiguous soft tissues. Further, there is a continuous structural adjustment to adapt itself to the intrinsic and extrinsic changes in conditions.

   Relocation function of remodelling: Bones remodel themselves during growth in order to undergo relocation. For example, a point on the posterior surface of the ramus of the mandible in an infant is relocated to the anterior border of the ramus in the adult. The relative position of the point has changed, but the actual point has not changed position. In the maxilla, the maxillary arch and palate move downward through a relocation process. This involves bone deposition on the downward-facing oral surface together with resorption from the upward-facing nasal surface of the palate. In the mandible, as the ramus is relocated posteriorly through combinations of resorption and deposition, the corpus becomes lengthened by a remodeling conversion. Generally, half of remodeled bone tissue is endosteal in origin, and half is periosteal. Half of the inner and outer surfaces are resorptive and half are depository.

b. *Displacement:* In displacement, the whole bone is carried by mechanical force as it simultaneously enlarges. This is physical movement of whole bone that occurs while the bone simultaneously remodels by resorption and deposition to an equivalent extent. As a bone enlarges in a given direction within the joint, it is simultaneously displaced in the opposite direction. The process of new bone deposition does not cause displacement by pushing against the articular contact surface of another bone. Rather, the bone is carried away by the expansive force of all the growing soft tissues surrounding and attached to it by anchoring fibers. For example, the maxilla is displaced downwards and forwards by an equivalent amount as remodelling occurs simultaneously in an upward and backward direction. Similarly the mandible is displaced "away" from its articulation in each glenoid fossa as the condyle and ramus grow upward and backward (relocate) into the space created by the displacement process. All joint contacts and bone ends are of basic significance in the growth. They are the points away from which displacement proceeds and, at the same time, the sites where remodeling lengthens a given bone. They are key locations where certain clinical procedures affect the growth process.

Two types of displacement process can be noticed. They are: (i) primary displacement and (ii) secondary displacement.

i. *Primary displacement*—In this, physical activity takes place in conjunction with bone's own enlargement. Joint contacts are important in this process.
ii. *Secondary displacement*—Here the movement of a bone and its soft tissues is not directly related to its own enlargement. It is a fundamental part of the overall process of craniofacial enlargement.

The primary and secondary displacement growth movements are based upon the "carry effect" produced by the expansion of the soft tissues associated with the bones, not a "pushing effect" of bones against bones.

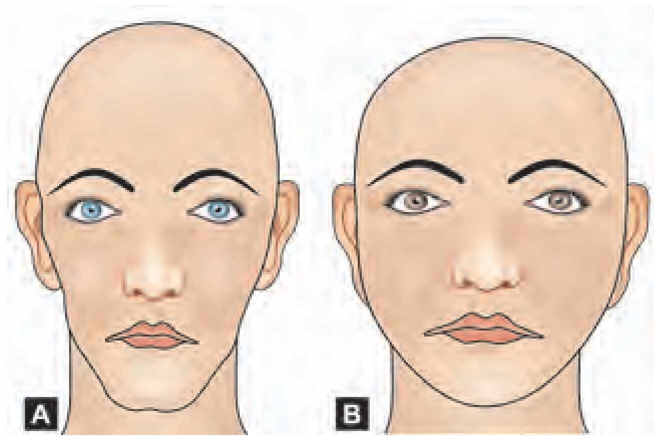
Remodelling and Displacement Combinations

Both primary and secondary displacements as well as remodelling are involved in the multiple-direction growth movements of all bones. A great many different combinations of all three processes are found throughout the craniofacial complex. Clinicians must understand exactly which combinations of processes are occurring, for successful treatment.

It is convenient to divide the craniofacial complex into four areas that grow rather differently: (1) the cranial vault, the bones that cover the upper and outer surfaces of the brain; (2) the cranial base, the bony floor under the brain, which also is the dividing line between the cranium and the face; (3) the nasomaxillary complex, made up of the nose, maxillae, and associated small bones; and (4) the mandible.

It may be noted that the facial complex attaches to the basicranium and the early growing cranial floor is the template that establishes many of the dimensional, angular and topographic characteristics of the face. This is an important factor to be appreciated by the clinicians.

Two extremes in form of the shape of the head are designated as Dolichocephalic (long and narrow) and Brachycephalic (wide short and globular) **(Figures 3-1A and B).** The intermediate form is called Mesocephalic. The dolichocephalic headform sets up a developing face that becomes narrow, long and protrusive. This facial type is termed leptoprosopic. The brachycephalic headform establishes a face that is more broad, but somewhat less protrusive. This facial type is called euryprosopic.



Figures 3-1A and B: (A) Dolichocephalic (long and narrow). (B) Brachycephalic (short and wide).

Cranial Vault

The cranial vault is made up of a number of flat bones that are formed directly by intramembranous bone formation, without cartilaginous precursors. From the time that ossification begins at a number of centers that foreshadow the eventual anatomic bony units, the growth process is entirely the result of periosteal activity at the surfaces of the bones. Remodelling and growth occur primarily at the periosteum-lined contact areas between adjacent skull bones, the skeletal sutures, but periosteal activity also changes both the inner and the outer surfaces of these plate-like bones. At birth, the flat bones of the skull are rather widely separated by relatively loose connective tissues **(Figure 3-2).** These open spaces, the fontanelles, allow a considerable amount of deformation of the skull at birth.

This is important in allowing the relatively large head to pass through the uterine cervix. Following birth, apposition of bone along the edges of the fontanelles

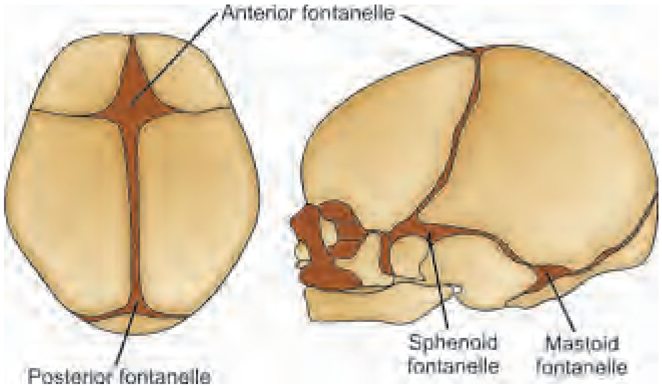


Figure 3-2: The fontanelles of the newborn skull (gray shaded area).

eliminates these open spaces fairly quickly, but the bones remain separated by a thin periosteum-lined-suture for many years, eventually fusing in adult life. Despite their small size, apposition of new bone at these sutures is the major mechanism for growth of the cranial vault. Although the majority of growth in the cranial vault occurs at the sutures, there is a tendency for bone to be removed from the inner surface of the cranial vault, while at the same time new bone is added on the external surface. This remodelling of the inner and outer surfaces allows for changes in contour during growth **(Figure 3-3).**

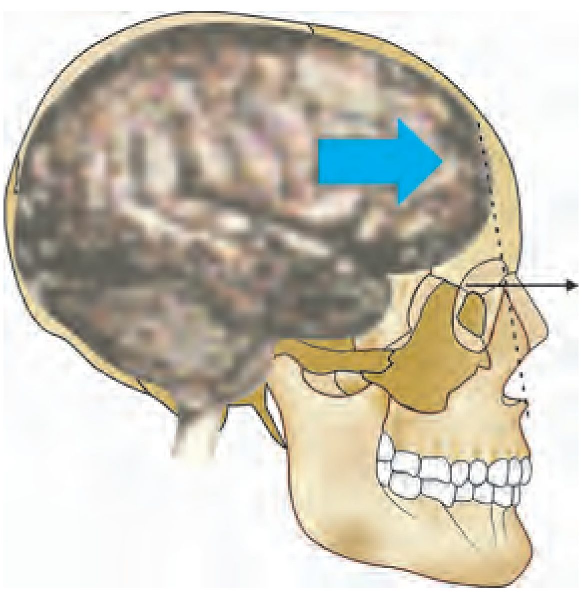


Figure 3-3: Pressure from the growing brain promotes resorption of bone in the inner surfaces of the cranial vault and remodeling allows for changes in the contour.

Cranial Base

In contrast to the cranial vault, the bones of the cranial base are formed initially in cartilage and are later transformed by endochondral ossification to bone. This is particularly true of the midline structures. As one moves laterally, growth at sutures and surface remodelling become more important. Centers of ossification appear early in embryonic life in the chondrocranium, indicating the eventual location of the basioccipital, sphenoid and ethmoid bones that form the cranial base. As ossification proceeds, bands of cartilage called synchondroses remain between the centers of ossification **(Figure 3-4).** These important growth sites are the synchondrosis between the sphenoid and the occipital bones, or spheno-occipital synchondrosis, the intersphenoid synchondrosis, between two parts of the sphenoid bone, and the spheno-ethmoidal synchondrosis, between the sphenoid and ethmoid bones

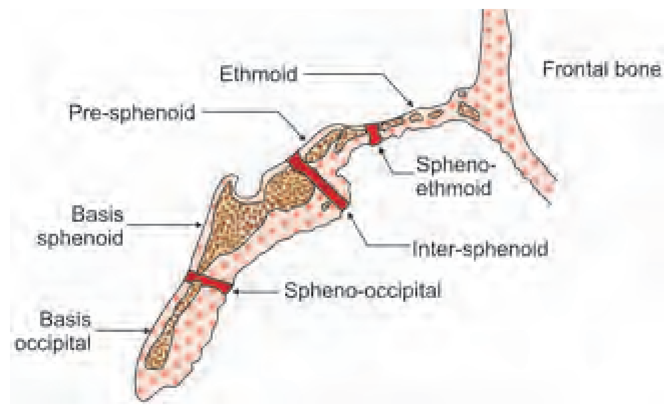
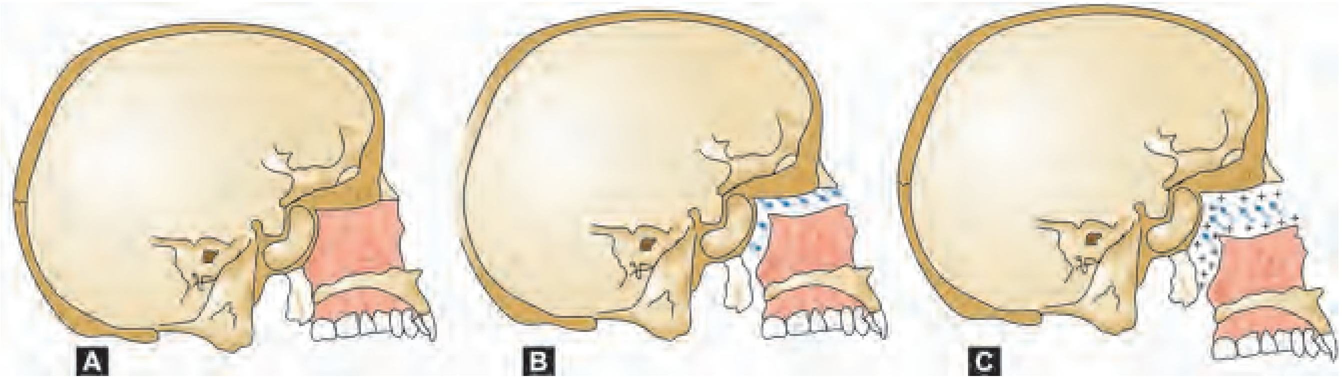


Figure 3-4: Synchondroses of the cranial base, showing the location of the growth sites.

The synchondrosis has an area of cellular hyperplasia in the center with bands of maturing cartilage cells extending in both directions, which will eventually be replaced by bone. Thus the cranial base is rather like a single long bone, except that there are multiple epiphyseal plate-like synchondroses. Immovable joints also occur between most of the other cranial and facial bones, the mandible being the only exception. The periosteum-lined sutures at other locations, containing no cartilage, are quite different from the cartilaginous synchondroses.

Nasomaxillary Complex

The maxilla develops postnatally entirely by intramembranous ossification. Since there is no cartilage replacement, growth occurs in two ways: (1) by apposition of bone at the sutures that connect the maxilla to the cranium and cranial base and (2) by surface remodelling. However, in contrast to the cranial vault, surface changes in the maxilla are quite dramatic and as important as changes



Figures 3-5A to C: Shows the downward and forward translation of maxilla. This results in opening of space at its superior and posterior attachments and new bone is added on both sides of the sutures.

at the sutures. The growth pattern of the face requires that the maxilla must move through a considerable distance downward and forward relative to the cranium and the cranial base **(Figures 3-5A to C).**

The sutures attaching the maxilla posteriorly and superiorly are ideally situated to allow its downward and forward repositioning. As the downward and forward movement occurs, the space that would otherwise open up at the sutures is filled in by proliferation of bone at these locations. The sutures remain the same width, and the various processes of the maxilla become longer. Bone apposition occurs on both sides of a suture, so the bones to which the maxilla is attached also become larger. Part of the posterior border of the maxilla is a free surface in the tuberosity region. Bone is added at this surface, creating additional space into which the primary and the permanent molar teeth successively erupt **(Figure 3-6).**

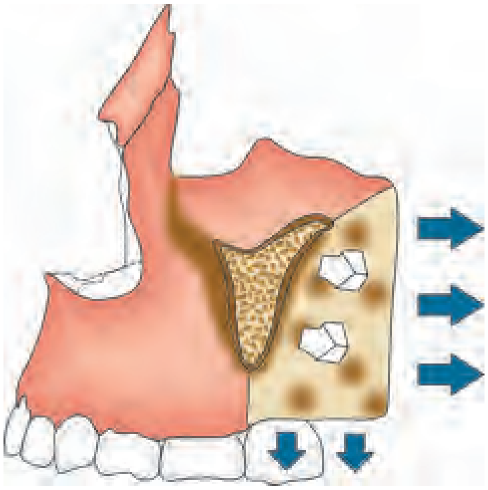


Figure 3-6: Apposition of bone in the tuberosity provides space for molars.

As the maxilla grows downward and forward its anterior surface is remodelled by removal of bone from this aspect. It can be noted in the **Figure 3-7**, that almost the entire anterior surface of the maxilla is an area of resorption, not apposition.

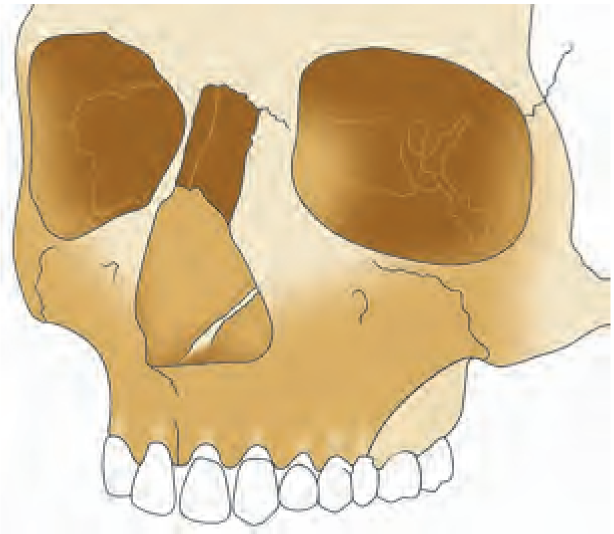


Figure 3-7: Showing the resorption of the anterior surface of the maxilla (shaded as gray).

It might seem logical that if the anterior surface of the bone is moving downward and forward, this should be an area to which bone is added, not one from which bone is removed. The correct concept, however, is that bone is removed from the anterior surface although the anterior surface is moving forward.

To understand this seeming paradox, it is necessary to comprehend that two quite different processes are going on simultaneously. The overall growth changes are the result of both a downward and forward translation of the maxilla and the simultaneous surface remodelling. The whole bony nasomaxillary complex is moving downward and forward relative to the cranium. Enlow who has conducted detailed study on the growth of facial skeleton has contributed greatly to our present understanding of the subject. He has presented this concept in the cartoon form shown in **Figure 3-8**.

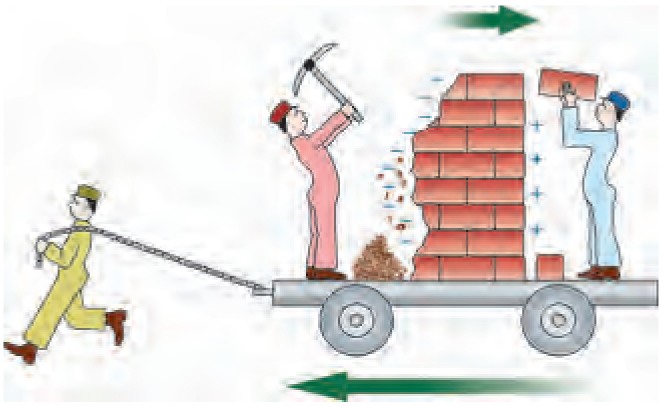


Figure 3-8: Showing surface remodelling of maxilla in the opposite direction to that in which bone is being translated creates a situation analogous to this cartoon, in which the wall is being rebuilt to move backward and at the same time the platform on which it is mounted is being moved forward (*courtesy* Enlow).

The maxilla is like the platform on wheels, being rolled forward, while at the same time its surface, represented by the wall in the cartoon, is being reduced on its anterior side and is built up posteriorly opposite to the direction of overall growth. It is not necessarily true that remodelling changes oppose the direction of translation. Depending on the specific location, translation and remodelling may either oppose each other or produce an additive effect. The effect is additive, for instance on the roof of the mouth. This area is carried downward and forward along with the rest of the maxilla, but at the same time bone is removed on the nasal side and added on the oral side, thus creating an additional downward and forward movement of the palate as shown in **Figure 3-9**.

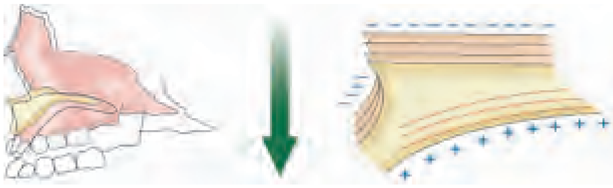


Figure 3-9: Showing remodelling of the palatal vault and floor of the nose. Bone is removed from the floor of the nose and added to the roof of the mouth.

It may be noted that the anterior part of the alveolar process is a resorptive area. Hence removal of bone from the surface tends to cancel some of the forward growth that otherwise would occur because of translation of the entire maxilla.

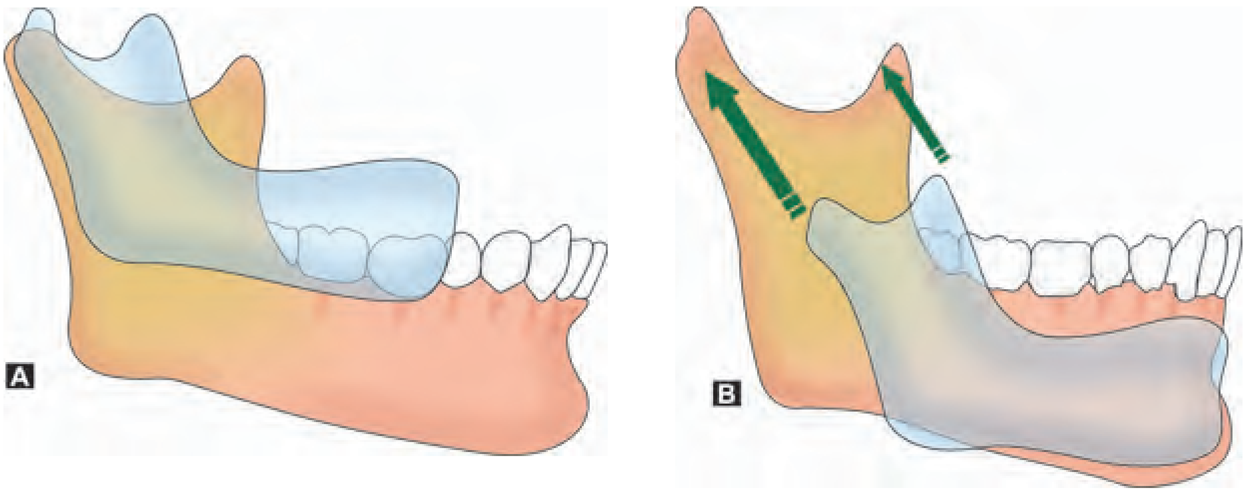
Malar (Zygomatic) Complex

The growth changes of the malar complex are similar to those of the maxilla itself. This is true for both remodelling and displacement processes. The anterior part of the zygoma undergoes posterior remodelling (relocation) movement. The inferior edge of the zygoma is heavily depository. The zygomatic arch moves laterally by resorption on the medial side within the temporal fossa and by deposition on the lateral side. As the malar region grows and becomes relocated posteriorly, the nasal region is enlarging in an opposite, anterior direction, drawing out the nose and making the face deeper, antero-posteriorly. The zygoma and cheekbone complex becomes displaced anteriorly and inferiorly in the same directions and amount as the primary displacement of the maxilla. The growth changes of the malar process are similar to those of the mandibular coronoid process.

Mandible

In contrast to the maxilla, both endochondral and periosteal activities are important in the growth of the mandible. Cartilage covers the surface of the mandibular condyle at the temporomandibular joint. Although this cartilage is not like the cartilage at an epiphyseal plate or a synchondrosis, hyperplasia, hypertrophy and endochondral replacement occur there. All other areas of the mandible are formed and grow by direct surface apposition and remodelling. The overall pattern of growth of the mandible can be represented in two ways as shown in **Figures 3-10A and B**.

Depending on the frame of reference both are correct. If the cranium is the reference area, the chin moves downward and forward. On the other hand if data from vital staining experiments are examined it becomes apparent that the principal sites of growth of the mandible are the posterior surface of the ramus and the condylar and coronoid processes. There is little change along the anterior part of the mandible. From this frame of reference **Figure 3-10B** is the correct representation. As a growth site the chin is almost inactive. It is translated downward and forward as the actual growth occurs at the mandibular condyle and along the posterior surface of the ramus. The body of the mandible grows longer by periosteal apposition of bone on its posterior surface while the ramus grows higher by endochondral replacement at the condyle accompanied by surface remodelling. Conceptually, it is



Figures 3-10A and B: Pattern of growth of the mandible (see text for description).

correct to view the mandible as being translated downward and forward while at the same time increasing in size by growing upward and backward. The translation occurs largely as the bone moves downward and forward along with the soft tissues in which it is embedded. The mandible grows longer by apposition of new bone on the posterior surface of the ramus. At the same time large quantities of bone are removed from the anterior surface of the ramus as shown in **Figure 3-11**.

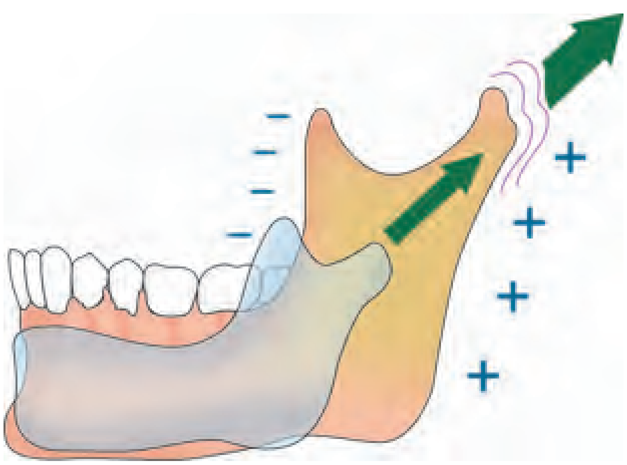


Figure 3-11: Showing extensive remodelling of the ramus as the mandible grows in length. The bone at the tip of the condylar process at an early age can be found at the anterior surface of the ramus some years later.

The body of the mandible grows longer as the ramus moves away from the chin and this occurs by removal of bone from the anterior surface of the ramus and deposition of bone on the posterior surface. Thus, what was the posterior surface at one time becomes the center at a later date and eventually may become the anterior surface as remodelling proceeds.

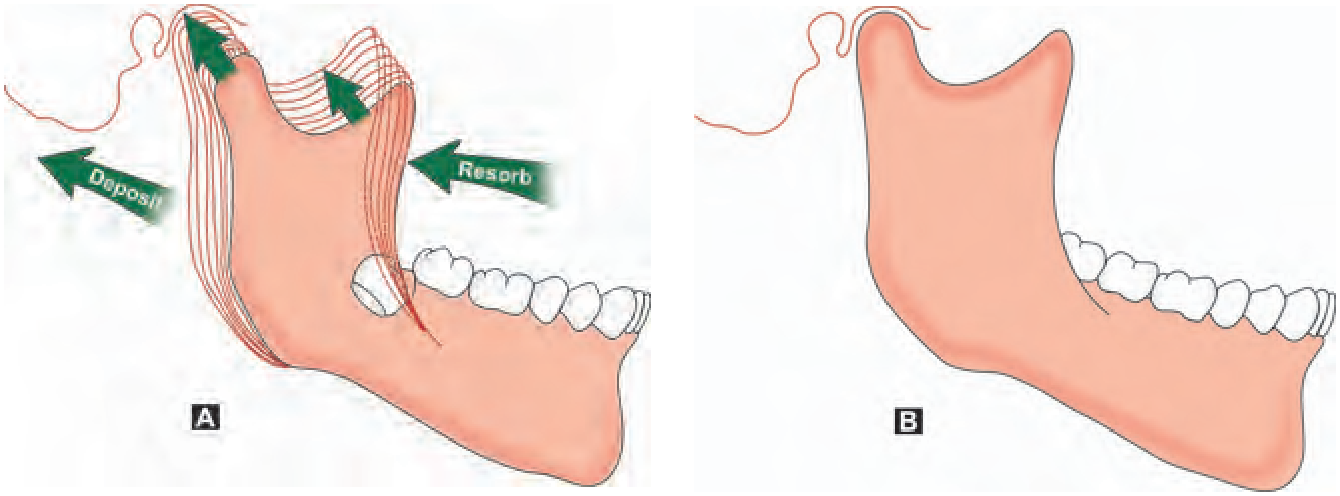
In infancy the ramus is located at about the spot where the primary first molar will erupt. Progressive posterior remodeling creates space for the second primary molar and then for the sequential eruption of the permanent molar teeth **(Figures 3-12A and B).**

However in certain instances, this growth ceases before sufficient space has been created for eruption of the third permanent molar, which gets impacted in the ramus.

Of the facial bones, the mandible undergoes the largest amount of growth postnatally and also exhibits the largest variability in morphology. While the mandible appears in the adult as a single bone, developmentally and functionally it is divisible into several subunits. The basal bone of the body forms one unit to which is attached the alveolar process, the coronoid process, the angular process, the condylar process and the chin. Each of these skeletal subunits is influenced in its growth pattern by a functional matrix that acts upon the bone. The teeth act as a functional matrix for the alveolar unit. The action of the temporalis muscle influences the coronoid process. The masseter and medial pterygoid muscles act upon the angle and ramus of the mandible, while the lateral pterygoid muscle has some influence on the growth of the condylar process. The functioning of the related tongue and the perioral muscles and the expansion of the oral and pharyngeal cavities, provide stimuli for mandibular growth to reach its full potential.

Functional Matrix Theory of Growth

Moss in the 1960s put forth the theory that growth of the face occurs as a response to functional needs and is



Figures 3-12A and B: Showing the progressive remodelling creating space for the eruption of molars.

mediated by the soft tissue in which the jaws are embedded. According to this view the soft tissues grow and both bone and cartilage react. Contrary to the previously held concept neither the cartilage of the mandibular condyle nor the nasal septum cartilage is a determinant of jaw growth.

The growth of the cranium illustrates this view of skeletal growth very well. The growth of the cranial vault is a direct response to the growth of the brain. Pressure exerted by the growing brain separates the cranial bone at the sutures and new bone passively fills in at these sites so that the brain case fits the brain. This is exemplified in the following conditions. In case of a microcephaly the size of the head is an accurate representation of the size of the brain. While in case of a hydrocephaly reabsorption of CSF is impeded and the fluid accumulates resulting in increase in intracranial pressure. The increased intracranial pressure impedes development of brain so that the hydrocephalic may have a small brain and will be mentally retarded. But this condition leads to an enormous growth of the cranial vault. Uncontrolled hydrocephaly may lead to a cranium two or three times its normal size. This is one of the excellent examples of the functional matrix theory.

Another remarkable example is the relationship between the size of the eye and the size of the orbit. An enlarged eye or small eye will cause a corresponding change in the size of the orbital cavity. In this case eye behaves as the functional matrix.

Similarly it is theorized that the major determinant of the growth of the maxilla and mandible is the enlargement of the nasal and oral cavities, which grow in response to functional needs. However it is not clear how functional needs are transmitted to the tissues around the mouth and nose. On the contrary the theory predicts that the cartilages of the nasal septum and mandibular condyle are not important determinants of growth. Hence their loss will have no significant effect on growth if proper function could be obtained.

However, the absence of normal function will have wide ranging effects. It has been noted that in 75 to 80% of children who sustain a condylar fracture, the resulting loss of the condyle does not impede mandibular growth. The condyle very often regenerates to normal size. In the remaining 20 to 25% cases growth retardation has been observed following condylar fracture. This has been explained due to interference with function following condylar fracture where there is a soft tissue injury leading to severe scarring as healing occurs. Subsequently the mechanical obstruction caused by the scar tissue in the vicinity of temporomandibular joint (TMJ) interferes with the movement of mandible, and finally ankylosis of the joint occurs (**Figures 3-13A and B).** This in turn results in growth deficiency in some children after condylar fractures.

Facial Growth and Tooth Movement

Tooth movement is a key part of facial growth. Movement of tooth helps to: (1) positions a tooth into changing functional locations, (2) sustains progressively changing anatomic relationships as the entire craniofacial assembly

Figures 3-13A and B: (A) Facial deformity in a 15-year-old girl with TMJ ankylosis on the right side following condylar fracture at childhood. (B) Radiograph of the patient showing ankylosed joint (yellow circle).

around it continues to undergo massive development. A tooth cannot move by itself; it must be physically moved by the soft tissue surrounding its root. The periodontal membrane surrounding the tooth is an osteogenic connective tissue comparable to the periosteal membrane. Because of its presence, pressure is converted directly into tension by the suspension of each tooth in a connective tissue sling of fibers within a socket. This translates pressure into direct tensions on alveolar bone.

Teeth drift for two basic functional reasons. The first reason is to close-up the dental arch during growth and keep it closed as the contact edges along interproximal contacts of the teeth progressively wear. This braces the arch to better withstand masticatory forces. The second reason is to anatomically place and progressively relocate the teeth as the whole mandible and maxilla grow and remodel. Drift of teeth is a three dimensional process. It has been a major point of controversy whether the pressure presumed to trigger alveolar bone resorption acts first on the connective tissue membrane, or, directly on the bone, which, in turn, causes the membrane to respond. It has been proposed that the actual source of the propulsive mechanical force that brings about eruption, vertical and horizontal drift, and other tooth movements is provided specifically by an abundant population of actively contractile fibroblasts ("myofibroblasts") on the resorptive sides of the sockets.

Orthodontic tooth movement harnesses and manipulates control systems in development through clinically induced signals that override and replace or modify the intrinsic signals.

Growth of Dentofacial Complex in Adolescence

This may be considered under the following headings:

a. Growth of the nasomaxillary complex
b. Growth of the mandible.

Growth of the Nasomaxillary Complex

This is produced by two mechanisms: (1) passive displacement created by growth in the cranial base that pushes the maxilla forward and (2) active growth of the maxillary structures and nose.

Passive displacement of the maxilla is an important growth mechanism during the primary dentition years but becomes less important as growth at the synchondroses of the cranial base slows markedly with the completion of neural growth at about seven years of age. During the period from 7 to 15 years of age about one-third of the total forward movement of the maxilla is brought about by the passive displacement. The rest is the result of active growth of the maxillary sutures in response to the stimuli from the enveloping soft tissues. The effect of surface remodelling by surface apposition and resorption must be taken into account when active growth of the maxilla is considered. The maxilla grows downward and forward as bone is added at the tuberosity area posteriorly and at the posterior and superior sutures while the anterior surface of the bone undergoes resorption simultaneously **(Figure 3-14).**

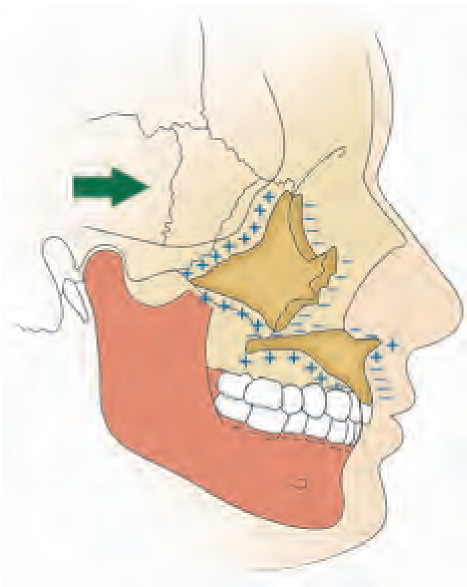


Figure 3-14: Showing the downward and forward translation of maxilla.

Surface remodelling removes bone from the anterior surface of maxilla except for a small area at the anterior nasal spine. For this reason, the amount of forward movement of anterior surface is less than the amount of displacement. However, in the roof of the mouth surface remodelling adds bone, while bone is resorbed from the floor of the nose. Therefore the total downward movement of the palatal vault is greater than the amount of displacement.

The nasal structures undergo the same passive displacement as the rest of the maxilla. However, growth of the nose occurs at a more rapid rate than growth of the rest of the face, particularly during the adolescent growth spurt. Nasal growth is produced in part by an increase in size of the cartilaginous nasal septum. In addition, proliferation of the lateral cartilages alters the shape of the nose as well as increases its size. The growth of the nose is extremely variable depending on the racial characteristics of the people.

Mandibular Growth

Growth of the mandible continues at a relatively steady rate before puberty. On an average, ramus height increases by one to two mm per year and the body length increases by two to three mm per year. One notable feature of mandibular growth is an accentuation of the prominence of the chin. Previously it was thought that this occurred primarily by addition of bone to the chin which was later disproved. Even though small amounts of bone are added, the change in the contour of the chin occurs largely because the area just above the chin below the base of the alveolar process is a resorptive site. The actual increase in chin prominence in later life occurs due to a combination of forward translation of the chin as part of the overall growth of the mandible and also due to the resorption above the chin, mentioned earlier. A significant factor contributing to the variability of the forward growth of the chin is the extent of growth changes occurring at the glenoid fossa. If the area of the temporal bone to which the mandible is articulated moved forward relative to the cranial base during growth, this would translate the mandible forward in the same way that cranial base growth translates the maxilla for the mandible. Nevertheless this rarely happens. Very often the attachment point moves straight down or posteriorly, resulting in a reduction rather than an augmentation of the forward projection of the chin.

Completion of Facial Growth

In maxilla and mandible there is a definite sequence in which growth is completed in the three planes of growth. Growth in width is completed first, followed by growth in length, and finally growth in height. Growth in width of both jaws including the width of dental arches generally is completed before the adolescent growth spurt and is affected minimally by the adolescent growth changes. Growth in length of both jaws continues through the period of puberty. In girls, usually growth in length of the jaws completes by the age of 14 to 15 years. While in boys growth length continues up to the age of 18 years. Growth in height of the jaws and face continues longer in both sexes than growth in length. It has been noted that increase in facial height and subsequent eruption of teeth continue throughout life. However, the rate of increase in height declines to the adult level by the age of 17 to 18 years in girls and 19 to 20 years in boys, i.e. it continues well after puberty in both the groups.

Jaw Rotation during Growth

Following the studies on growth using metallic implants by Bjork et al in the 1960s, the rotation of maxilla and mandible during growth was understood. The rotation that occurs in the core of each jaw is termed internal rotation. This tends to be masked by surface changes and alterations in the rate of tooth eruption. The surface changes produce external rotation. Evidently the overall change in the orientation of each jaw as evaluated by the palatal plane and mandibular plane, results from a combination of internal and external rotation. Generally, in most individuals the core of the mandible rotates during growth in a way that would tend to decrease the mandibular plane angle, i.e. up anteriorly and down posteriorly. While considering maxilla, for most individuals, the external rotation is equal in magnitude and opposite in direction to internal rotation. This result in cancellation of the effects of the two rotations, and the net change in jaw orientation, as evaluated from the palatal plane, is zero.

In clinical practice, this difference in the rotational patterns of growth can be well appreciated in individuals with short face and long face types of vertical facial development.

For example: in individuals of short facial height, who are characterized by short anterior lower face height, have excessive anterior forward rotation of mandible resulting from both an increase in internal rotation and decrease in external compensation. This results in a horizontal palatal plane and decreased mandibular plane angle and a square gonial angle. Such individuals are included in the square jaw type and have an associated deep bite and crowding of incisors.

On the other hand, in long face individuals, who have excessive lower anterior face height, the palatal plane rotates down posteriorly. The mandible at the same time has an opposite backward rotation with an increase in mandibular plane angle. The mandibular changes result from the lack of forward internal rotation or even from a backward internal rotation. This results in the classical appearance of long face individuals with anterior open bite and mandibular deficiency due to rotation of chin downwards and backwards.

Facial Growth in Adults

Until recently it was thought that growth of the facial skeleton ceased in the late teens or in the early twenties. However, recent studies have shown that facial growth continues at a moderate level throughout adult life. There is an increase in all of the facial dimensions. Vertical changes in adult life is more prominent than the anteroposterior changes. On the other hand width changes are minimal. This means that the growth changes observed in the adult facial skeleton seem to be a continuation of the pattern observed during maturation. Although the magnitude of the adult growth changes is quite small, the cumulative effect over decades will be significant. It is also observed that rotation of both jaws continue into adult life in conjunction with the vertical changes and eruption of teeth. In general, males show a rotation of jaws in a forward direction with a decrease in the mandibular plane angle, while in females there is a tendency for a backward rotation with an increase in the mandibular plane angle. In both the groups compensatory changes were noted in the dentition with the maintenance of occlusal relationship.

Summary of Changing Features of Growing Face

Development of the head and face is a complex process. The face of a baby has large eyes, dainty jaws, a pug nose, puffy cheeks, a high forehead without coarse eyebrow ridges, a low nasal bridge, a small mouth, velvety skin and overall wide and short proportions. The child's face appears broad. The baby's face appears diminutive relative to the precociously large cranium above and behind it. Growth of the mandible begins later and continues longer than midfacial or orbital growth.

- The eyes along with the brain are more precocious, thus they appear large in a young child.
- The ears of the infant and child appear to be relatively low compared to the adult's.
- The forehead of a child is upright and bulbous compared to the adult which is sloping. The child's forehead also seems relatively larger compared to the adult.
- The nasal bridge is low which makes the eyes appear wide-set. The whole nasal region of the infant is vertically shallow. The nasal region of a growing child's midface is, almost literally, a keystone of facial architecture, that is, a key part upon which other surrounding parts, and the multiple anatomic arches formed by them, are dependent for placement and stability.
- During later childhood and into adolescence, vertical nasal enlargement keeps pace with growing body and lung size, and dental and other oral components have approached adult sizes and configuration. The face and head are longer (more so in dolichocephalics than in brachycephalics).
- The mandible of the young child appears quite small and "underdeveloped" relative to the upper jaw and the face in general. The young child's mandible appears to be pointed. In the infant and young child, the gonial

region lies well inside (medial to) the cheekbone. The ramus of the adult mandible is much longer vertically and is also more upright. The chin is incompletely formed in the infant.

- The premaxillary region normally protrudes beyond the mandible in the infant and young child and it lies in line with or forward of the bony tip of the nose. The forward surface of the bony maxillary arch in the infant, with its yet unerupted dentition has a vertically convex topography.
- The small mastoid process of the infant later develops into the sizable protuberance of the adult. In the newborn, six fontanelles ("soft spots") are present among the bones of the skull roof. In the child, the slender neck below a relatively large cranium gives a characteristic "boyish" appearance to the whole head.
- The entire face of the adult is much deeper anteroposteriorly and the whole face is drawn out in many directions. The adult face has much bolder topographic features, and it is much less "flat".

Summary of Developmental Sequence

The multiple growth process in the various parts of the face and cranium can be described separately as individual "stages" for convenience. However, it must be kept in mind that the whole growth process is a continuous one and takes place simultaneously.

Stage	*Regional changes*
Stage 1	The bony maxillary arch lengthens horizontally in a posterior direction. Bone is deposited on the posterior-facing cortical surface of the maxillary tuberosity. Resorption occurs on the opposite side of the same cortical plate, which is the inside surface of the maxilla within the maxillary sinus.
Stage 2	As the maxillary tuberosity grows and lengthens posteriorly, the whole maxilla is simultaneously carried anteriorly. The amount of forward displacement exactly equals the amount of posterior lengthening
Stage 3	The mandibular corpus (body) lengthens to match the elongation of the maxilla by remodelling conversion from the corpus
Stage 4	Like the maxilla, the whole mandible is displaced anteriorly. This is achieved through posterior remodelling of the condyle and the posterior part of the ramus.
Stage 5	The whole mandible is displaced anteriorly by the same amount as that the ramus has relocated posteriorly. As the bone becomes displaced, it simultaneously remodels (Stage 4) to keep pace with the amount of displacement.
Stage 6	Along with the growth and remodelling changes described above, the dimensions of the temporal lobes of the cerebrum and the middle cranial fossae have also been increasing at the same time.
Stage 7	All cranial and facial parts lying anterior to the middle cranial fossa become displaced in a forward direction. This is a secondary type of displacement because the actual enlargement of these various parts is not directly involved. The anterior cranial fossa and nasomaxillary complex are carried, not pushed forward as the frontal and temporal lobes of the cerebrum enlarge by respective growth increases.
Stage 8	The expansion of the middle cranial fossa has a displacement effect on the mandible (via secondary displacement), but to a lesser extent.
Stage 9	Just as the lengthening of the middle cranial fossa places the maxillary arch in a progressively more anterior position, the horizontal growth of the **ramus** places the mandibular arch in a like position. The ramus is the specific structural counterpart of the middle cranial fossa.
Stage 10	The entire mandible is displaced anteriorly at the same time as it remodels posteriorly. The oblique manner of condylar growth necessarily produces an upward and backward projection of the condyle with a corresponding downward as well as forward direction of mandibular displacement.
Stage 11	The floor of the anterior cranial fossa and the forehead grow by deposition on the ectocranial side with resorption from the endocranial side. The posterior-anterior length of the anterior cranial fossa is now in balance with the extent of horizontal lengthening by its structural counterpart, the maxillary arch (Stage 1). The enlarging brain displaces the bones of the calvaria outwards. The ethnomaxillary (nasal) region undergoes equivalent growth increments to the anterior cranial fossa above and the maxillary arch and palate below it.
Stage 12	The vertical lengthening of the nasomaxillary complex, as with its horizontal elongation, is

brought about by a composite of (1) growth by deposition and resorption, and (2) a primary displacement movement associated directly with its own enlargement.

Stage 13 Vertical growth by displacement is associated with bone deposition at the many and various sutures of the maxilla where it contacts the multiple, separate bones above and behind it. The increment of bone growth in the suture exactly equals the amount of inferior displacement of the whole maxilla. This is primary displacement. Vertical changes also occur by direct relocation by resorptive and depository remodelling. Teeth move also by the processes of vertical drift and eruption.

Stage 14 The amount of vertical separation between the upper and lower arches caused by the vertical growth of both the middle cranial fossa and the ramus is balanced by an equivalent amount of lengthening in the nasomaxillary complex and the dentoalveolar region of the mandible. The mandibular teeth and alveolar bone drift upward to attain full occlusion. This is produced by a superior drift of each tooth, together with a corresponding remodelling increase in the height of the alveolar bone.

Stage 15 While the upward movements of the mandibular teeth and remodelling of the alveolar sockets are taking place, remodelling changes also occur in the incisor alveolar region, the chin, and the corpus of the mandible.

Stage 16 The forward part of the zygoma and the malar region of the maxilla remodel in conjunction with the contiguous maxillary complex, and their respective modes of growth are similar. Just as the maxilla lengthens horizontally by posterior remodeling growth, the malar area also remodels posteriorly by continued deposition of new bone on its posterior side and resorption from its anterior side

Stage 17 Just as the whole maxillary complex is displaced anteriorly and inferiorly as it simultaneously enlarges in overall size, the malar area is moved anteriorly and inferiorly by primary displacement as it enlarges.

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Chapter 4

Bobby John

Shakespeare's reverence for the structure of the human body found expression in his writings: " What a piece of work is a man! How noble in reason! how infinite in faculty! In form and moving, how express and admirable! In action how like an angel! In apprehension how like a god! The beauty of the world! The paragon of animals!" (Hamlet 2.2.315–319).

The Maxillae

The maxillae are the largest bones of the face, excepting the mandible. They make an articulation with every bone of the face except the mandible. The two maxillae unite at the midline and provides the support for the upper teeth. Incisors, cuspids, premolars, and molars are anchored in the alveolar process of the maxilla . The body of maxilla assists in forming the boundaries of three cavities, the roof of the mouth, the floor and lateral wall of the nose and the floor of the orbit; it also contributes in the formation of two fossae—the infratemporal and pterygopalatine, and two fissures—the inferior orbital and pterygomaxillary. Each bone is a three sided pyramid consists of a body and four processes—zygomatic, frontal, alveolar, and palatine. The maxilla supports the nasal cartilage, provides the attachment of facial muscles, constitutes the shell for the maxillary sinus, and houses the teeth. The lateral surface of the maxilla can be anterolateral or posterolateral. The former exhibits the infraorbital foramen which transmits the neurovascular elements, highlighting the importance of protecting these elements while elevating the buccal mucoperiosteum during the Leforte osteotomies. The posterolateral surface also called as infratemporal surface, its posterorinferior limit is confined by the maxillary tuberosity, and it outlines the pterygomaxillary fissure. This in turn leads into the pterygopalatine fossa. The pterygomaxillary fissure is an important anatomical site in the mobilization of maxilla during mid face orthognathic surgeries.

A number of techniques are used to achieve pterygomaxillary separation. A curved Obwegeser osteotome is often used through a blind approach to the pterygomaxillary suture to gain the separation. Swan neck and shark fin modification of osteotomes also used to improve the safety of procedure. Use of pterygoid chisel is practiced by many of the surgeons. The method advocated by Precious et al without the use of pterygoid chisel and by leverage alone by employing Tesseir spreaders and digital manipulation claim to have more safety.[9,12]

Procedure of separating maxilla from ptreygoid plates carries risk of hemorrhage and neurological complications. Vascular complications can arise from direct trauma to vessels because of the blind nature of the osteotomy and unwanted fracture extending to the pterygopalatine fossa, base of the skull and orbit. The zygomatic buttress which is the meeting place of the two lateral surfaces limits the posterior extension of the mucoperiosteal incision in osteotomies. Osteotomy cuts are planned in such a way that it should be at least 3 mm apical to the root tips so as to avoid the interruption of the vascularity of the dentition. The alveolar process meets in the midline and on either side is the nasal aperture. The rim of these apertures can be used as the site of suspension wiring. Just below the nasal aperture is the anterior nasal spine which is removed during orthognathic procedures. The nasal septum is fractured during the osteotomy procedure to separate it from maxilla, taking care to avoid complications like injury to vomer or perforation of palate. The palatine process, a horizontal plate of the maxilla, forms the greater portion of the hard palate. The incisive foramen is located in the anterior region of the hard palate, behind the incisors and transmits the neurovascular elements. Palatal mucoperiosteum is firmly adherent to the underlying bone and maintains the vascularity in osteotomised segments. Infraorbital foramen is located under each orbit and serves as a passageway for the infraorbital nerve and artery to the nose. A final opening within the maxilla is the inferior orbital fissure. It is located between the maxilla and the greater wing of the sphenoid and is the external opening for the maxillary branch of the trigeminal nerve and infraorbital vessels. The large maxillary sinus located within the maxilla is one of the four paranasal sinuses . If the two palatine processes fail to join during early prenatal development (about 12 weeks), a cleft palate results. A cleft palate may be accompanied by a cleft lip lateral to the midline. These conditions can be surgically treated with excellent cosmetic results. An immediate problem, however, is that a baby with a cleft palate may have a difficult time of nursing because of the inability to create the necessary suction within the oral cavity for feeding purposes.

Mandible (Figures 4-1 and 4-2)

The mandible, the largest and strongest bone of the face, accommodates the lower teeth. It is constituted by a curved, horizontal portion termed as the body, (corpus mandibulae), which fuses at the symphysis menti. The

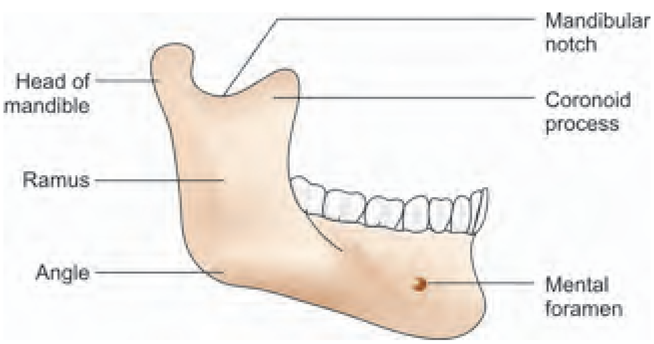

Figure 4-1: Lateral view of mandible

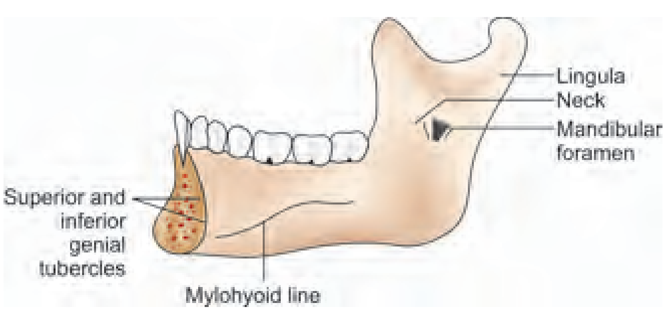

Figure 4-2: Medial view of mandible

fusion occurring at the 2nd year of life. The two perpendicular portions, the rami, which meets the body nearly at right angles. The body is horseshoe shaped and has two surfaces and two borders.

The symphysis is the line of junction of the two halves. Below it there is a triangular eminence-the mental protuberance, with mental tubercles on either side of it. On either side of the symphysis, just below the incisor teeth there is a depression termed as the incisive fossa giving origin to the mentalis and a small portion of the orbicularis oris. On either side below the second premolar tooth, midway between the upper and lower borders of the body, is the mental foramen, through which the mental vessels and nerve exit. The risk of damage to these structures should be taken into account during the surgical procedures like genioplasty and plate fixation for the fracture reduction. Running backward and upward from each mental tubercle is a faint ridge, the oblique line, which is continuous with the anterior border of the ramus and provides the attachment to the quadratus labii inferioris and triangularis. The platysma is attached just below it.

The medial surface is concave in shape. Near the lower part of the symphysis is a pair of laterally placed spines, termed the genial tubercles, giving origin to the genioglossi and geniohyoid muscles. Below it, on either side of the midline is an oval depression for the attachment of the anterior belly of the digastric. Extending upward and backward on either side from the lower part of the symphysis is the mylohyoid line, which gives origin to the mylohyoid muscle. The posterior part of this line, near the alveolar margin, gives attachment to a small portion of the superior pharyngeal constrictor muscle and to the pterygomandibular raphe. The medial surface presents about its center the mandibular foramen, the entrance of the inferior alveolar vessels and nerve. The margin of this opening is irregular, with a prominent ridge in the front and surmounted by a sharp spine, the lingula mandibulae. This gives attachment to the sphenomandibular ligament and constitutes an important anatomical landmark in judging the osteotomy cut in saggittal split osteotomy. The mandibular canal runs forward and downward in the ramus and then horizontally forward in the body, under the alveoli and communicates with them by small openings. On arriving at the incisor teeth, it turns back to communicate with the mental foramen, giving off two small canals which run to the sockets containing the incisor teeth. The anterior border of the ramus is thin above and thicker below and it is continuous with the oblique line. The posterior border is thick, smooth, rounded, and covered by the parotid gland. The upper border is thin and is surmounted by two processes, the coronoid in front and the condyloid behind, separated by a deep concavity, the mandibular notch. The muscle attached to the condyle is the lateral pterygoid which determines the direction of displacement in fractures. Coronoids are perfusesd by the temporalis and the fracture of the coronoids mainly due to the reflex contraction of this muscle.

The width of the ramus or the mediolateral thickness is an important factor in surgical procedures like sagittal split osteotomy.[6] A common clinical finding is the smaller width of ramus in patients with mandibular prognathism when compared with those having retrognathia. Comparison of mandibular rami width in patients with prognathism and retrognathism are well studied.[1]

Arterial Supply

Facial Artery

The facial artery (*a. maxillaris externa*) arises from the external carotid artery either individually or in combination with lingual artery. It runs through the submandibular triangle and swings around the lower border of mandible entering the facial area immediately anterior to the massteter.

The branches of the artery may be of two kinds: those given off in the neck (cervical), and those on the face (facial). Ascending palatine, tonsillar, glandular, submental, muscular arising in the neck region.

Inferior labial, superior labial, lateral nasal, angular, muscular arising in the facial arena. The profuse bleeding from this vessel may occur during surgical procedures or in traumatic episodes with severe facial lacerations. Conventional measures may be insufficient in such cases, and may need ligation. Ligation can be attempted at the point of anterior border of masseter or near its origin before its entry into submandibular triangle. Facial artery exhibits a tortous course in the face so as to facilitate the movements of the facial muscles.

Internal Maxillary Artery

The internal maxillary artery. (*a maxillaris interna*) the larger of the two terminal branches of the external carotid, originating behind the neck of the mandible, embedded in the substance of the parotid gland, It passes forward between the ramus of the mandible and the sphenomandibular ligament and then runs, either superficial or deep to the pterygoideus externus, to the pterygopalatine fossa. It supplies the deep structures of the face, and may be divided into three portions—mandibular, pterygoid, and pterygopalatine portions. The terminal portion termed as the pterygopalatine has the following portions.

Descending palatine artery which supplies the middle and posterior palate.

Infraorbital artery which supplies the malar region. Sphenopalatine artery which supplies the nasal cavity and the anterior palate. Artery of the pterygoid canal—this portion of maxillary artery is important in maintaining the vascularity of osteotomised segment.

The maxillary artery passes upward across the lower head of lateral pterygoid muscle inside the sigmoid notch, the course of the maxillary artery varies, the distance from the midsigmoid notch to the maxillary artery was about 3 mm in cadaveric mandibles so to avoid damage these vessels it is recommended to place a suitable retractor against the midsigmoid notch.[5]

The internal maxillary artery enters the pterygopalatine fossa approximately 16.6 mm above the nasal floor and gives off the descending palatine artery. The descending palatine artery travels a short distance within the pterygopalatine fossa and then enters the greater palatine canal. It travels approximately 10 mm within the canal in an inferior, anterior, and slightly medial direction to exit through the greater palatine foramen in the region of the second and third molars. Injury to the descending palatine artery during Le Fort I osteotomy can be minimized by not extending the osteotomy more than 30 mm posterior to the piriform rim in females and the distance can be extended to 35 mm in males. Pterygomaxillary separation should be made by closely adapting the cutting edge of a curved osteotome or right-angled saw to the pterygomaxillary fissure while avoiding excessive anterior angulation. Furthermore, the superior cutting edge of the osteotome or saw blade should be less than 10 mm above the nasal floor. Location of the descending palatine artery in relation to the Le Fort I osteotomy can be assessed, since it is the most involved vessel causing vascular complications during pterygomaxillary separation. Less often the maxillary artery and its terminal branches, the ptrerygoid plexus, the internal carotid artery, and internal jugular vein may be damaged. Wilke described the possible cause of ocular symptoms as intraarterial injection into the maxillary artery with backflow of anesthetic solution into the middle meningeal artery. He claimed the instantaneous blindness results from the anesthetic solution being carried into the central artery of the retina through the anastomosis of the ophthalmic and middle meningeal arteries.[10]

Veins of the Head and Neck Region (Figure 4-3)

Superficial Veins

The arrangement of the superficial veins of the head and neck is somewhat variable. The superficial temporal and maxillary veins join to form the retromandibular vein. While traversing the parotid gland, its posterior division together with the posterior auricular vein form the external jugular vein and the anterior division joins the facial vein to form the common facial vein which finally opens into the internal jugular vein. The external jugular vein crosses the sternocleidomastoid in the superficial fascia, traverses the roof of the posterior triangle then plunges through the deep fascia (2.5 cm) above the clavicle to enter the subclavian vein. The anterior jugular vein runs down one on either side of the midline of the neck, crossing the thyroid isthmus. Just above the sternum it communicates with its fellow of the opposite side, then passes outwards, deep to the sternocleidomastoid to enter the external jugular vein.

Frontal Vein

The frontal vein (v. frontalis) starts in the forehead and it communicates with the frontal branches of the superficial temporal vein. The veins unite together, runs downward almost in the middle of the forehead parallel with the vein of the opposite side. The two veins unite at the root of the nose, forming the nasal arch. At the root of the nose the veins diverge, and at the medial angle of the orbit, joins the supraorbital vein, and forms the angular vein.

Supraorbital Vein

The supraorbital vein (v. supraorbitalis) begins on the forehead where it communicates with the frontal branch of the superficial temporal vein. It runs downward superficial to the frontalis muscle, and joins the frontal vein at the medial angle of the orbit to form the angular vein. Previous to its junction with the frontal vein, it sends through the supraorbital notch into the orbit a branch which communicates with the ophthalmic vein, as this vessel passes through the notch, it receives the frontal diploic vein through a foramen at the bottom of the notch.

The union of the frontal and supraorbital veins forms the angular vein (v. angularis) runs obliquely downward, on the side of the root of the nose, to the level of the lower margin of the orbit, where it becomes the anterior facial vein. It receives the veins of the ala nasi, and communicates with the superior ophthalmic vein through the nasofrontal vein, thus establishing an important anastomosis between the anterior facial vein and the cavernous sinus. The superficial temporal vein (v. temporalis superficialis) begins on the side and vertex of the skull in a plexus which communicates with the frontal and supraorbital veins, with the corresponding vein of the opposite side, and with the posterior auricular and occipital veins. From this network frontal and parietal branches arise, and unite above the zygomatic arch to form the trunk of the vein, which is joined in this situation by the middle temporal vein, from the substance of the temporalis. It then crosses the posterior root of the zygomatic arch, enters the substance of the parotid gland, and unites with the internal maxillary vein to form the posterior facial vein.

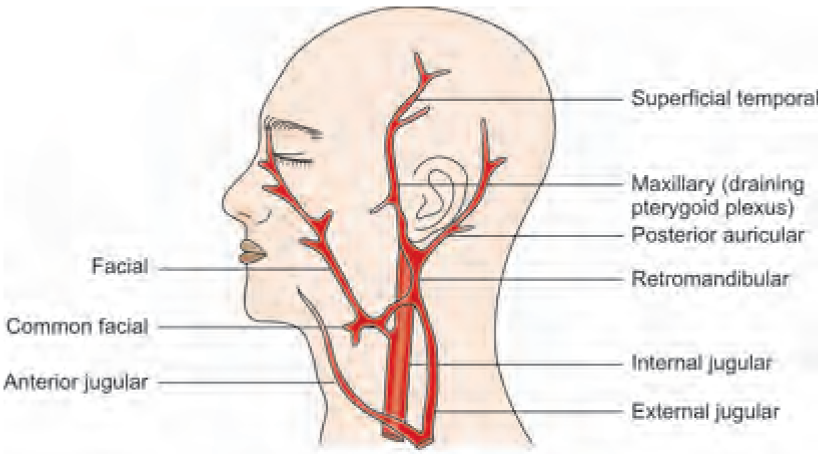

Figure 4-3: Venous arrangement of the facial area.

Muscles of the Head and Neck

Three general groups of muscles are found in the head and neck: those that move the head or neck, the muscles of facial expression, and the muscles for chewing.

Masseter

Masseter is a quadrilateral muscle, with two portions, superficial and deep. The superficial portion, being the larger, takes its origin as a thick, tendinous aponeurosis from the anterior two-third of the lower border of the zygomatic arch, and from the zygomatic process of the maxilla, and its fibers run downward and backward, getting inserted into the angle and lower half of the outer surface of the ramus of the mandible. The deep portion is much smaller compared to the former, and more muscular in texture, it originates from the posterior third of the lower border and from the whole of the medial surface of the zygomatic arch, its fibers run downward and forward, getting inserted into the upper half of the ramus and the lateral surface of the coronoid process of the mandible. The deep portion of the muscle is partly concealed by the superficial portion, behind it is covered by the parotid gland. The fibers of the two portions are continuous at their insertion.

Action: Elevates mandible as in closing the mouth, innervated by mandibular division of trigeminal nerve.

Lateral Pterygoid

Lateral pterygoid is a short, thick muscle, which extends between the infratemporal fossa and the condyle of the mandible. It originates by two heads, an upper from the lower part of the lateral surface of the great wing of the sphenoid and from the infratemporal crest, a lower from the lateral surface of the lateral pterygoid plate. Its fibers pass horizontally backward and laterally, to be attached into a depression in front of the neck of the condyle of the mandible, and into the front margin of the articular disk of the temporomandibular articulation.

Action: Protracts mandible, depress mandible as in opening mouth and moves mandible from side to side. Innervated by mandibular division of trigeminal nerve.

Medial Pterygoid

Medial pterygoid is a thick, quadrilateral muscle. It originates from the medial surface of the lateral pterygoid plate and the grooved surface of the pyramidal process of the palatine bone, It has a second slip of origin from the lateral surfaces of the pyramidal process of the palatine and tuberosity of the maxilla. Its fibers pass downward, lateralward, and backward, and are inserted, by a strong tendinous lamina, into the lower and back part of the medial surface of the ramus and angle of the mandible, as high as the mandibular foramen.

Action: Elevates and protracts mandible and moves mandible side to side. Innervated by mandibular division of trigeminal nerve.

Temporalis

Temporalis is a fan shaped radiating muscle, situated at the side of the head. It takes its origin from the whole of the temporal fossa and from the deep surface of the temporal fascia. As they descend, its fibers converge and end in a tendon, which passes medial to the zygomatic arch and is inserted into the medial surface and anterior border of the coronoid process, and the anterior border of the ramus of the mandible nearly as far forward as the last molar tooth.

Action: Elevates and retracts mandible, innervated by mandibular division of trigeminal nerve.

Temporal Fascia

The temporal fascia covers the temporalis muscle. It is a strong, fibrous investment, covered, laterally, by the auricularis anterior and superior, by the galea aponeurotica, and by part of the orbicularis oculi. The superficial temporal vessels and the auriculotemporal nerve cross it from below upward. Above, it is a single layer, attached to the entire extent of the superior temporal line; but below, where it is fixed to the zygomatic arch, it consists of two layers, one of which is inserted into the lateral, and the other into the medial border of the arch. A small quantity of fat, a filament from the zygomatic branch of the maxillary nerve and the orbital branch of the superficial temporal artery are contained between these two layers. It affords attachment by its deep surface to the superficial fibers of the temporalis.

The relationship between the masticatory muscle volume and mandibular skeletal measurements with or without facial asymmetry has been studied. The asymmetric masticatory functions or occlusion were also important in the development of facial asymmetry. Changes in the mechanical strain in the muscle insertion area, which are caused by masticatory force, can influence the local skeletal structure. It has also been determined that large masseter and medial pterygoid muscle volume shows a flat mandibular angle and a short gonial angle. Thicker masseter muscle shows a correlation with a larger ramus. It has also been determined that bony hypoplasia was related to masticatory muscle hypoplasia in patients with hemifacial microsomia.[3,4,7,8]

Trigeminal Nerve (V Cranial Nerve) (Figure 4-4)

Upper Face

The trigeminal nerve, the largest of the cranial nerves, is a mixed nerve. It contains boths general somatic afferent and motor special visceral efferent fibers. It derives from the reunion of three branches - ophthalmic (VI), maxillary (V2) and mandibular (V3). The trigeminal nerve emerges from two roots on the ventrolateral surface of the pons. The sensory root is larger and associated with trigeminal ganglion, located in the fossa on the inner surface of petrous portion of temporal bone. The smaller motor root originates in a nucleus in the pons.

The ophthalmic nerve derives from the conjunction of three main branches: lacrimal, frontal and nasociliary. The lacrimal branch carries sensations from the upper face and the eye, exits the skull through the superior orbital fissure. The frontal nerve divides into supratrochlear and supraorbital branches and supplies the skin of the forehead. The nasociliary supplies the eyeball, conjunctiva and ethmoidal mucosa. This traverses the cavernous sinus and reaches Meckel's cave, where the trigeminal ganglion (or Gasserian or semilunar ganglion) is located.

The sensitivity of the maxillary region and the upper teeth is carried by the maxillary nerve. It escapes through the foramen rotundum, passes through the cavernous sinus and reaches the Gasserian ganglion and enters the pterygopalatine fossa.

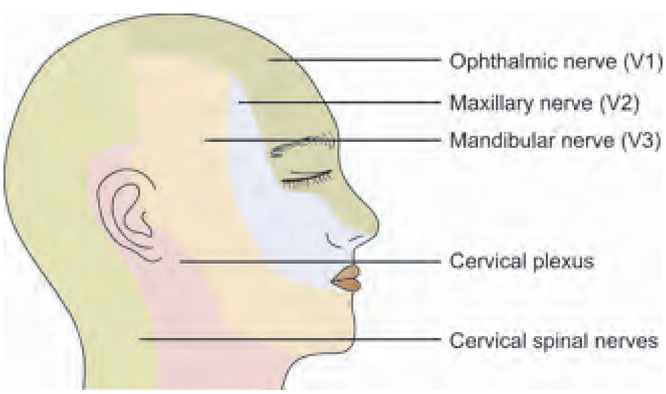

Figure 4-4: Neural pattern of the maxillofacial arena.

Branches: Its branches may be divided into four groups, according as they are given off in the cranium, in the pterygopalatine fossa, in the infraorbital canal, or on the face.

In the Cranium	Middle meningeal.
In the Pterygopalatine fossa	Zygomatic. Posterior superior alveolar.
In the Infraorbital canal	Anterior superior alveolar. Middle superior alveolar.
On the Face	Inferior palpebral. External nasal. Superior labial.

Infraorbital nerve: Passes anteriorly between orbit and maxillary antrum in infraorbital groove. Twigs to supply the mucosal lining of maxillary antrum. Emerges at infraorbital foramen to supply skin over cheek and upper lip.

Zygomatic nerve: (n. zygomaticus; temporomalar nerve; orbital nerve). Enters orbit through inferior orbital fissure. Two small cutaneous branches penetrate zygoma—zygomaticofacial (ramus zygomaticofacialis; malar branch) and zygomaticotemporal (ramus zygomaticotemporalis; temporal branch). Conveys postganglionic parasympathetic fibers from pterygopalatine ganglion to lacrimal gland **(Figure 4-5)**.

The posterior superior alveolar branches (posterior superior dental branches, rami alveolares superiores posteriors) arise from the trunk of the nerve just before it enters the infraorbital groove, running on the tuberosity of the maxilla and giving off several branches to the gums and neighboring parts of the mucous membrane of the cheek. Entering the posterior alveolar canals on the infratemporal surface of the maxilla, communicate with the middle superior alveolar nerve, and give off branches to twigs to each molar tooth the lining membrane of the maxillary sinus.

The middle superior alveolar branch (middle superior dental branch, ramus alveolaris superior medius), arises in the posterior part of the infraorbital canal, and runs downward and forward in a canal in the lateral wall of the maxillary sinus to supply the two premolar teeth. It forms a superior dental plexus with the anterior and posterior superior alveolar branches.

The anterior superior alveolar branch (anterior superior dental branch ramus alveolaris superior anteriores) emerging from the nerve just before its exit from the infraorbital foramen, it runs in a canal in the anterior wall of the maxillary sinus, and divides into branches which supply the incisor and canine teeth.

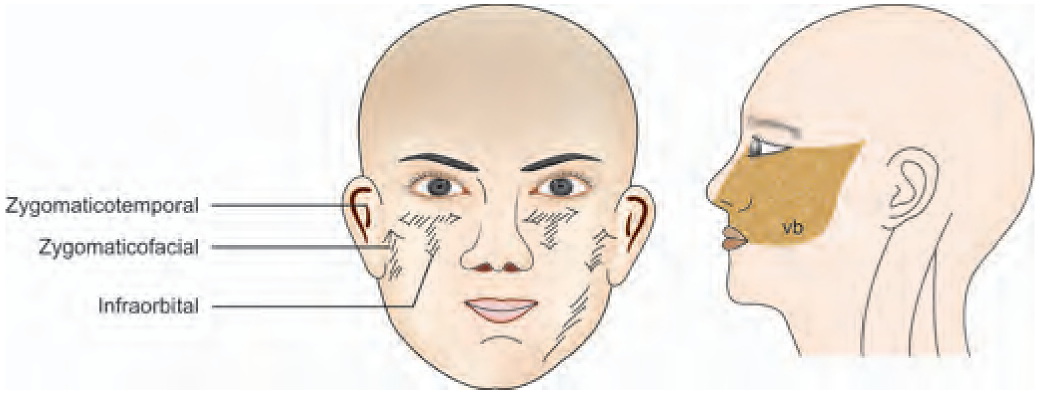

Figure 4-5: Cutaneous distribution.

Clinical Notes

Infraorbital injuries: malar fractures: Trauma to infraorbital margin may cause sensory loss of infraorbital skin.

Maxillary sinus infections: Infections of the maxillary sinus may cause infraorbital pain or may cause referred pain to other structures supplied by V2 (e.g. upper teeth).

Maxillary antrum tumors: Malignant tumors of the mucus lining of the maxillary antrum may expand into the orbit, damaging branches of V2, particularly the infraorbital. This may lead to anesthesia over the facial skin. The orbital contents may also be displaced causing proptosis or a squint.

The mixed component of the trigeminal nerve is represented by the 3rd branch, the mandibular nerve. It carries sensitivity from the lower region of the face and the lower teeth and receives the meningeal branch through the foramen spinosum. Moreover, it carries motor fibers mostly directed to masticator muscles (temporal, masseter and pterygoid) and the tensor veli palatini and tensor tympani muscles. The three branches join together in Gasserian ganglion and forms a plexiform structure, situated in a proper cistern inside Meckel's cave. The ophthalmic fibers are more ventral, mandibular dorsal and maxillary ones are intermediate.

The nerve's special visceral efferent (SVE) component originates from the motor nucleus at the level of the pons, and exits medially at the access of the sensory root.

Mandibular nerve: The mandibular nerve is a mixed nerve with both sensory and motor functions. The sensory root originates at the inferior angle of the trigeminal ganglion, whereas the motor root arises from motor cells in the pons and medulla. The two roots emerge from the cranium separately through foramen ovale, the motor root lying medially to sensory. They unite outside the skull and form the trunk of the third division. The trunk later divides into a small anterior and a large posterior division.

It transmits sensory fibers from the skin over the mandible, side of the cheek and temple, the oral cavity and contents, the external ear, the tympanic membrane and temporomandibular joint (TMJ). It also supplies the meninges of the cranial vault. It is motor to the muscles derived from the first branchial arch: Temporalis, masseter, medial, lateral pterygoids, tensor tympani, tensor palate. mylohyoid, anterior belly of digastric.

Some of its distal branches also convey parasympathetic secretomotor fibers to the salivary glands, and taste fibers from the anterior portion of the tongue.

The mandibular nerve gives off branches in three areas: from the undivided nerve, and the anterior and posterior divisions.

Branches from the undivided nerve include the nervus spinosus which supply the dura mater and mastoid air cells and nerve to medial pterygoid. Branches of the anterior division are the buccal, deep temporal, the masseter and the lateral pterygoid. Branches from the posterior division are the auriculotemporal, the lingual and the inferior alveolar.

Lower Face

Auriculotemporal nerve: Arises beneath foramen ovale by two rootlets on either side of middle meningeal artery. Passes above parotid gland, between TMJ and external auditory meatus to emerge on side of head. Ascends close to superficial temporal artery. Supplies TMJ, parotid fascia, skin of temple, most of skin of external auditory meatus and tympanic membrane. For short distance between foramen ovale and parotid gland it conveys parasympathetic fibers for innervation of parotid gland. Care should be taken to protect the nerve during preauricular incisions.

Buccal nerve: Supplies sensory fibers to skin and mucosa of cheek (it does not supply buccinator).

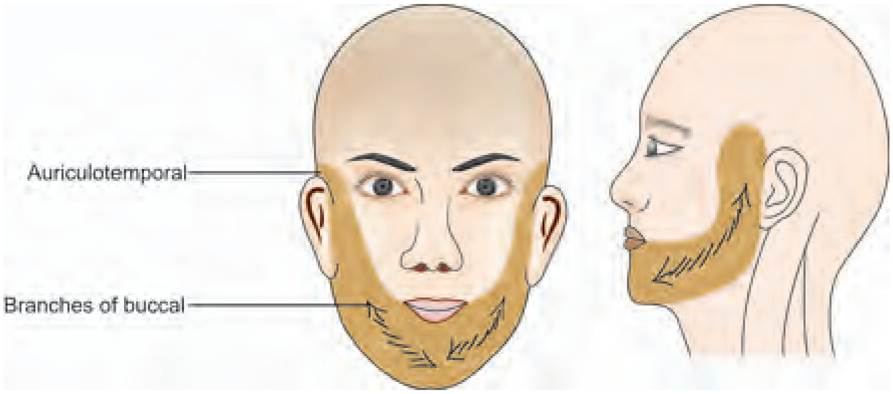

Figure 4-6: Neural pattern of lower face.

Muscular branches: Temporal nerves to temporalis, and other muscular twigs.

Meningeal branches: Small twigs re-enter middle cranial fossa through foramen ovale, and other foramina, to supply meninges.

Inferior alveolar nerve: Enters mandibular foramen, supplies, lower teeth, just before entering, it gives off the nerve to mylohyoid and anterior belly of digastric, it founds its exit through the mental foramen supplying the overlying skin. Nerve is at risk during the procedures of mandibular surgeries. During the procedure of sagittal split osteotomy, identification of the nerve is done and protected **(Figure 4-6).**

Lingual nerve lying immediately below and medial to the third lower molar tooth, is prone to damage during many surgical procedures due to its anatomical position. Most likely traumatized during the surgical removal of the last molar tooth, which involves the manipulation of the lingual flap or cortical bone.[2]

Clinical Notes

Lingual nerve: Careless extractions of the third lower molar (wisdom) tooth, abscesses of its root, etc., or fractures of the angle of the mandible may all damage the lingual nerve. This may result not only in loss of somatic sensation from the anterior portion of the tongue, but also loss of taste sensation and parasympathetic function.

Inferior alveolar nerve: Trauma to the mandible may damage or tear the inferior alveolar nerve in the mandibular canal leading to sensory loss distal to last molars.

The inferior alveolar nerve (IAN) is at significant risk during the orthognathic surgeries of mandible. It is at risk in all stages of surgery, including incision, dissection, retraction, bone cuts, mobilization and internal fixation. Nerve damage apparent at operation during BSSO is reported from 1.3% to 18% according to Turvey, et al and van Merkesteyn, et al. The most commonly injured branches of the trigeminal nerve are the inferior alveolar nerve 64% and the lingual nerve 28%. The most common etiologies are odontectomy, local anesthetic injections, orthognathic surgeries and implant surgeries.[13]

Motor Innervation

The facial nerve (VII): The facial nerve supplies the muscles of facial expression. Its other functions are, taste sensation from the anterior portion of the tongue and oral cavity; parasympathetic secretomotor function of the salivary, lacrimal, nasal and palatine glands.

It originates from cerebellopontine angle. Two adjacent roots, motor root being larger and more medial,the sensory also termed as nervus intermedius, smaller and more lateral. Nervus intermedius conveys parasympathetic and sensory fibers and may be part of VIII initially.

Course and Branches

Intracranial course and branches: From cerebellopontine angle it crosses posterior cranial fossa and enters internal acoustic meatus (IAM with VIII). Nervus intermedius joins main root of facial nerve in IAM. Chorda tympani given off just before VII emerges at stylomastoid foramen and this passes anteriorly across tympanic membrane into infratemporal fossa where it joins lingual nerve. Emerges at stylomastoid foramen.

Extracranial course and branches: Outside stylomastoid foramen, small branches of VII supply occipital belly of occipitofrontalis, stylohyoid and posterior belly of digastric, and a variable amount of cutaneous sensation from skin of external auditory meatus. Nerve enters parotid gland where it forms an intricate plexus. The arrangement is termed as "pes anserinus".

Branches of VII are superficial in the gland. Five groups of branches emerge superficially from anterior border of parotid gland—temporal, zygomatic, buccal, mandibular and cervical.

The facial nerve is at risk during the procedures of parotid surgery, condylar surgery and severe lacerations of the preauricular area.

Iatrogenic injuries occur most often with extirpation of parotid malignancy where the facial nerve passes through the tumor and must be removed. Temporal bone fractures are a unique form of non-penetrating injury that can cause significant damage to the intratemporal facial nerve.

Injury to the intracranial segment of the facial nerve is usually iatrogenic, secondary to tumor removal, but infrequently can result from penetrating injuries or medial transverse temporal bone fracture.[11]

Surface Anatomy and Surface Markings of the Head

Many of the important landmarks of the skull are easily felt by methods of palpation, this include the nasion, which is the depression between the two supraorbital margins, external occipital protuberance, the apex of this is termed the inion, and the glabella, which is the ridge above the nasion. The lateral margin of the orbit is formed by the frontal process of the zygomatic bone can be easily palpated. Behind the zygomatic bone is the zygomatic arch with the superficial temporal artery crossing its posterior extremity and giving a convenient pulse. The jugal point is the junction between the zygomatic bone and the zygomatic process of the frontal bone and it is a surface marking for the middle meningeal artery. The superficial surface of the mandible is palpable apart from its coronoid process. The condyloid process can be felt by a finger placed immediately in front of, or within, the external auditory meatus with the mouth in opened and closed positions. When the teeth are clenched, the masseter and the temporalis can be felt contracting respectively over the ramus of the mandible and above the zygomatic arch. The parotid duct orifice seen within the mouth at the level of the 2nd upper molar tooth.

The pulsation of the facial artery can be felt as it crosses the lower margin of the body of the mandible immediately in front of the masseter and again opposite the angle of the mouth. In the latter situation, if the cheek is gripped lightly with the finger placed within the mouth and the thumb placed on the skin surface, the pulse will be felt a little more than a centimeter from the angle of the mouth. A line drawn vertically between the first and second premolar teeth passes through the mental foramen, the infraorbital foramen and the supraorbital notch. Through these three orifices, pass branches from each of the divisions of the trigeminal nerve, respectively, the mental branch of the inferior alveolar nerve, the infraorbital nerve and the supraorbital nerve. The middle meningeal artery can be represented by a line drawn upwards and somewhat forwards from a point along the zygomatic arch, two fingers' breadths behind the jugal point. The posterior branch of this artery passes backwards a thumb's breadth above, and roughly parallel to the zygomatic arch.

"For you created my innermost being; you knit me together in my mothers womb. I praise you because I am fearfully and wonderfully made; your works are wonderful, I know that full well." The psalmist sings in praise to God the creator.

Psalms 139 :13-14.

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Chapter 5

Binnoy Kurian

Introduction

A yardstick for measuring beauty is the dream of every aspirant involved in the study of Esthetics in various disciplines of art and science. The complexities and perceptions involved in the subject make it a very distant possibility, turning the dream even dearer. Interestingly these perceptions contributes in planning the treatment as the ethnic and racial factors play a major role in defining beauty.

The treatment outcome of a case largely depends on the esthetic outlook of the clinician, which in turn is influenced by a series of factors starting from the complaints and expectations of the patient to the social and racial perception regarding what is 'normal'. This may vary from clinician to clinician, region to region, etc. Irrespective of the treatment goals, the treatment plan has to be based on a thorough data-base assimilated through various methods like case history, clinical examination, model analysis and radiographic studies. Among these the Cephalometric analysis with the support of other investigations has been generally accepted as providing an insight into the underlying skeletal condition of the patient.

Cephalometrics, the fusion of craniometry and radiography, has come a long way after its inception in 1923 by Paccini. Various clinicians in different parts of the world have tried to study and explain the Cephalogram in their own ways with appreciable degrees of success, leaving behind a pool of analyses and explanations. Although tiresome, it is the duty of the clinician to pull out the right sets of analyses from this pool to arrive at a thorough 'Data base', in which lies the foundation of a sound treatment plan.

Prescribing a set of analysis for each and every clinical condition is beyond the scope of this chapter. An attempt has been made here to provide a general guidance to the aspiring clinician. Further analysis or deviations at any point from these guidelines may be necessary and sometimes even mandatory for a complete study of the problem involved.

Conventionally, cephalometric analysis has been done to interpret the position of the middle and lower thirds, of the face in relation to the upper third. The inter-maxillary dentoskeletal relations were given utmost importance and every possible landmark was successfully explored over time. Analysis was always done under the presumption that the patient had a normal cranium. Measurements – both linear and angular – were taken assuming that cranial landmarks are "constant". Although this may go well with a patient requiring orthodontic correction, surgical alterations of skeletal components of face demand a more definitive approach.

For a comprehensive evaluation, the face can be divided into 5 building blocks:

1. The cranium
2. The maxilla
3. The maxillary dentoalveolus
4. The mandibular dentoalveolus
5. The mandible.

Most of the cephalometric analyses consider the cranium as a stable structure. Although this may not always be true, the fact remains that the cranial structures are seldom altered during orthognathic surgeries. So in most of the cases the cranium or the building block can be considered a template over which the rest of the building blocks are arranged.

In 1955, Sassouni had successfully explored the possibility of a cephalometric explanation on various vertical discrepancies of face. He observed that the horizontal planes of the face converged to a common point behind the head in a reproducible pattern **(Figure 5-1)**. Any variation in the vertical facial proportions clearly reflected as changes in angulations between these horizontal planes. The acceptable range of angulations between these horizontal planes are as follows:

SN-FH = 7° ± 1
SN-PP = 8° ± 3
SN-OP = 14° ± 4
SN-MP = 32° ± 3

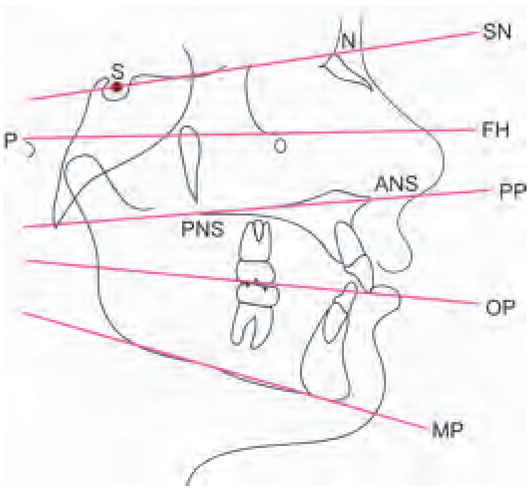

Figure 5-1: The horizontal planes: Sassouni observed that the horizontal planes of a cephalogram converged to meet at a point behind the cranium.

Once these changes are observed the following pattern of assessment may be followed:

1. Conformation of individual bone measurements of the four building blocks.

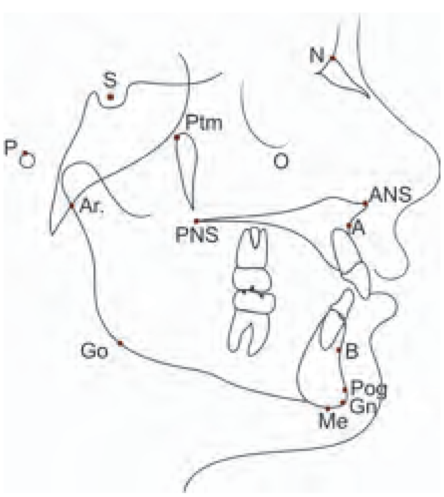

Figure 5-2: Cephalometric landmarks relevant to the analysis: N—Nasion, S—Sella, O—Orbitale, ANS—Anterior Nasal Spine, PNS—Posterior Nasal Spine, A—Point A, B—Point B, Pog—Pogonoin, Gn—Gnathion, Me—Menton, Go—Gonion, Ar—Articulare, P—Porion, Ptm—Ptm point.

2. Assessment of the skeletal rotations and compensations in relation to each block and its effect on the adjacent block.
3. Overall growth pattern.

This chapter tries to ascertain whether the size and position of these building blocks are within normal limits. Any change from normality is brought under a measurable scale, determining the extent of deformity in terms of the size and position.

Cranium

The first step is to make sure that the template itself is within the boundaries of normality. The cranial base can roughly be assessed by 2 measurements:

1. Saddle angle (Ba-S-N)
2. Length of the cranial base

Saddle Angle (Ba-S-N)

Saddle angle is the angle formed by the intersection of lines connecting S-N and Ba-S (**Figure 5-3).** It denotes the flexure of the cranial base.

Normal value: BaSN =130° ± 4.5

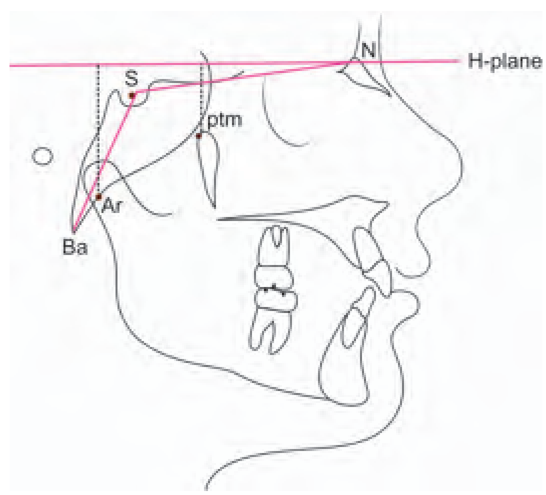

Figure 5-3: The cranium:Most of the analysis considers cranium as a stable structure,making it a template based on which other values are calculated.

Length of the Cranial Base

Perpendiculars are dropped from the horizontal plane constructed 7 degree to the SN plane at the level of Articulare, Ptm point and nasion. The distance from nasion to Ptm point denotes the length of anterior cranial base whereas Ptm point to Articulare represents the posterior cranial base. The sum of these measurements (N-Ptm-Ar) represents the anteroposterior length of the cranial base **(Figure 5-3).**

Normal Values:

Anterior Cranial Base (PtmN):

Males—52.8 mm ± 4.1; Females—50.9 mm ± 3

Posterior Cranial Base (ArPtm):

Males—31.7 mm ± 2.8; Females—32.8 mm ± 1.9

Total Length of the Cranial Base (ArN):

Males—90 mm ± 4; Females—83.7 mm ± 3

Although the measurements do not have a direct impact on the later measurements, any deviation in the flexure from the normal range should be kept in mind while evaluating the other values to give allowances wherever necessary.

If these fall within the normal range, proceed to the next analysis. If not, allowances may be made accordingly in later values, keeping in mind the variations in the cranial anatomy. This is important, as surgical correction of cranial structures is phenomenon seldom undertaken, unless there is a functional impairment.

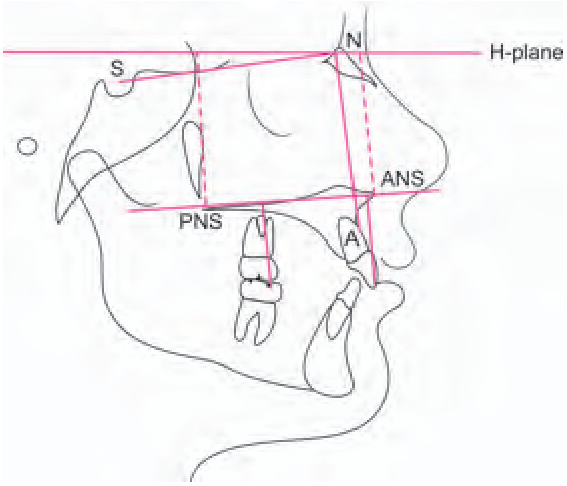

Figure 5-4: The maxilla: Maxillary measurements are pitted against the horizontal plane which is drawn 7° above the SN plane.

Maxilla

To determine whether the maxilla is normal:

A. By size
1. Anterior maxillary height
2. Posterior maxillary height
3. Effective maxillary length

B. By position (relative to the cranium)

4. SNA
5. N perpendicular to A

Measurement by Size

Anterior Maxillary Height (N-ANS)

It is the vertical distance from the anterior nasal spine (ANS) to the horizontal plane drawn through nasion **(Figure 5-4)**. An increase in this measurement is indicative of anterior vertical maxillary excess, and vice versa.

Normal values: Males—54.7 mm ± 3.2
Females—50 mm ± 2.4

Posterior Maxillary Height (N-PNS)

It is the vertical distance from the posterior nasal spine to the horizontal plane drawn through the nasion **(Figure 5-4)**. Increase in this measurement denotes an increase in the posterior vertical maxillary height, and vice versa.

Normal values: Males—53.9 mm ± 1.7
Females—50.6 mm ± 2.2

Effective Maxillary Length (ANS-PNS)

It is the distance between the two perpendiculars dropped from the horizontal plane to the ANS and the PNS **(Figure 5-4)**. An increase in this value indicates an increase in the size of the maxilla in the horizontal plane.

Normal values: Males—57.7 mm ± 2.5
Females—52.6 mm ± 3.5

Measurement by Position

SNA

It is the angle formed by the line joining the Nasion and Point A to the SN plane **(Figure 5-4)**. An increase in the angle indicates maxillary excess in the sagittal plane and vice versa.

Normal value: 82° ± 2°

Point-A to N-Perpendicular

A perpendicular to the horizontal plane is dropped through the nasion. Then the distance from point–A to this perpendicular is measured to get the relative positioning of the maxilla to the cranium **(Figure 5-4)**. An increase in this value is indicative of maxillary protrusion, and vice versa.

Normal values: Males—0.0 mm ± 3.7
Females—2 mm ± 3.7

Maxillary Dentoalveolar Measurements

Maxillary Anterior Dentoalveolar Height (Vertical)

It is the vertical distance from the upper incisal tip to the palatal plane **(Figure 5-4)**. An increase in this value denotes vertical dentoalveolar excess, and vice versa.

Normal values: Males—30.5 mm ± 2.1
Females—27.5 ± 1.7

Maxillary Posterior Dentoalveolar Height (Vertical)

It is the vertical distance from the tip of the mesial cusp of the upper first molar to the palatal plane **(Figure 5-4)**. An increase in the value denotes increased dentoalveolar height in the posterior region, and vice versa.

Normal values: Males—25.2 mm ± 2
Females—23.0 mm ± 1.3

Mandible

To determine whether mandible is normal.

A. By size
   1. Ramus height
   2. Body length
B. By position
   3. SNB
   4. N perpendicular to point B
C. Orientation
   5. Angle of the mandible
   6. Mandibular plane angle

Measure by Size

Ramus Height (Ar-Go)

Distance between the Articulare and the Gonion is measured to determine the length of the ramus **(Figure 5-5)**.

Normal values: Males—52 mm ± 4.2
Females—46.8 mm ± 2.5

Mandibular Body Length (Go-Gn)

It is the distance between the Gonion and the Gnathion **(Figure 5-5)**. An increase in this value denotes increased length of the body of the mandible, and vice versa.

Normal values: Males—83.7 mm ± 4.6
Females—74.3 mm ± 5.8

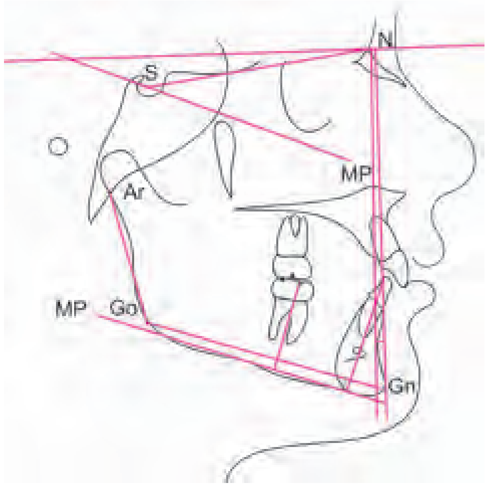

Figure 5-5: The mandible: Like the maxilla, the mandibular values are also measured against the horizontal plane.

Measurement by Position

SNB

It is the angle that the line joining the nasion and the point-B makes with the SN plane **(Figure 5-5).** An increase in SNB indicates forward positioning of the mandible, and vice versa.

Normal values: 80° ± 2°

N-Perpendicular To Point-B

A perpendicular from the horizontal plane is dropped from the Nasion point. Then the distance from the Point-B to this perpendicular is measured to find the positioning of the mandible in relation to the cranium **(Figure 5-5)**. An increase in the value indicates retrusion of the mandible while a decrease indicates protrusion.

Normal values: Males—5.3 mm ± 6.7
Females—6.9 mm ± 4.3

Orientation of the Mandible

Angle of the Mandible

The angle formed between the lines Ar-Go and Go-Gn determines the angle of the mandible **(Figure 5-5)**. An increase in this angle is projected as an increase in anterior vertical measurement of the mandible, and vice versa.

Normal values: Males—119.1° ± 6.5
Females—122.0° ± 6.9

Mandibular Plane Angle

It is the angle that the mandibular plane makes with the horizontal plane **(Figure 5-5)**. An increase in the angle indicates clockwise rotation of the mandible resulting in increased lower anterior facial height. On the other hand, a decrease in this angle is indicative of decreased lower anterior facial height.

Normal values: Males—23.0° ± 5.9
Females—24.2 ± 5

Mandibular Dentoalveolar Measurements

Mandibular Anterior Dentoalveolar Height (Vertical)

It is the length of the perpendicular drawn from the tip of the lower incisor to the mandibular plane **(Figure 5-5)**. Increased value denotes increased height of the mandibular dentoalveolar region, and vice versa.

Normal values: Males—45.0 mm ± 2.1
Females—40.8 ± 1.8

Mandibular Posterior Dentoalveolar Height (Vertical)

It is the length of the perpendicular drawn from the tip of the mesial cusp of the mandibular first molar to the mandibular plane **(Figure 5-5)**. An increase in the measurement indicates increased mandibular posterior dentoalveolar height and vice versa.

Normal values: Males—35.8 mm ± 2.6
Female—32.1 mm ± 1.9

The Chin

Position: Pg-N Perpendicular

A perpendicular to the horizontal plane is dropped at the Nasion point. Then measurement is taken from Pog to Nasion perpendicular (**Figure 5-6)**. An increase in this value indicates retruded chin, and vice versa.

Normal values: Males—4.3 mm ± 8.5
Females—6.5 mm ± 5.1

B-N Perpendicular

The linear measurement from Point-B to the perpendicular dropped at nasion point denotes the depth of the mental fold when assessed in relation to Pog-N perpendicular value. This in turn is indicative of the chin prominence **(Figure 5-6)**.

Normal values: Males—5.3 mm ± 6.7
Females—6.9 mm ± 4.3

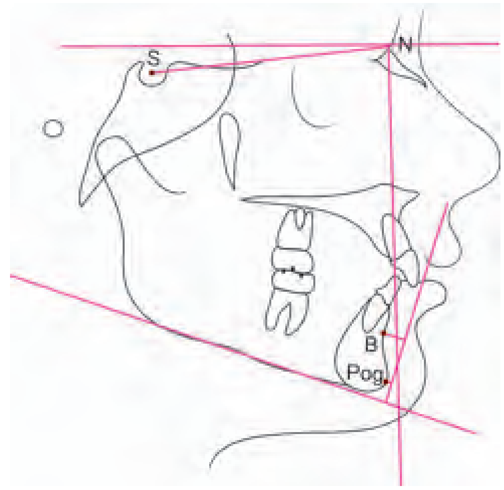

Figure 5-6: The Chin:Cephalometric values for assessing the chin position and prominence

Orientation

A perpendicular is drawn from the mandibular plane through the Pogonion. Then the distance to this perpendicular from point–B is measured to determine the depth of the mental fossa corresponding to the soft tissue mentolabial sulcus **(Figure 5-6)**.

Normal values: Males—8.9° ± 1.7
Females—7.2° ± 1.9

Dental

A. Maxilla
1. Upper incisor to NA-Angular
2. Upper incisor to NA-Linear
3. Upper incisor to Nasal floor.

B. Mandible
4. Lower incisor to NB-Angular
5. Lower incisor to NB-Linear
6. Lower incisor to mandibular plane

C. Intermaxillary Incisal Relations
7. Interincisal angle
8. Overjet
9. ANB
10. Ao-Bo

Maxilla-Dental

Upper Incisor Protrusion/Retrusion

Angular: It is the angle formed by the intersection of the long axis of the upper incisor to the line joining Nasion and Point-A (**Figure 5-7)**. An increase in the value indicates anterior proclination, and vice versa.

Normal values: Upper Inc–NA (angle) 22.0°± 2

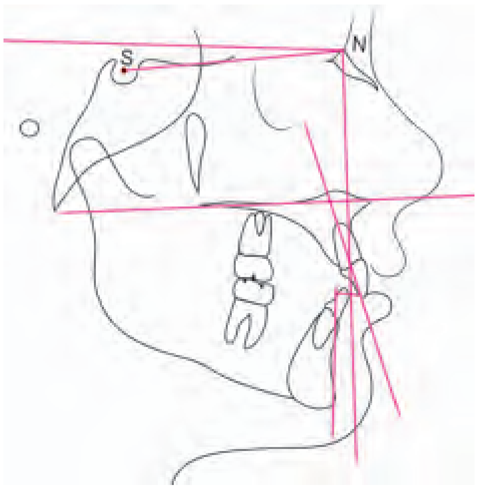

Figure 5-7: The maxilla-dental: Maxillary dentition is assessed against the cranium and the maxilla itself.

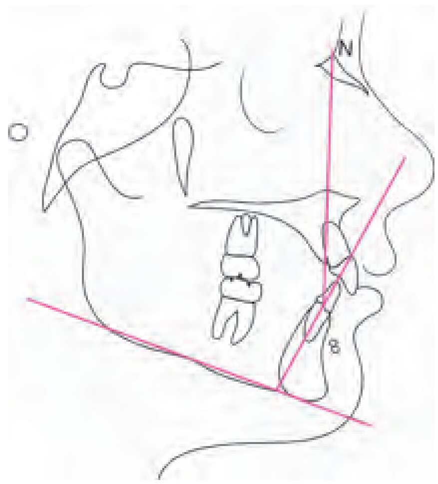

Figure 5-8: The mandible-dental: mandibular dental values are obtained in relation to the cranium and the mandible itself.

Upper Incisor Protrusion/Retrusion (11 to NA)

Linear: It is the horizontal distance measured from the tip of the upper incisors to the line joining Nasion and Point-A (**Figure 5-7**). Increased value indicates upper anterior proclination while a decrease in the value indicates retrusion.

Normal values: Upper Incisor–NA (linear) + 4 ± 1

Upper Incisor Orientation in Relation to Maxilla (11—ANS-PNS)

It is the angle formed by the long axis of the upper incisor to the nasal floor (Nasal floor denotes the plane joining ANS and PNS) **(Figure 5-7).** An increase in the angle denotes proclination of the upper incisors in relation to the basal bone, i.e. the maxilla, and vice versa.

Normal values: Males 111º± 4.7
Females 112.5º ± 5.3.

Lower Incisor protrusion/Retrusion (41 to NB)

Angular: It is the angle formed by the intersection of the long axis of the lower incisor to the line joining nasion and point B (**Figure 5-8**). Increased angle indicates lower anterior proclination while decreased angle indicates retrusion.

Normal values: Lower Incisor – NB (angle) 20± 2

Lower Incisor Retrusion/Protrusion (41 to NB)

Linear: It is the horizontal distance measured from the tip of the lower incisor to the line joining Nasion and Point-B (**Figure 5-8).** An increase in this value indicates lower incisor proclination, and vice versa.

Normal values: Lower Incisor – NB (linear) 2 ± 1

Lower Incisor Orientation in Relation to Mandible (41 to MP)

It is the angle formed by the long axis of the lower incisor to the Mandibular plane.[Mandibular plane is formed by drawing a line tangent to the lower border of mandible. (**Figure 5-8**)]. Excess value indicates lower incisor proclination, and vice versa.

Normal values: Lower Incisor – MP (angle):
Males 95.9°± 5.2
Females 95.9°± 5.7

Intermaxillary Orientation

Skeletal	Dental
1. ANB	3. Interincisal angle
2. Ao-Bo	4. Overjet
	5. Overbite

ANB

It is the angle formed by the lines connecting the Nasion Point-A and Nasion Point-B (**Figure 5-9**). An increase in the ANB angle indicates Class ll skeletal pattern while decreased or negative ANB denotes Class lll pattern.

Normal values: ANB 2º

AO-BO

It is the horizontal distance between the two perpendiculars dropped from point-A and point-B to the occlusal plane (**Figure 5-9)**. Increase in this distance denotes Class II pattern while decrease denotes Class III pattern.

Normal values: Males—1.1 mm ± 2.0
Females—0.4 mm ± 2.5

Interincisal Angle

It is the angle formed by the intersection of the long axes of upper incisor and the lower incisor (**Figure 5-9).** A decrease in this angle is indicative of bimaxillary dental proclination, and vice-versa.

Normal values: Interincisal (angle) 131°± 4.7

Overjet

It is the distance, measured horizontally, between the labial incisal edges of the upper and lower incisor teeth, with the dental arches in occlusion.

Normal value: 2 ± 1 mm

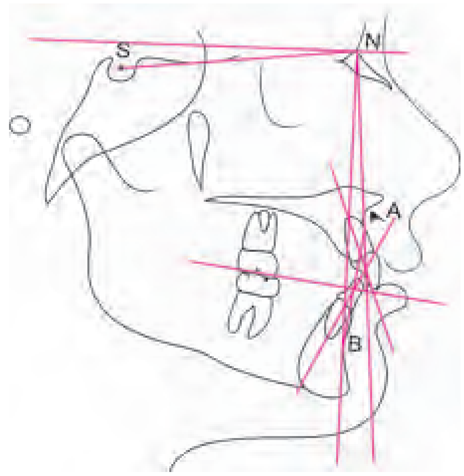

Figure 5-9: Intermaxillary: The intermaxillary relations are assessed by plotting the values against each other rather than using cranium as a template.

Overbite

The distance, measured vertically, between the incisal edges of the upper and lower incisor teeth, with the dental arches in occlusion (vertical overlap).

Normal value: 2 ± 1 mm

Intermaxillary Orientation

SKELETAL

	THE CRANIUM			
			NORMAL VALUES	
1	Cranial base length	Ar-Ptm-N	Males:	90 mm ± 4
			Females:	83.7 ± 3
	Anterior cranial base	Ar-Ptm	Males:	31.7 mm ± 2.8
			Females:	32.2 mm ± 1.9
	Posterior cranial base	N-Ptm	Males:	52.8 mm ± 4.1
			Females:	50.9 ± 3
2	Flexure of the cranial base	Ba-S-N	130° ± 4.5	

	THE MAXILLA			
	SIZE			
1	Maxillary length	ANS-PNS	Males:	57.7 mm ± 2.5
			Females:	52.6 mm ± 3.5
2	Anterior vertical maxillary height	N-ANS	Males:	54.7 mm ± 3.2
			Females:	50 mm ± 2.4
3	Posterior vertical maxillary height	N-PNS	Males:	53.9 mm ± 1.7
			Females:	50.6 mm ± 2.2
	POSITION			
4	Protrusion/retrusion in relation to cranium	SNA	82 mm ± 2	
5	Protrusion or retrusion in relation to the cranium	AN	Males:	0.0 mm ± 3.7
			Females:	2 mm ± 3.7
	DENTOALVEOLAR			
6	Anterior dentoalveolar height	1 to NF	Males:	30.5 mm ± 2.1
			Females:	27.5 mm ± 1.7
7	Posterior dentoalveolar height	6 to NF	Males:	25.2 mm ± 2
			Females:	23.0 mm ± 1.3

	THE MANDIBLE			
	SIZE			
1	Ramus height	Ar-Go	Males:	52 mm ± 4.2
			Females:	46.8 mm ± 2.5
2	Body length	Go-Gn	Males:	83.7 mm ± 4.6
			Females:	74.3 mm ± 5.8
	POSITION			
3	Protrusion/Retrusion in relation to cranium	SNB	80 mm ± 2	
4	Protrusion or retrusion in relation to cranium	B-N	Males:	5.3 mm ± 6.7
			Females:	6.9 mm ± 4.3
	ORIENTATION			
5	Angle of mandible	Ar-Go-Gn	Males:	119.1° ± 6.5
			Females:	122.0 ± 6.9
6	Mandibular plane angle	HP-MP	Males:	23.0° ± 5.9
			Females:	24.2 ± 5
	DENTOALVEOLAR			
7	Anterior dentoalveolar height	1 to MP	Males:	45.0 mm ± 2.1
			Females:	40.8 mm ± 1.8
8	Posterior dentoalveolar height	6 to MP	Males:	35.8 mm ± 2.6
			Females:	32.1 mm ± 1.9

	THE CHIN			
	POSITION			
1	Anterior –Posterior positioning of the chin in relation to cranium	Pg-N	Males:	4.3 mm ± 8.5
			Females:	6.5 mm ± 5.1
2	Anterior –Posterior positioning of the chin in relation to the mandible	B-Pg	Males:	8.9º ± 1.7
			Females:	7.2° ± 1.9
3	Depth of the mental fold	B-N	Males:	5.3 mm ± 6.7

	DENTAL				
	MAXILLA				
1	Upper incisor orientation in relation to maxilla	1 to NF		Males:	111° ± 4.7
				Females:	112.5° ± 5.3
2	Upper incisal protrusion or retrusion	1 to NA	Linear	4 ± 1 mm	
			Angular	22.0° ± 2	
	MANDIBLE				
3	Lower incisor orientation in relation to maxilla	1 to MP		Males:	95.9° ± 5.2
				Females:	95.9° ± 5.7
4	Lower incisal protrusion or retrusion	I to NB	Angular		20° ± 2
			Linear		2 ± 1 mm
	MAXILLA MANDIBLE				
5	Skeletal orientation of maxilla to mandible	Ao-Bo(wits)		Males:	1.1 mm ± 2
				Females:	0.4 mm ± 2.5
		ANB		2°	
		Interincisal angle		131° ± 4.7	
6	Skeletal orientation of maxilla to mandible	1 to 1		2 ± 1 mm	
7	Orientation of maxillary teeth to mandibular teeth				
8	Overjet				

Basing all the cases on a uniform set of values need not always expose the underlying discrepancy. Analyzing a group of values relevant to each patient will definitely provide an insight into the diagnosis. But decisions should be made keeping in mind the fact that cephalometric values are not conclusive, and clinical acumen should always dominate the process of arriving at a proper diagnosis.

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Chapter 6

Varghese Mani

Introduction

Before a patient is taken up for surgery a thorough evaluation and documentation is necessary. Patients are to be subjected to general medical examination and specialist consultation. The specialist consultation includes, speech, audiometric, dental, oral, psychologic, neurologic, ophthalmologic and ENT consultations. Database collection is imperative as a diagnostic aid, a tool for treatment planning, for communication between specialists, medicolegal problems and research.[35,36] Surgery for skeletal problems may alleviate or sometimes aggravate TMJ problems.[16,26,33]

Medical Evaluation

Usually, patients seeking help for dentofacial deformities are young and healthy. However, facial deformities can be present as features of certain syndromes. Patients should be evaluated for their general medical condition especially with regard to cardiopulmonary, endocrinal, hematological and neurological status. Even though most of the orthognathic surgery patients are healthy adults, physical and laboratory investigations are important.[13]

All men above forty years, and all women in post-menopausal age should have their ECG tracing and evaluation before surgery.[19] Epidemiologic studies show that the risk of myocardial infarction reduces slowly for six months and remain stable later though the risk is much higher than a similar patient without history of myocardial infarction. So it is advisable to postpone surgery for six months in such cases.[9, 19] The heart tolerates hypotensive anesthesia well. The after load reduction sharply cuts myocardial oxygen requirements. All patients with a history of smoking should have chest radiographs done.[1]

Evaluation of Oral Cavity

A thorough evaluation of oral cavity has to be done. The dental history must be recorded and the presenting problems noted. General dental health and the periodontal status have to be evaluated and necessary treatment if any should be instituted prior to surgery. Care should be taken to eliminate apparent and potential foci of infection. Oral health directly influences the result of aesthetic surgery. Patients with pre-existing periodontal disease are at an increased risk of exacerbation of the disease during the course of the orthodontic treatment and the postsurgical period. The risk is more in the areas of interdental osteotomies.[12]

Psychological Evaluation

Patients seeking orthognathic surgery are mainly of two types. One group attributes all their problems, either social or personal, to their facial appearance. Usually, psychological problems, though originally stemming from their deformity, get deeply rooted in their character make-up. Therefore esthetic rehabilitation alone may not correct their psychological problems. Such persons should be taken up very carefully. They often remain unhappy even after optimum surgical results are achieved.

Patients belonging to the second group are self motivated. They want to improve their facial appearance for esthetic reasons rather than personality problems. They are more realistic. Patients' expectations about the surgery should also be evaluated. Persons with unrealistic expectations do not make good patients. It is the duty of the surgeon to enlighten his patients regarding the outcome of the treatment. Surgery can change a smile into a brighter one; but it is hard to alter a grim face to a smiling one.

Face is considered as the index of the mind.

Esthetic Evaluation of the Patient

A lot can be written about functional and psychological rehabilitation of the patient, but aesthetic rehabilitation is equally important, if not more. Many patients are reluctant to agree that they are unhappy about their appearance, and try to project that they seek correction to improve the functional efficiency or alleviate imaginary pains and discomforts.

It is important that the aesthetic desires of the patients are clearly noted. It is advisable to make the patients understand the possible changes that can occur on the face after surgery and the extent of aesthetic harmony that can be achieved.

Aesthetic evaluation is mandatory to understand the problems systematically. Harmony of the facial structures is very important for facial aesthetics. Proper balance between the different parts of the face - forehead, eyebrows, eyes, nose, ears, cheeks, lips, mouth, chin, etc. - and the morphology and symmetry of the face are the main factors related to aesthetics.

To evaluate the harmony and balance of the face certain norms are established by artists, scientists and scholars. The concept of beauty varies from race to race and from place to place. However, established norms may be taken as a standard for evaluating facial esthetics. Esthetics and function often go hand in hand.

Facial evaluation is inevitable for the following: (1) To systematically analyze the face as a whole, and part by part, to understand the problems objectively. (2) To help in deciding the surgical procedure, that will benefit the patient most (planning the surgery).

Aesthetic facial evaluation is usually done with the patient seated in a relaxed and comfortable position. Many of the patients with gross deformities of the face, have certain mannerisms related to the facial musculature. Those who have an open bite and incompetent lips try to appose their lips very often. Patients having vertical excess of the maxilla with a gummy smile do not smile heartily, and usually try to restrict the upward movement of the lips while smiling. For a proper objective analysis of the soft tissues, the patient should be completely relaxed. To get the natural head position, it is better that the patient fix the gaze at a distant object (horizon-horizontal). Aesthetic evaluation is done better when the patient keeps the head in a natural position.[17,26,30]

The details of the facial measurements are done directly on the patient. The useful facial analyses are the frontal analysis and the profile analysis.

It is advisable to keep the Clinical Frankfort Horizontal Plane (ClFHP)- the line passing through the tragus and inferior orbital border- parallel to the floor. This is often the natural head position. However, depending on the deformity the head posture may vary. This variation of head posture could be for comfort or to mask the deformity. Since the intention is to correct the deformity, measurements are done after keeping the ClFH plane parallel to the floor. The evaluation is done with the teeth in centric relation. Most often it is not easy to get the patient occlude the teeth in centric relation. Asking the patient to flex the tongue backward and bite, or to swallow and bite, etc. are different methods. An easy and successful method is keeping bits of cotton fibers on the occlusal surface of the molars on both sides and instructing the patient to bite on it. The masticatory and facial muscles, especially the lips, should be completely relaxed for proper evaluation.

Frontal Analysis

Harmony and balance are very much related and dependent on facial proportions. Facial proportions can be measured using calipers clinically. Most of the horizontal measurements are to be taken clinically. Vertical proportions can be taken from cephalograms as well. Bizygomatic width to facial height is 0.88 for males and 0.86 for females in a well proportioned face. The ratio of bigonial to bizygomatic width is about 0.70.[8] Likewise a face that tapers down to the chin is more pleasing.

Facial symmetry can be analyzed from the frontal view. Evaluation of symmetry can be done clinically, from true frontal photographs and from PA cephalograms.The midline of the chin, teeth, nose, etc. are noted and recorded as part of the evaluation **(Figure 6-1).**

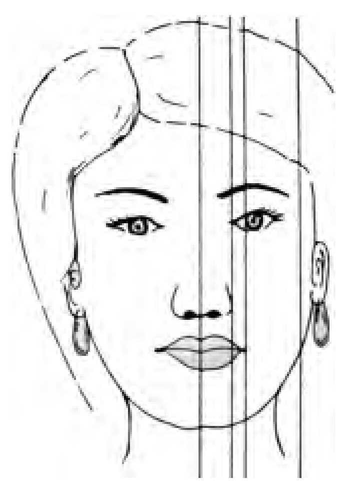
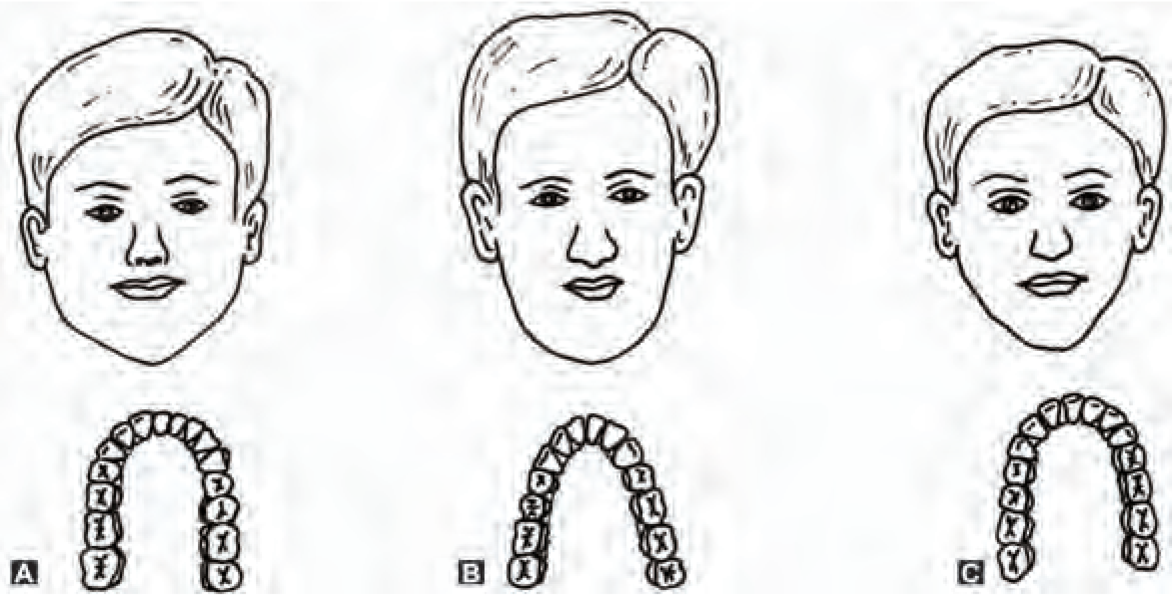


Figure 6-1: Analysis of facial symmetry.

Face can be roughly classified into three types. Dolichocephalic individuals have a long narrow face with



Figures 6-2A to C: (A) Brachycephalic, (B) Mesocephalic, (C) Dolichocephalic.

relatively 'V' shaped dental arches. Brachycephalic persons have broad and short face with broad and round dental arches. Mesocephalic individuals are in between the former two categories with a parabolic arch **(Figures 6-2A to C).**

In general, face can be divided into three equal parts from the hairline to the menton. Upper-third extends from hairline to glabella, middle third from glabella to subnasale and lower third from subnasale to menton **(Figure 6-3).**

Figure 6-3: Face can be divided into three almost equal parts from the hairline to the menton. This gives harmony to the face.

Upper Third of the Face

This extends from the hairline to the eyebrows. In dentofacial deformities, this part of the face is considered less important due to the varying hair styles. However, in craniofacial syndromes, analysis of the upper third of the face is important.

Middle Third of the Face

This part extends from the eyebrows to the subnasale. Important structures in this part of the face are the eyes, malar bones, cheeks, nose, etc. Intercanthal and interpupillary distances are to be noted. Intercanthal distance is 34 ± 4 mm and interpupillary distance is 65 ± 4 mm. These values are usually established at the age of 6 to 8 years and do not vary much. Morphologic variations of the eyes should be noted (ptosis, ectropion or entropion). Skeletal deficiency of the midface may be associated with visibility of the sclera above the lower eyelids. Nose should be evaluated for its shape, length, prominence and morphology of the tip and ala.

Lower Third of the Face

This extends from the subnasale to the menton and equals the middle-third length. Relationship between the lips, stomion, subnasale and menton should also be noted. Smile is one of the most important aesthetic factors and this depends on the tonicity and competence of the lips, contraction of the perioral structures, visibility and angulation of the teeth and dental midline. Chin also should be evaluated in relation to the face for its symmetry and morphology **(Figure 6-4).**

Figure 6-4: Lower third of the face: From subnasale to stomion is half that of stomion to menton.

The relationship between the structures of the face tells upon the harmony and balance of the face. Certain salient points are listed below:

a. Middle third of the face: Lower third of the face = 1:1.
b. Subnasale to stomion is half of stomion to menton, i.e. in the ratio 1:2.
c. Subnasale to lower lip vermilion border and lower lip vermilion border to menton are almost equal in length.
d. At rest position, lower lip vermilion is 25% more exposed than upper lip vermilion.
e. Interlabial distance in normal cases is 0 to 3 mm.
f. Interpupillary distance equals the length from commissure to commissure.
g. At rest, upper incisal border is in line with the upper lip border or the teeth are exposed up to 3 mm.
h. While smiling, upper lip margin lies on the gingival margin.
i. Width of the nose is approximately equal to the inner intercanthal distance.
j. Width of the mandible at the gonial angles should be approximately the same as the width of the outer border of the orbits.
k. Dental arch midline should be in harmony with other midpoints.
l. Chin should be symmetrical.
m. Normal intercanthal distance is 32 ± 3 mm in Caucasians 35 ± 3 mm in Africans and about 34 ± 3 mm in orientals.
n. Normal interpupillary distance is 65 ± 3 mm.
o. Width of the nasal dorsum is one half of the intercanthal distance and the width of the nasal lobule is two-third of the intercanthal distance.
p. Normal upper lip length from subnasale to stomion is 22 ± 2 mm in males and 20 ± 2 mm in females.
q. Line tangent to the globe of the eye; perpendicular to the Frankfort Horizontal Plane should fall in the infraorbital soft tissues, ± 2 mm.

Profile Analysis

This is a very valuable and unavoidable analysis to assess the facial proportions and anteroposterior dimensions.

In a natural head position the profile line in relation to the clinical Frankfort horizontal plane (ClFHP) can be assessed. It could be straight or divergent posteriorly or anteriorly. The ClFH is the line from the tragus of the ear to the bony infraorbital rim. The evaluation is preferably done with the line parallel to the floor. This is often the natural head position.[14]

Patients with dentofacial deformity acquire varied head postures in an effort to mask the deformity. While evaluating, the head postures are adjusted by orienting the ClFH plane parallel to the floor.[6] In general, the facial profile can be classified into convex, concave or straight types **(Figure 6-5)**.

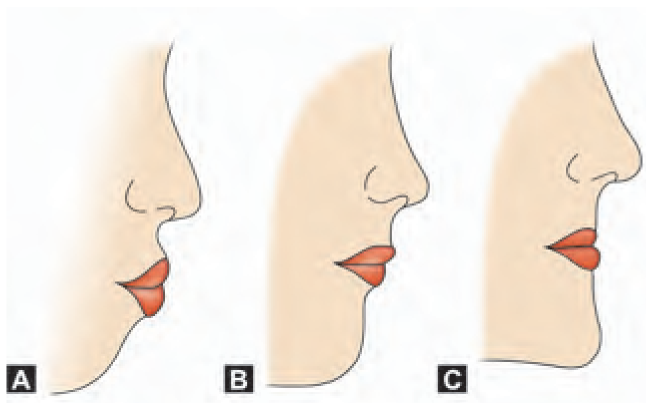


Figure 6-5: On profile analysis face can be convex (A), straight (B), or Cocave (C).

The forehead has an anterior slope with mild projection of the supraorbital rims. Usually the supraorbital rims project about 5 to 10 mm ahead of the most anterior part of the globe of eye.

In frontal bossing, reverse slope is seen. This also may be seen in supraorbital hypoplasia, but the projection in relation to the globe in supraorbital hypoplasia is minimal or normal.

The nasal bridge in the glabellar area projects 5 to 8 mm from the globes. Nasal dorsum can be straight, convex or concave. The nasal tip is evaluated for supratip break and whether the tip is upturned or down turned.

The nasolabial angle demands considerable attention. Normally this ranges between 90 and 110° **(Figure 6-6).**

Figure 6-6: The nasolabial angle varies from 90 to 110°. Acute angle is an indication of protrusion of the upper teeth if the angulation of the columella is normal.

Abnormality in this angulation is either due to lip position or nasal angulation. This can be assessed by drawing a perpendicular to the Frankfort plane through the subnasale. In the normal lip, this line passes through the most anterior part of the upper lip vermilion; ± 2 mm is considered normal.

Ratio of the linear distance, in the horizontal plane, from nasal tip to subnasale and from subnasale to the alar base crease is normally 2: l. Decreased distance from the tip to subnasale suggests either decreased support for the alar base or maxillary and/or middle-third deficiency.

Normally upper lip projects slightly anterior to lower lip in repose. Labiomental fold gives a pleasant definition to the face. Depth of labiomental sulcus is ideally 4 mm **(Figure 6-7).**

Figure 6-7: Labiomental sulcus is about 4 mm deep.

To evaluate the horizontal relations of the soft tissues of the face, one of the ideal methods is to draw a perpendicular from the Frankfort horizontal plane through the subnasale. This line is taken as the reference line for further analysis. Most anterior part of the upper lip vermilion is 0 ± 2 mm to the subnasale perpendicular line. Lower lip is -2 ± 2 mm and chin is - 4 ± 2 mm from the line **(Figure 6-8).** Generally the bony chin should fall in a line through nasion perpendicular to Frankfort horizontal.

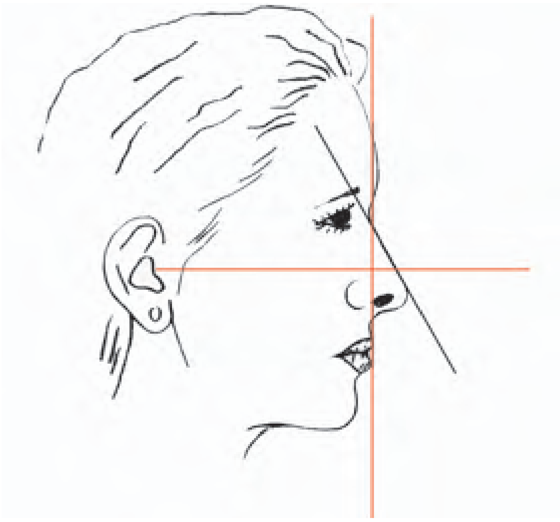


Figure 6-8: Subnasale perpendicular to F H plane passes through upper lip vermilion and 2 mm anterior to lower lip vermilion and 4 mm anterior to the chin. Though simple this is an excellent method to assess the relationship of the facial features. Nasal projection angle formed by a tangent on the dorsum of the nose and the perpendicular to the FH plane is normally 35° ± 2°.

A line drawn from tip of nose to the chin is known as the aesthetic line. This line just touches or goes anterior to the upper and lower lip vermilon borders. Balance

Figure 6-9: Aesthetic line.

depends on the relationship of the facial structures. The prominent parts of the face are nose, lips and chin. Relationship of these structures can be assessed with reference to the aesthetic line **(Figure 6-9).**

Nasion: Nasion is the lowest part on the groove formed at the frontonasal junction. It usually lies at a point between the margin of the upper eyelid and the upper edge of the tarsal plate with the eye open and looking straight ahead.

Analysis of the Nose

Functional and aesthetic nasal evaluation should be done prior to the surgery. History of any trauma, allergies, airway obstruction, sinus problems, mouth breathing habit, any previous surgeries, etc. should be noted. Thorough evaluation of the nasal structures is mandatory especially for septal deviations, scars, soft tissue thickness, asymmetries, polyps, hypertrophy of turbinates and adenoids.

Normally one-third or less of the vertical dimension of the nares is visible from frontal view. Nasion (N) should be at the same level as the upper palpebral crease. Nasal dorsum should be preferably straight. Normal nasolabial angle ranges from 90 to 110° in females and 90 to 95° in males. Columella should extend 3 to 4 mm below the lateral alar rims. Distance from base of the nose to anterior extent of the nares and that from the anterior aspect of the nares to the tip of the nose should be in 2:1 ratio. Length of the nose is measured from the nasion to the most prominent point on the tip. Dorsum may appear saddled if the nasion is positioned lower. If so, this may require grafting.

A horizontal line drawn parallel to the FH line through the tip of the nose and a tangential line drawn at the vermilon border of the upper lip perpendicular to the horizontal line should meet approximately at the middle of the length of the nose. If the anterior part is more than 60% the nose is over projected. If it is less than 40% it is considered under projected **(Figure 6-10).**

Another method to calculate the nasal projection is to relate the nasal dorsum to the perpendicular of FH plane. This is 34° in females and 36° in males **(Figure 6-8).** The nasofrontal angle is created by a line tangent to glabella and intersecting at nasion with a line tangent with the nasal dorsum. It should be between 125° and 135°. A large angle is indicative of poor tip projection. [25,26]

The chin neck contour is defined by the tangents to the soft tissue lower border of the mandible and the cervical point. This angle is approximately 135°.[25]

Figure 6-10: Nasal projection can be assessed by drawing perpendicular lines through the nasal tip, upperlip vermilon border, and the alar cheek junction.

Animation gives face the character. It is difficult, if not impossible, to correct learned habits and expressions of facial muscles. So evaluation of relaxed smile, full smile, etc. will help assess symmetry of muscle movement, action and hyperactivity of muscles groups. This also helps in evaluating the gingival exposure while smiling.

Cephalometric Analysis

Cephalometric analysis is a useful aid in treatment planning. McNeil, Proffit and White were the first to discuss the use of cephalometric prediction for orthognathic surgery patients.[21] Broadbent in 1931 developed the new X-ray technique and described its application in cephalometrics.[3] Later many investigators have proposed cephalometric analysis for orthodontics and orthognathic surgery which included soft tissue and skeletal analysis.[4,11,12,18,20,22,28,31] There are scores and more varied types of cephalometric analysis. To rely totally on cephalometrics alone for treatment planning could be disastrous. Usually there will be significant differences in the conclusions obtained from clinical analysis and cephalometric analysis. Experienced surgeons often rely on their clinical judgement. However, in certain two-jaw skeletal discrepancies (e.g. Mandibular prognathism with maxillary deficiency/excess) cephalometric analysis will serve as an important aid for planning the treatment.[37] Relaxed lip position with the mandible in centric relation is advisable while taking cephalograms.[5] In Steiner analysis, angles SNA and SNB are measured to evaluate the relative position of maxilla and mandible to the cranial base. It is one of the most popular methods of analysis.[31]

In McNamara analysis maxillary position is evaluated in relation to a nasion perpendicular to anatomical FFH line. Point A is on this line or slightly ahead **(Figure 6-11).**[20]

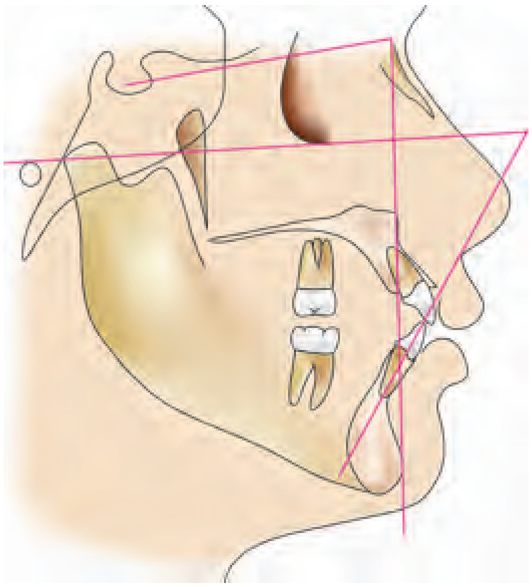


Figure 6-11: Nasion perpendicular.

Maxillary and mandibular lengths are measured and compared. Anteroposterior discrepancy between maxilla and mandible can be assessed by measuring the distance between point A (subspinale) and point B (supramentale). A cephalogram is taken in a standardized fashion with the head tipped 5° down from the Clinical Frankfort Horizontal Plane.[2] Numerous Cephalometric analyses are available. There could be significant differences between the cephalometric analysis and clinical evaluation.

When a significant difference occurs, clinical evaluation is far more important for treatment planning. Cephalometric analysis is an aid to clinical assessment and should not be used as the sole treatment planning tool.[37] Cephalogram is a two dimensional radiograph. It cannot give the three dimensional understanding, which is necessary to treat the patient. It may also be noted that cephalometric normal values should not be the treatment objective.[28] Computer digitalization and analysis have provided many advantages to the clinician as laborious manual measurement of angles and distances can be avoided. Moreover computer measurements are equally accurate, and eleminates human error.[10,15] Simplified softwares are being developed for analysis and combined orthodontic and surgical predictions.[10, 24, 27, 29, 32, 34]

Computer programmers allow the surgeon to do a variety of bony movements and assess the resultant soft tissue changes. Speed, ease, accuracy and wide application have redefined the state-of-the-art of predictions of surgical outcomes as well as cephalometric analysis.[10] Traditional method of manual tracing of the radiograph is time consuming and is open to random and creeping errors when locating landmarks.[23]

Computer technology has made digital tracing possible. However, the human errors in landmark location do remain.[7]

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Chapter

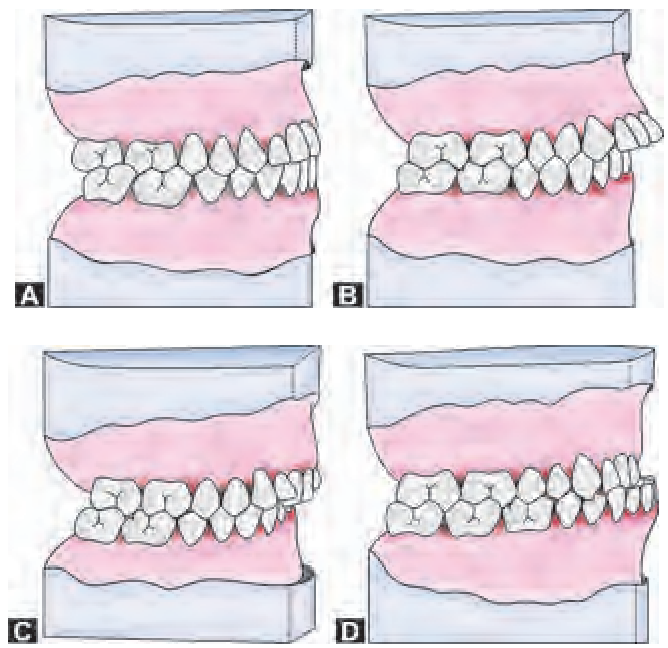
7

Varghese Mani

Introduction

Once evaluation is completed, the problem list is made. Importance is given to patient concerns as well as to clinical and cephalometric analysis. Depending on the problems a treatment plan is evolved. Classifying the deformity helps in understanding the defect systematically. This is the first step towards treatment planning. Database helps to generate a problem list according to severity or importance.[1-3]

Surgical correction of facial deformity orginally developed as an aid to orthodontics and used to be referred as orthodontic surgery. Later this branch advanced in leaps and the possibilities found expanded bounds. Surgery is now based on the architectural requirements of the skeleton and not solely on the occlusal requirements. Occlusion is classified according to Angle's classification (Class I, Class II, and Class III) and its subdivisions **(Figures 7-1A to D).** This classification is commonly used by orthodontists. The term orthodontic surgery later came to be known more appropriately as Orthognathic Surgery. Naturally, the major aim of the surgery changed from occlusal rehabilitation alone to dentoskeletal rehabilitation. At this point it should be stressed that the occlusal balance, stability and interdigitations of teeth substantially contribute to the skeletal stability. Otherwise the chances of postoperative relapse will be higher. Considering these factors a general classification of maxillofacial deformities is derived.



Figures 7-1A to D: Angle's classification of occlusal relationship. (A) Class I, (B) Class II Div I, (C) Class II Div II, (D) Class III.

Classification

1. Maxillary protrusion
   a. Skeletal
   b. Dentoalveolar
2. Maxillary retrusion
   a. Skeletal
   b. Dentoalveolar
3. Maxillary vertical deformity
   a. Excess Skeletal
      Dentoalveolar
   b. Deficient Skeletal Dentoalveolar
4. Maxillary transverse deformity
   a. Broad
   b. Narrow
5. Mandibular protrusion
   a. Skeletal
   b. Dentoalveolar

6. Mandibular retrusion
   a. Skeletal
   b. Dentoalveolar
7. Mandibular transverse deformity
   a. Broad
   b. Narrow
8. Malar deformity (Bilateral/Unilateral)
   a. Broad
   b. Narrow
   c. Prominent
   d. Deficient
9. Chin deformity-excess
   a. Vertical
   b. Transverse
   c. Anteroposterior
10. Chin deformity deficient
   a. Vertical
   b. Transverse
   c. Anteroposterior
11. Deep bite deformity
12. Open bite deformity (Apertognathia)
13. Asymmetry.

Maxillary Deformity

Maxillary Excess (Figures 7-2A to C)

Maxillary excess can be either dentoalveolar, skeletal or a combination of both. This deformity can be seen as a vertical excess or anteroposterior excess and is usually associated with development and growth. Hence, the skeletal deformity is often seen as a combination. The problems associated with maxillary excess in general are the following:

Clinical Findings

1. Vertical excess of the lower third of the face.
2. Visibility of upper teeth by more than 2-3 mm, in repose.
3. Gummy smile.
4. Difficulty in apposing the lips.
5. Acute nasolabial angle.
6. Convexity of facial profile.
7. Upper lip vermilion is more than 2 mm anterior to subnasale perpendicular to the FH plane.
8. Over jet and/or deep bite.
9. Class II relationship of occlusion in isolated maxillary excess.

Cephalometric Findings

Angle SNA	More than 84° indicates AP excess of maxilla.
Occlusal plane angle Angle SN – occlusal plane	Angulation more than 16° indicates vertical excess
Nasion–Anterior nasal spine Linear measurement to be measured perpendicular to horizontal plane	More than 50 mm indicates vertical excess
Vertical line extending downwards from the NASION perpendicular to Frankfort horizontal plane	Point A ahead of the line more than 3 mm

Maxillary Deficiency (Figures 7-3A to C)

Maxillary deficiency could be associated with many of the syndromes like Crouzon's syndrome, Treacher-Collin syndrome, etc. Non-syndromic maxillary deficiency could be due to growth and developmental factors. In cleft lip

Figures 7-2A to C: Vertical and sagittal excess of maxilla.

Figures 7-3A to C: Deficiency of the maxilla in a repaired cleft lip and palate case.

and palate patients who have undergone surgical repair, underdevelopment of the maxilla is often observed. This is attributed to cicatrization of the palatal tissues restricting the growth of the maxilla. Important clinical features associated with maxillary deficiency are the following:

1. Concave facial profile.
2. Nasolabial angle could be acute or obtuse depending on the combination of defects.
3. Reduced vertical dimension of the lower third of face.
4. Dishing of upper third of face.
5. Prominent lower lip.
6. Narrow upper arch.
7. Subnasal perpendicular to FH plane is anterior to the upper lip vermilion border.

Cephalometric Findings

Angle SNA	Less than 78°
Occlusal plane angle Angle SN – Occlusal plane	Angulation less than 12° shows vertically deficient maxilla
Nasion–Anterior nasal spine Linear measurement to be measured perpendicular to horizontal plane	Less than 50 mm shows vertically deficient maxilla
Vertical line extending downwards from the Nasion perpendicular to Frankfort horizontal plane	Point A behind the line more than 3 mm

Maxillary Transverse Deformities

Transverse deformity is usually associated with the growth of maxilla. Maxillary deficiency is often associated with narrow maxilla and maxillary excess is often associated with wide maxilla. Clinical feature usually observed is posterior cross bite.

Mandibular Deformity

Mandibular Excess (Figures 7-4A to C)

Common cause for mandibular prognathism is either developmental or genetic. However it is commonly observed that people with mandibular prognathism are relatively taller though this is not always the rule. Acromegaly is associated with large mandible. The clinical features associated with mandibular excess are the following:

1. Prognathism of mandible.
2. Anterior cross bite.
3. Elongated face.
4. Lower third of the face is relatively long.
5. Stomion-menton length is proportionately long.
6. Face appears concave.
7. Lower lip and chin are much anteriorly placed than normal.
8. Class III relationship of occlusion.

Cephalometric Findings

Angle formed by the intersection of Nasion – Pogonion and Frankfort horizontal plane	Angulation more than 95° indicates prognathic mandible
Mandibular plane angle Angle obtained by joining Mandibular plane and Frankfort horizontal plane	Angulation more than 28° indicates vertical growth pattern of the mandible
Growth axis angle Angle formed by joining Sella – Gnathion line to Frankfort horizontal plane	Angulation more than 66° indicates vertical growth pattern of the mandible
Sella – Nasion to Point B	Angle more than 82° indicates prognathic mandible
Sella – Nasion to Gonion-Gnathion	Angulation more than 36° indicates vertical growth pattern of mandible

Figures 7-4A to C: Mandibular prognathism.

Mandibular Deficiency (Figure 7-5)

It is often due to genetical and developmental reasons. Ankylosis of temporomandibular joint, trauma to mandibular condyle and aplasia of condyle can also cause deficiency in the growth of the mandible.

Clinical features associated with mandibular deficiency are the following:

1. Bird face appearance.
2. Severe over jet.
3. Class II relationship.
4. Crowding of lower teeth.
5. Flaring compensation of lower anterior teeth.
6. Face appears small.
7. Lower third of the face is short.
8. Stomion-menton is proportionately short.
9. Labiomental fold is usually absent.
10. Chin neck angle is obtuse.

Figure 7-5: Deficiency of the mandible.

Cephalometric Findings

Angle formed by the intersection of Nasion– Pogonion and Frankfort Horizontal Plane	Angulation less than 82° indicates retrognathic mandible
Mandibular Plane Angle Angle obtained by joining Mandibular Plane and Frankfort Horizontal Plane	Angulation less than 17° indicates horizontal growth pattern of the mandible
Growth Axis Angle Angle formed by joining Sella – Gnathion line to Frankfort Horizontal Plane	Angulation less than 53° indicates horizontal growth pattern of the mandible
Sella–Nasion to Point B	Angle more than 78° indicates retrognathic mandible
Sella–Nasion to Gonion-Gnathion	Angulation less than 28° indicates horizontal growth pattern of mandible

Malar and Midface Deformity (Figure 7-6)

Line tangent to the globe of the eye, perpendicular to the FH plane usually falls on the infra orbital soft tissue. Any

Figure 7-6: Crouzon's syndrome.

discrepancy of more than the standard deviation of 2 mm is usually due to mid-facial deformity.

Width of the mandible at the gonial angle approximately corresponds to the outer border of the orbit. This parameter helps to assess the mid-facial deformity. Other than genetical and developmental factors, certain syndromes also could be the reason for mid-facial deficiency. In Crouzon's syndrome, mid-face is deficient and eye balls are protruded (Proptosis) due to malar deficiency.

Deformities of Chin

Deformities of chin could be three dimensional – vertical, anteroposterior or horizontal. Vertical excess of chin is usually associated with mandibular prognathism. Though in prognathic mandible, chin appears prominent, it need not be so in objective analysis. Hence it is essential that the chin is assessed independently in relation to the other structures. To assess the vertical discrepancy the best technique is to measure the length from lower lip stomion to menton and compare this with the length from subnasale to upper lip stomion, in rest position. The former should be double the latter.

Chin projection is better assessed by dropping a perpendicular to the FH plane through the subnasale. Normally chin is 4±2 mm behind this line. It should be born in mind that in set back surgery for mandibular prognathism, the chin goes backward. This should be taken into consideration while assessing the chin and during planning of the surgery and in prediction tracing.

Bite Deformities

Bite deformities are assessed by orthodontic classifications. Excessive over jet is seen in maxillary excess and in mandibular deficiencies. Likewise deep bite deformity could be due to vertical excess of the maxilla or mandibular deficiencies. This could be either skeletal or dento-alveolar. Often occlusal discrepancy could be due to the compensatory mechanism exerted by the perioral musculature in an effort to achieve satisfactory function.

Apertognathia is mostly associated with deficiency of the anterior part of the facial skeleton, either anterior maxilla or the anterior region of the mandible. Vertical excess of the posteriors could cause anterior open bite. Analysis of the curve of spee, the occlusal plane and cephalogram are the frequently data to determine the extent of the deficiency **(Figure 7-7).** Exact location of the deformity can be assessed by comparing the anterior and posterior facial heights.

Figure 7-7: Open bite deformity (Apertognathia)

If there is difficulty in apposing the lips the deformity is usually due to increased posterior facial height. If so, the surgery should be aimed at impacting posterior dento-skeletal segment vertically.

Another common reason for anterior open bite is trauma to the temporomandibular joint. Fracture of the condyles decreases the ramus height of the mandible, creating an anterior open bite. If the fracture is not managed properly, the open bite persists and warrants surgical correction.

Facial Asymmetry (Figures 7-8 and 7-9)

The reasons for facial asymmetry are many. A few of the etiological factors are the following:
1. Hemifacial microsomia.
2. Unilateral cleft lip and palate, and other unilateral clefting syndromes.
3. Childhood trauma especially to the condyle.
4. Discrepancy in blood supply to the maxillofacial region.
5. Habits.
6. Early unilateral loss of teeth.
7. Faulty use of functional appliances.
8. Pathologies and childhood surgeries of the face.

Figure 7-8: Facial asymmetry due to under-development of the condyle; the mandible is deficient and the chin is deviated.

Figure 7-9: Facial asymmetry due to hypertrophy of the condyle on one side. The mandible is prognathic.

Asymmetry could be pan facial or limited to certain areas. Frontal analysis is the ideal method to assess asymmetries. Drawing vertical and horizontal parallel lines on the face will help to locate the area of asymmetry. This can also be done using a grid. PA cephalogram is very helpful in analyzing facial asymmetry, especially of the facial skeleton.

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Chapter

8

Varghese Mani

Introduction

It is important that a clinician listens to patient's concerns and expectations and plans the treatment with mutual agreement.[15,24,27] Patient's chief concerns and the severity of the problems are taken into consideration and a prioritized problem list is prepared.[26] Treatment is based on the plan developed by a team consisting of maxillofacial surgeon, orthodontist and other specialists.[25]

Possibilities and Limitations of Orthognathic Surgery

Orthognathic surgery which had a humble beginning as an aid to orthodontics—initially called orthodontic surgery—has now grown to the stature of a surgical specialty in Maxillofacial surgery. To start with, the procedures were dentoalveolar corticotomies and individual tooth osteotomies. During the sixties and the seventies orthognathic surgery underwent a revolution and substantial advancement was made in this field. Exclusive research in orofacial physiology and blood supply, as well as advancements made in medical equipments, imaging technologies and other allied fields, helped the progress of maxillofacial surgery in general, and orthognathic surgery in particular. The research works of Kole and Bell provided the clinical basis for maxillary and mandibular osteotomies.[5,6,14]

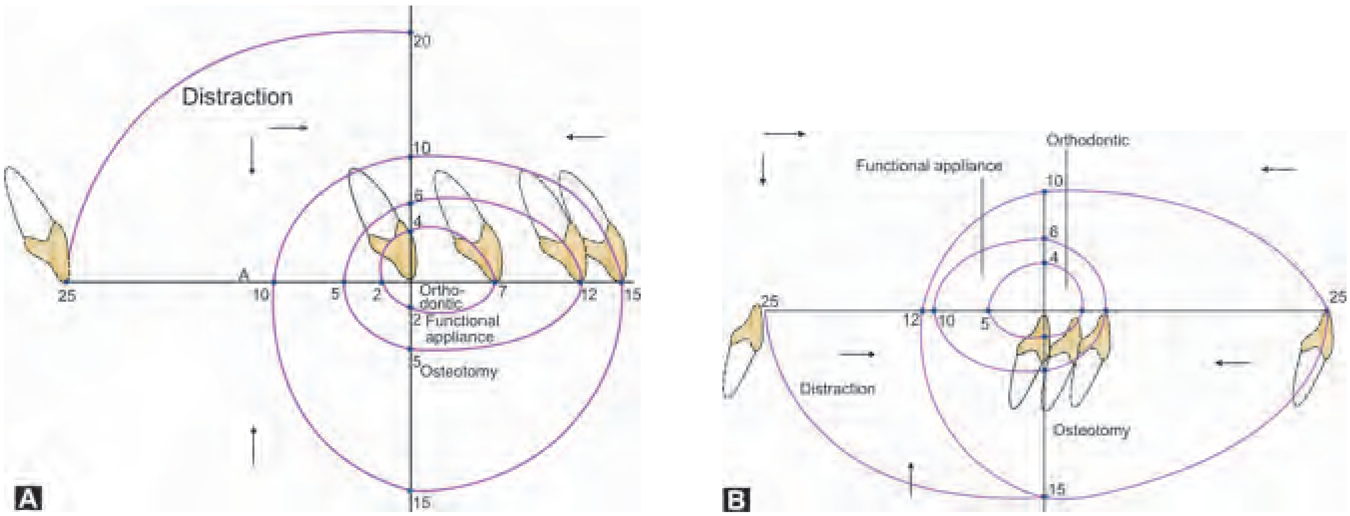
Possibilities of remodelling and reshaping the maxillofacial region have improved enormously and the limitations have been scaled down. Orthopedic appliances to modulate growth can achieve remarkable results if applied during the growing period. After completion of growth, surgery may be required to change the shape. However surgically assisted maxillofacial orthopedics is gaining acceptance as a useful mode of treatment in adults, especially when the requirement is expansion and/or elongation. Patients whose maxillary deficiency is due to early synostosis of sutures (Crouzon's and Apert's syndromes) are not good candidates for dentofacial orthopedics.

Proffit and Ackerman have presented "envelope of discrepancy" of changes that can be achieved by three different modalities of treatment diagrammatically. They are the movements achieved by orthodontic means, by myofunctional appliances and by orthognathic surgery.[2] Later a fourth modality of treatment, viz 'Distraction Osteogenesis' came in vogue, specially for advancement **(Figures 8-1A and B)**. The introduction of distraction osteogenesis in maxillofacial region has opened a new arena of possibilities in the field of orthognathic procedures.

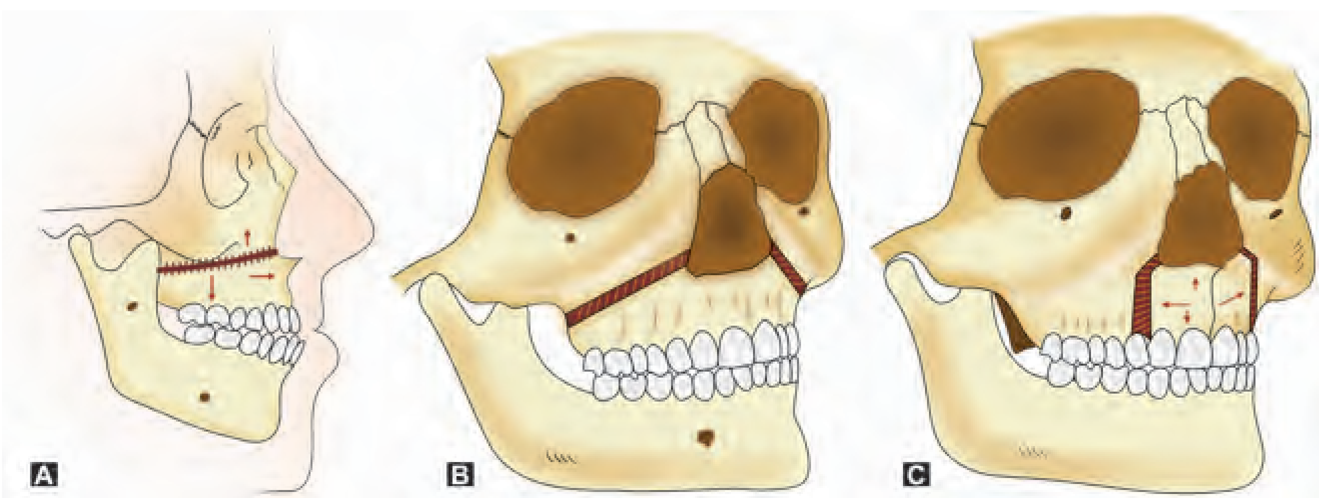
Maxilla: Possibilities and Limitations

Maxilla can be moved surgically in all the three dimensions of space **(Figures 8-2A to C)**. It is hard to expand the maxilla, because of the fused mid palatine sutures and the tough, non-elastic palatal tissues. Before the growth period is completed - till mid-teens- it is possible to expand the palate by orthopedic forces. Midpalatine sutures may give way and reasonable expansion can be achieved. There is restriction to expansion from the lateral aspect of the maxilla. Relapse rate is high after the appliance is removed.[19] Surgical expansions also have a similar relapse tendency of about 40%.

Narrowing the maxilla is a difficult proposition though, it is possible to reduce the width surgically. Orthodontically the intermolar width can be reduced, but not the skeletal width. According to William R Proffit the maximum width change that can be achieved in the maxilla is 15 mm and a reasonable change possible is 10 mm.[11,22]



Figures 8-1A and B: Comparison of four different modalities of treatment. The center represents the final position after the treatment. The outer circle represents the amount of movement that can be achieved by surgery, the middle represents the result from myofunctional appliance and the inner circle represents the orthodontic movement. The segmental part represents the advancement that can be achieved by distraction osteogenesis. (A) Maxilla, (B) Mandible *(This picture is a modification from 'the envelope of discrepancy' by Proffit and Ackerman)*.



Figures 8-2A to C: Diagrammatic representation of maxillary osteotomy. Maxilla can be moved in all the three dimensions. However backward movement of the maxilla is rather difficult though it can be achieved by pterygoid plate and tuberosity osteotomies (A and B). Anterior push back can easily be achieved by anterior maxillary osteotomy (C).

Anteroposterior Movement of the Maxilla

By Le Fort I osteotomy it is possible to move the maxilla anteriorly by about 1 cm without compromising the stability. The major limitation in advancing the maxilla is the anterior soft tissues, mainly the lip. A tight lip is often a hindering factor. In patients who have undergone cleft lip repair, this limitation of movement is enhanced, and relapse will be more. Distraction osteogenesis has revolutionized the advancement procedures. By the slow distraction of the cut segment, new bone is formed at the osteotomy site. More than 2 to 2.5 cm of lengthening of the maxilla can be achieved. Since the surrounding soft tissue envelope also favourably reacts to the bony movement. Hence this technique is also known as distraction histiogenesis, and relapse is less **(Figures 8-1A and B).**

In patients who have undergone cleft palate correction the problem of relapse is worse because of the scarring and cicatrization at the palatal region. To overcome this the maxilla has to be mobilized about 50 to 60% more than the required movement.

Another limiting factor is the velopharyngeal incompetence seen in cleft palate patients. This is the primary reason for nasal speech in cleft palate patients. When the maxilla is brought forward the incompetence is increased and the speech defect may get aggravated. In normal patients with maxillary deficiency, without any palatal pathology or speech defect, this is seldom a problem. In cleft palate patients pharyngoplasty helps to establish better speech.

It is difficult to push the maxilla backward in toto. The pterygoid plates prevent such movements. Positioning posterior osteotomy cut at the level of the tuberosity and trimming off the tuberosity could give way for the maxilla to move backward by about 3 to 5 mm. Further movement can be achieved by osteotomizing the pterygoid plates after down fracturing the maxilla. The maxilla along with the pterygoid plates can be pushed backward to about 10 mm. Sectioning the maxilla at the premolar area with extraction of one premolar from each side (anterior maxillary osteotomy) is a predictable technique for pushing the maxilla backward. The author prefers this technique to push back the maxilla, as this gives better aesthetic result. Pushing the entire maxilla backward may be executed in selected cases. Of this, a relative indication is the maxillary excess which had undergone orthodontic treatment with premolar extraction. Another indication is mild maxillary anteroposterior (overjet of 5 mm or less) excess and the nasolabial angle is normal. Segmenting in such cases may cause anterior cross bite or create increased obtuse nasolabial angle.

Vertical Movements

Vertical excess of maxilla is the primary indication for maxillary Le-Fort I osteotomy. It is possible to take the maxilla upward by about 15 mm or even more if the face is long enough. Relapse is minimal in superior repositioning of maxilla and stability is excellent.[21]

However there are a few problems associated with superior repositioning of the maxilla. Nasal septum may get buckled and deviated. This can be easily prevented by cutting off the lower part of the septum appropriately. Maxillary osteotomy, in addition to the direct effect on the face, can widen the alar base, elevate the nasal tip and increase the chin projection. Superior repositioning of the maxilla auto rotates the mandible and the resultant occlusal stress moves the maxilla forward and the naso-labial angle decreases slightly. LeFort I advancement decreases the nasolabial angle by 1 to 4° per 1 mm of advancement, and set back increases the nasolabial angle by about 1 to 1.5°.[4, 8,10, 18, 20]

Superior repositioning of the maxilla may reduce the space of the nasal cavity. Up to 10 mm superior positioning will not usually create much nasal problem. If a problem is perceived, inferior turbinectomy or a 'U' osteotomy of the hard palate can prevent the reduction of the nasal space.

Widening of the alar base, while taking the maxilla upward, can cause an aesthetic problem. This can be controlled by cinch suturing of the alar base.

Moving the maxilla downward is relatively a hard proposition because of the relapse tendency. The stretch of the muscles and the pressure from the lower jaw are the main causes.[1] Moreover the inferior positioning of the maxillary posteriors can push the lower posteriors and cause anterior open bite. Rigid fixation techniques can to some extent prevent relapse.

Mandible: Possibilities and Limitations

Width Changes

Removing a segment of bone from the anterior region can narrow the mandible, with good stability. Expansion of the mandible is difficult as it is almost impossible to get a soft tissue envelope. Distraction osteogenesis is an alternative to surgical expansion.

Anteroposterior Movements

Mandible can be moved posteriorly by 2 cm or even more, depending on the size of the mandible. Amount of movement is proportional to the size of the jaw. In sagittal split, ramus is the area addressed. This is a versatile procedure by which mandible can be moved backward or forward **(Figure 8-3)**.

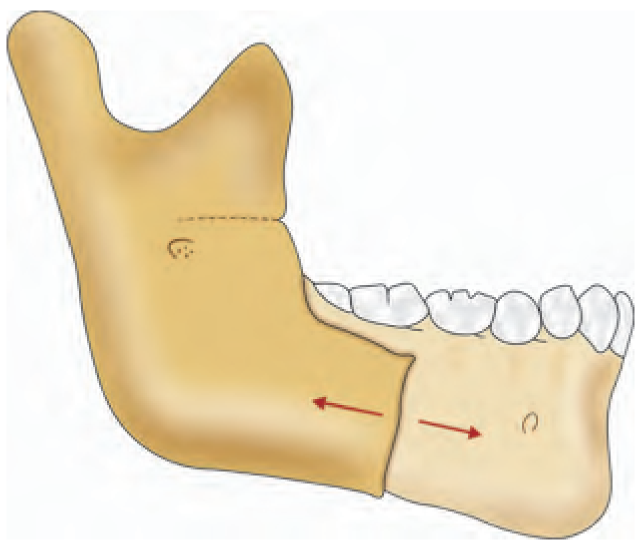


Figure 8-3: Diagram to show the osteotomy lines for sagittal split osteotomy.

By vertical subsigmoid osteotomy the mandible can be moved backward **(Figure 8-4).** The coronoid process may cause hindrance to the posterior movement and hence, for substantial movements, coronoidectomy may be required.

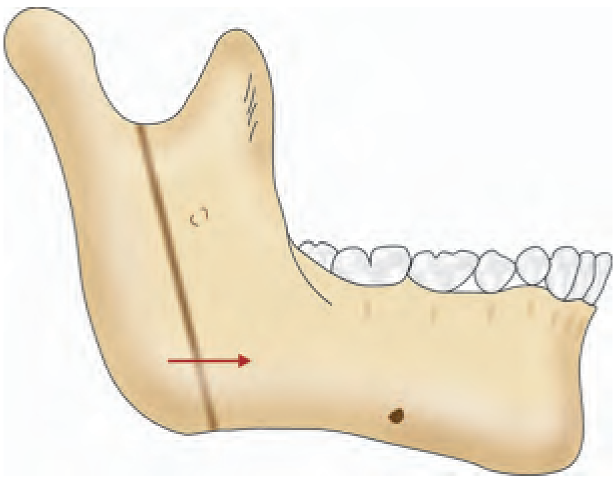


Figure 8-4: Diagram showing subsigmoid vertical osteotomy.

Advancement of the maxilla is harder than pushback. Sagittal split osteotomy is a versatile procedure and mandible can be pushed backward or pulled forward. Relapse tendency is higher in advancement as there is stretch on the soft tissues. By 'C' or inverted 'L' osteotomy of the ramus, advancement can be achieved, provided grafting is done in the gap created.

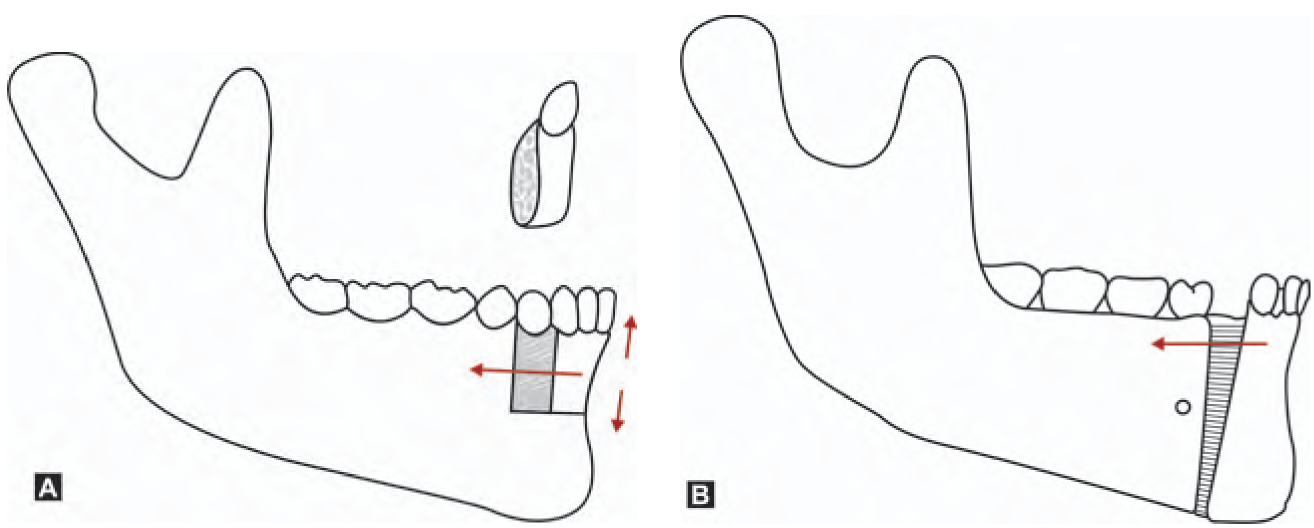
It is not hard to reduce the vertical dimension of the ramus. If this is done, without superior positioning of the maxilla, this may result in anterior open bite. Increasing the vertical dimension of the mandible by surgery is difficult due to counter forces and restrictions exerted by the pterygomasseteric sling and the periosteum. However the development of distraction techniques has come as a promise to tackle difficult bone lengthening requirements.

Postsurgical stability is dependent on many factors. When the mandible is rotated downward it has got better stability than when the mandible is rotated upward and anteriorly.[9] The lower border of the mandible can be osteotomized and can be moved laterally, anteriorly or inferiorly.

Dentoalveolar Region

It is possible to reposition the dentoalveolar segment posteriorly, laterally and vertically **(Figures 8-5A and B)**. The surgical movement is comparable to the orthodontic movements. Relapse is inevitable if the tooth is placed where soft tissue acceptance is lacking. The question often asked is, "why surgery? when orthodontics can achieve the same result." The answers are, anchorage and duration of treatment.

For any tooth movement there is a reactionary counter force on the anchorage which exerts a displacing force. To avoid this a head gear or an extra-oral anchorage has to be used. These are cumbersome and patient cooperation is hard to come by. Development of titanium micro/mini screws has advanced the anchorage techniques and many cumbersome extraoral appliances can be avoided now. The technique is to implant the mini screws in appropriate positions and use the same for anchorage purposes. This is an easy and successful method developed recently.



Figures 8-5A and B: (A) Lower anterior subapical osteotomy. (B) Mandibular body osteotomy at the premolar area.

The anchorage loss can also be avoided by using mini screws.

Intrusive movements are very difficult in orthodontics, and it is impossible to move an ankylosed tooth by orthodontics but, possible by surgery.

In surgery, larger segments ensure better blood supply. It is hazardous to section the bone into segments having less than three teeth. Hence, fine tooth movements and individual tooth movements are better achieved by orthodontic means. Though blood supply is not lost, in dentoalveolar surgical orthodontics, nerve supply may be affected. Usually this will be restored within six months.

Chin

Chin can be repositioned in all three dimensions by doing an inferior border osteotomy **(Figure 8-6)**. Soft tissue movements in relation to the chin are not always equal to the bony movements. In advancement, the soft tissue reacts 80% to 100%; in reduction it is less, whereas in vertical repositioning almost 100% soft tissue movement is achieved. Various studies show different results. Chin is a prominent part of face, second only to nose, changes brought about in the chin have a tremendous impact on the facial appearance, as it can alter vertical dimension, symmetry, aesthetic line, mentolabial fold, nasion perpendicular, neck chin angle, etc.

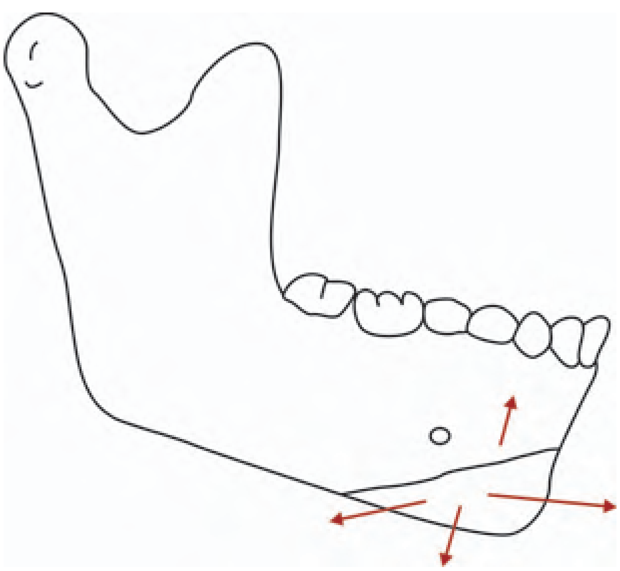


Figure 8-6: Diagram of genioplasty. The chin can be moved in all the three dimensions.

Analysis

Clinical analysis is the primary tool in deciding and planning of surgery. An experienced surgeon is often able to decide on the treatment plan by frontal and profile analysis. Cephalometric analysis acts as an aid to clinical assessment. There are numerous cephalometric analyses. There could be significant discrepancies in the findings from cephalometric and clinical findings. If such discrepancy exists clinical findings are given more importance. Often, cephalometric analysis is used when a definitive treatment cannot be arrived at, from clinical analysis alone. However, cephalometric analysis helps in quantifying the movements.

Clinical Criteria for Identification of the Problem and Treatment Planning

Nasolabial Angle

Normal nasolabial angle varies from 90 to 110° **(Figure 8-7).** Decreased value could be due to the morphology of the nasal dorsum, tip or columella. The important reason for an acute nasolabial angle is the position of the upper anteriors, such as dentoalveolar protrusion, labial inclination of incisors or maxillary skeletal protrusion.

Figure 8-7: Nasolabial angle.

Lip Position

Normally the upper lip is expected to lie in line with the incisal margin of the upper anteriors. However up to 3 mm of exposure (about 25% of the length of the incisors) may be considered normal. More than this is to be considered as vertical excess of the maxilla or dentoalveolar excess. Dentoalveolar excess is frequently associated with deep bite.

Reduced visibility of upper anteriors while smiling, is often due to vertical deficiency. Visibility of teeth in repose is occasionally due to a short upper lip. Lip position in smiling also should be taken into consideration to assess the visibility of the gum. Hyperactivity of the levator muscles could be one of the reasons for gummy smile. This can be decided by comparing the position of the lip in repose and in smiling **(Figures 8-8A and B).**

Figure 8-8: (A) Visibility of the teeth in repose is an indication of vertical excess of the maxilla, provided the lip length is normal. (B) Gummy smile too is an indication of the vertical excess of the maxilla. However hyperactivity of the levator muscles of the lip can also cause gummy smile.

Facial Proportions

Under normal conditions the upper third of the face (extending from the hairline to the glabella), the middle third of the face (extending from glabella to subnasale) and the lower third of the face (extending from subnasale to menton) are almost equal. The relationship between middle third and lower third could be up to 1:1.2. The relationship between subnasale to upper lip stomion and from upper lip stomion to menton is 1:2. These proportions of the face help us to assess the vertical discrepancies of the maxilla, mandible and chin **(Figure 8-9)**.

Subnasale Perpendicular

Subnasale perpendicular to the Frankfort horizontal plane is to be considered as an important criterion for profile analysis and identifying the sagittal deformities of the face. The upper lip vermilion border is almost in line with the subnasale perpendicular while the lower lip vermilion is about 2 mm behind and the soft tissue menton about 4 mm behind the perpendicular. ± 2 mm from the ideal is within acceptable limits **(Figure 8-10)**.

Figure 8-9: Face can be divided into three equal parts from the hairline to the menton; from the glabella to the subnasale forming the middle third.

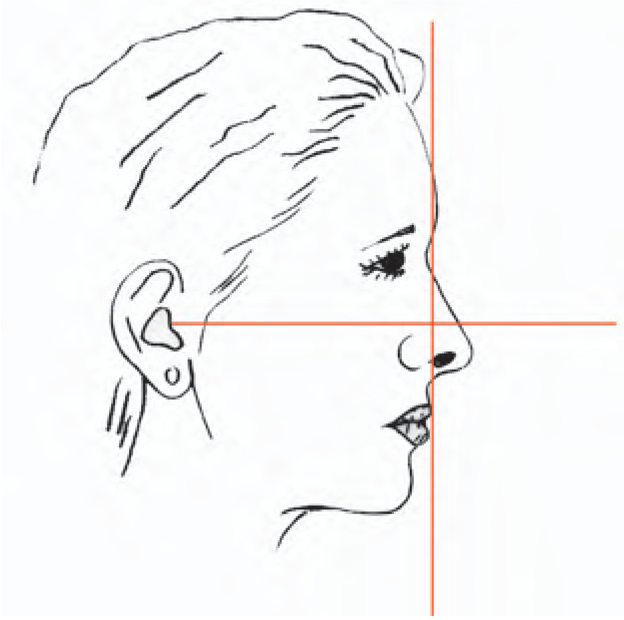


Figure 8-10: Subnasale perpendicular to the Frankfort horizontal plane is an excellent tool to assess the balance of the facial structures. This also gives an indication of the site of deformity.

Labiomental Fold

This is the relationship of the mandibular dentoalveolar segment and the chin. Labiomental fold is unique for Homo sapiens and gives a pleasant definition to the face. Ideally the depth of labiomental fold is 4 mm **(Figure 8-11).**

Alar Base

The width of alar base is usually equal to the width of inner intercanthal distance **(Figure 8-12)**. Modifications

Figure 8-11: Labiomental fold is unique to the humans and gives a pleasant definition for the face.

can be done along with surgery. The alar width may get increased in Le Fort I impaction osteotomies. By cinch suturing of the alar base and pyriformplasty, widening of alar base can be controlled.

Figure 8-12: The width of the medial canthi equals the width of the ala of the nose. The width of the mouth equals 1.5 times the width of the ala.

Nasal Dorsum

Nasal hump, saddle nose, deviated nose, tip asymmetry, etc. should be taken into consideration before planning an orthognathic surgery. Since a good number of nasal deformities can be corrected along with orthognathic surgery, rhinoplasty should be considered as an adjuvant.

Occlusal Relationship

Open bite, deep bite, cross bite, sagittal relationship of teeth (Angle's—class 1, class 2, class 3), occlusal plane, curve of spee, etc. should be taken into consideration for treatment planning.

Treatment Planning

Once the deformity is confirmed the treatment plan can be decided with ease.

Common modalities of treatment and their modifications for dentofacial deformities are the following:

Le Fort I Osteotomy

By this osteotomy the maxilla is separated from the cranial base, at the level of maxillary sinus and can be moved in all the three dimensions of space. Maxilla can also be rotated or tilted. Backward movement of the maxilla is usually limited to 1 or 2 mm. However by doing anterior segmental osteotomy, substantial backward movement of the anterior maxilla can be achieved. Le Fort I osteotomy is used in cases of maxillary deficiency, vertical excess of maxilla and sagittal or transverse discrepancy, seen in asymmetries **(Figure 8-13).**

Figure 8-13: Photograph of a down fractured maxilla after Le Fort I osteotomy.

Anterior Maxillary Osteotomy

This osteotomy is mainly used in cases of dentoalveolar protrusion of maxilla where there is no marked vertical excess **(Figure 8-14).** Often AMO is combined with Le Fort I osteotomy.

Figure 8-14: Anterior maxillary osteotomy is often used for dento alveolar protrusion. The photograph shows the design of AMO.

Ramus Osteotomy

Sagittal split osteotomy, vertical sub-sigmoid osteotomy and inverted 'L' osteotomy are usually done on the ramus. Sagittal split osteotomy is a versatile technique by which mandible can be pushed backward or pulled forward. This procedure can be used for asymmetric transverse movement of mandible as well **(Figure 8-15).**

Figure 8-15: Osteotomy design of the sagittal split of the ramus. By this osteotomy mandible can be moved either forward or backward.

Anterior Subapical Osteotomy of the Mandible

This is often used for dentoalveolar protrusion of mandible **(Figures 8-16A and B).**

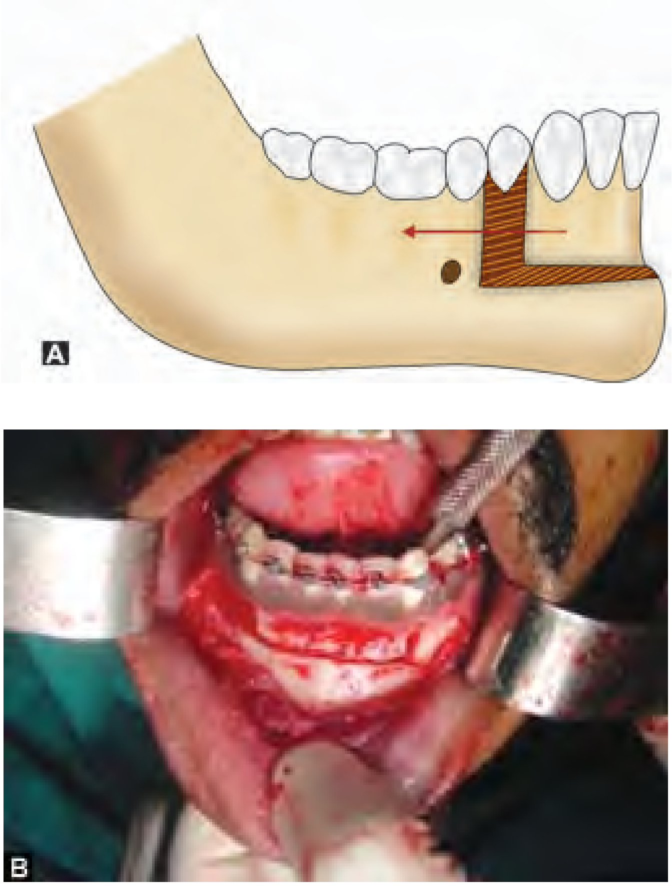


Figure 8-16A and B: (A) Diagrammatic representation of lower anterior subapical osteotomy. (B) Photograph.

Body Osteotomy of the Mandible

Body osteotomy at the premolar region is mainly used in open bite deformity where the defects are at the anterior region of the mandible **(Figure 8-17A).** Midline body osteotomy can be used to reduce the mandibular size, cross bite and mild prognathism **(Figure 8-17B).**

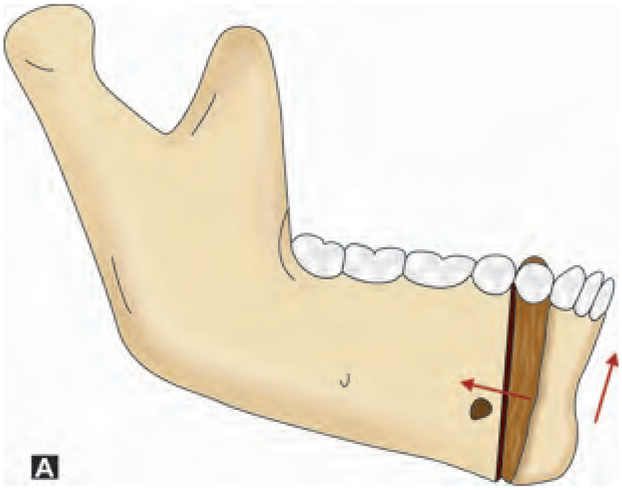
Genioplasty

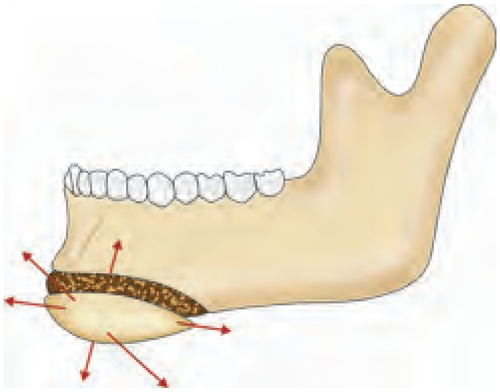
The chin can be moved in all three dimensions and hence this procedure can be used for augmentation, reduction and for correcting asymmetry **(Figure 8-18).**

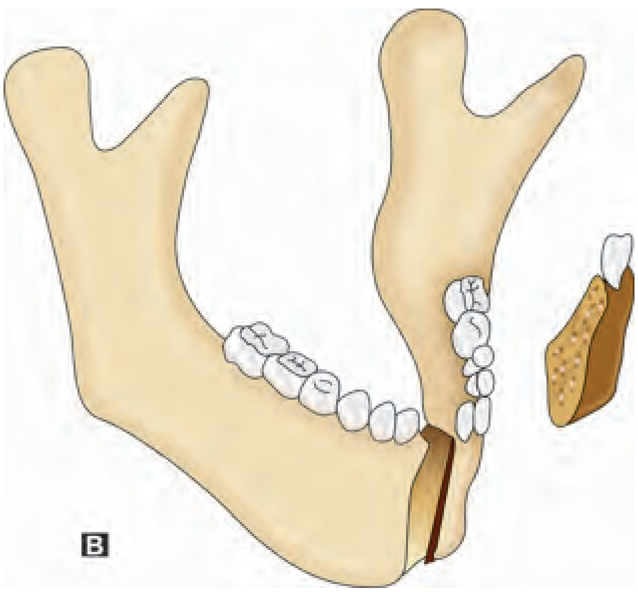
Modifications and combinations of the above mentioned procedures can almost totally restructure the entire faciomaxillary bony architecture to the desired shape, and change the facial appearance remarkably.

Model Analysis

Model analysis is important to plan presurgical orthodontics. The important objectives of model analysis are the following:







Figures 8-17A and B: (A) Body osteotomy of mandible at the premolar level. (B) Osteotomy at the midline region.

Figures 8-18A and B: (A) Diagrammatic representation of genioplasty. The chin can be moved in all the three dimensions. (B) Photograph of augmentation genioplasty.

1. *Crowding or spacing*: Discrepancy of arch length and tooth size can be measured to find out the gravity of crowding or spacing. This will help to decide whether extraction is needed during pre-surgical orthodontics in case of crowding, and how much retraction can be achieved orthodontically in case of spacing.
2. *Tooth size relationship*: Upper and lower anterior teeth size is correlated to find out the relationship after the orthodontic treatment. Bolton's analysis is a method to correlate the upper and lower anterior teeth width. Width of the upper anterior six teeth at the contact level is proportioned with the width of the lower anterior six teeth. The value is called the Bolton's index. This is 77.5 +/- 3.5. If the total width of the lower anterior teeth is multiplied by 1.3 the product will be the ideal width of the upper anterior teeth.
3. *Arch width*: Width of the upper and lower arches are analysed to find out the discrepancy. This will help to plan the pre-surgical orthodontics.
4. *Curve of Spee*: An exaggerated curve of Spee of lower arch may require intrusion of the lower anteriors. For every vertical millimeter correction the lower anterior may move 0.6-1 mm forward. More than 2 mm vertical intrusion may become unstable orthodontically.

5. *Anteroposterior relationship of upper and lower arches*: Class I relationship is the most desirable occlusion. Class II is acceptable and class III still less or undesirable. The presurgical relationship gives an idea for treatment planning.
6. *Curve of Wilson*: It is the horizontal occlusal plane. Orthodontic expansion of the upper arch usually renders the molar teeth to tip buccally. Buccally tilted molars do not give a stable occlusion.
7. *Symmetry of the arches*: Symmetry of the arch in horizontal and vertical planes has to be assessed. Face bow transfer is helpful in assessing any discrepancy between both the sides.
8. *Condition of the dentition*: Missing teeth, crowding, spacing, caries, periodontal condition, etc. are also assessed.

Cephalometric Prediction Tracing

After recognizing of the problem, and provisionally deciding the type of surgeries, prediction tracing is performed on the cephalogram. Cephalogram is a two dimensional picture, and prediction gives only a profile aesthetic assessment. The purpose of prediction tracing is to get an understanding of the facial profile after surgery.

Model surgery, on the other hand, gives a three dimensional understanding of the postsurgical dental relationship. It also acts as a vehicle for fabricating the splints. A combination of cephalometric prediction and model surgery gives the team a satisfactory idea of the aesthetic and the overall outcome of the surgery. This also helps the team to decide on presurgical orthodontics.

Though the mandible can be moved in an antero posterior direction other movements have certain limitations. It is difficult to increase the vertical dimension of the ramus. It is also difficult to rotate the mandible (clockwise or anti-clockwise movement). While doing surgery to superiorly reposition the maxilla, the mandible rotates till the lower teeth touch the upper ones. The fulcrum of this auto rotation is in the vicinity of the condyle. In actuality the fulcrum changes position in the condyle when performing the translator movement. However it is sufficient to rotate the mandible on the center point of the condyle in prediction tracing.

Bony movements can be predicted in principle, with mathematical precision. Soft tissue movements are arbitrary and requires a little bit of artistic imagination to trace the predicted soft tissue. Aesthetics directly depends on the soft tissue morphology. It is important to know the soft tissue changes associated with the surgical repositioning of the underlying dentoalveolar and skeletal segments.

Important Points

Certain important points are noteworthy as below.

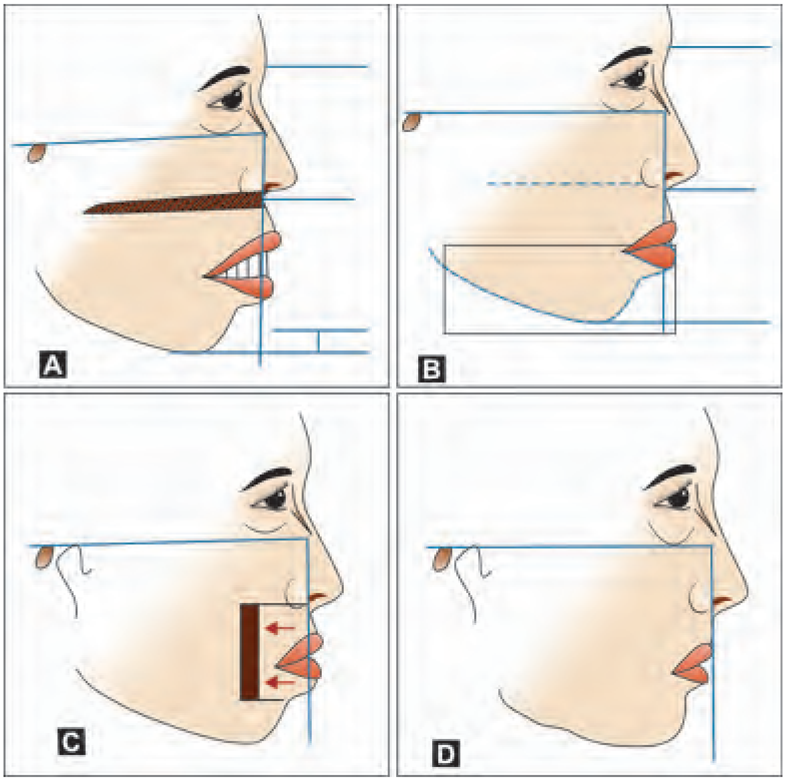
1. With anteroposterior movement of the incisors (both mandibular and maxillary) the lip moves only 60-70%. When both the dentoalveolar segments are retracted as in the case of anterior segmental osteotomy for bimaxillary protrusion, lip movement stops as the lips appose each other. With vertical movement of incisors, associated soft tissue changes are minimal, but with the rotation of the bony segment about 80% soft tissue change is noticed. Lip rotation is almost equal to the rotation of mandible.
2. In mandibular advancement lip movement is 60 to 70%. Soft tissue chin movement is almost equal to the bone movement. In mandibular set-back, soft tissue chin movement is similar to that in advancement, but lip movement is only 60%.
3. In case of maxillary advancement nose tip is slightly elevated. Only 20% advancement is achieved at the base of upper lip by the advancement of point A. 1 to 2 mm shortening of the upper lip is noticed when maxilla is advanced but the change of the nose is usually temporary. In maxillary retropositioning or set-back, the movement of the base of the upper lip is only 20% of that of point A**.** Lip movement is 60% of incisor movement. In any vestibular incision the lip length is reduced by about 1 to 2 mm. Lower lip rotates along with the mandibular rotation.
4. In chin surgery, soft tissue reacts about 80 to 100% to forward advancement. In upward repositioning, soft tissue reaction is almost equal to the bony movement.

In cephalometric prediction, the above mentioned factors are to be translated to the final prediction tracing of the soft tissue profile.

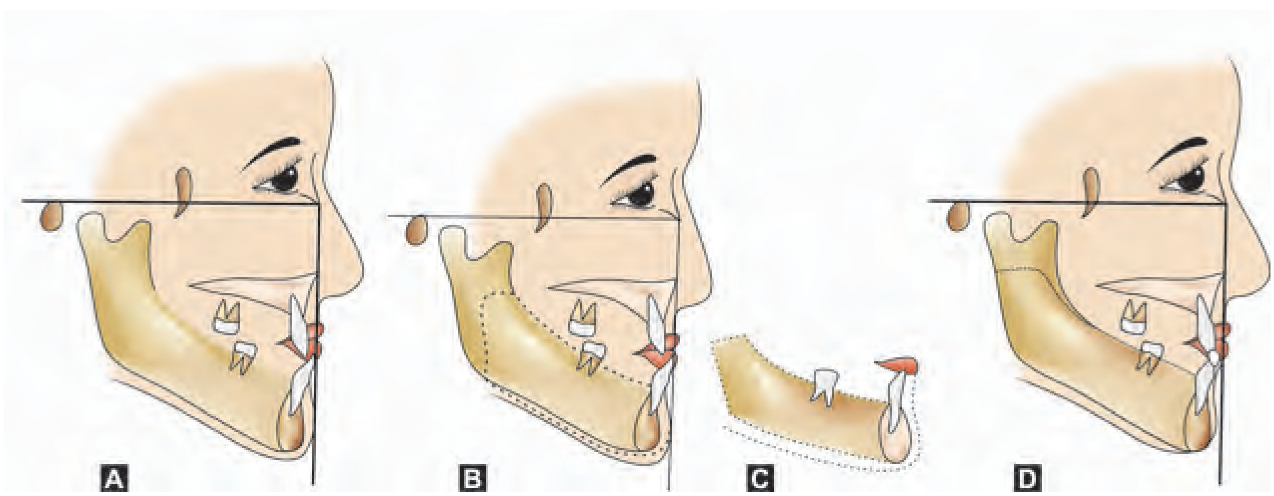
Technique of Prediction Tracing

A tracing paper is placed over the cephalogram and both soft and hard tissues are traced. The part that has to be moved is marked in color. Another tracing paper is placed over this and the color coded part is traced first and the paper is slid appropriately and tracing is completed.

The tracing is done mainly of the soft tissues. Anatomical Frankfort plane and the subnasale perpendicular are drawn. This helps to assess the horizontal discrepencies. The vertical discrepencies are also noted. The surgical



Figures 8-19A to D: Technique of prediction tracing in vertical excess of the maxilla with bimaxillary protrusion. (A) Tracing is done on a transparent sheet. Vertical excess is measured. The same width is marked at the Le Fort I osteotomy site. (B) Another transparent sheet is placed over the tracing which is already marked for osteotomy. Retracing of the upper part is done till the upper end of the osteotomy. The upper lip is also traced since the movements of the upper lip are minimal to the superior repositioning of maxilla. Now the prediction tracing is slid down so that the upper end of the osteotomy line corresponds to the lower osteotomy line of the first tracing. The rest of the tracing (lower lip, chin and mandible) is completed to get the prediction tracing. (C) Prediction in 'B' is considered as a second patient for further prediction for bimaxillary protrusion. On 'B' another transparent sheet is placed and the AMO and the lower subapical osteotomy sites are marked. The tracing is slid forward to correspond to the final position. (D) The prediction tracing is completed to get the final result.

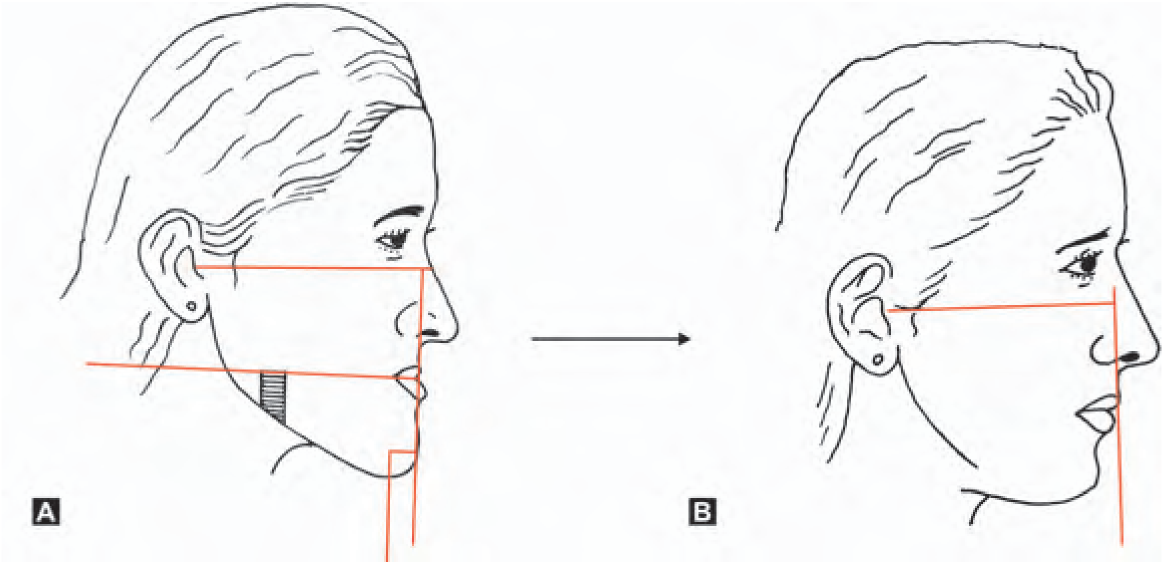


Figures 8-20A to D:(A) A tracing paper is placed over the cephalogram and the bony landmarks and the soft tissue morphology is traced. On this tracing the osteotomy lines and the part of the bone and soft tissue to be moved by surgery are marked with heavy dotted lines or in colour. (B) Over this marked sheet another tracing paper is placed and only the dotted or colour coded lines are marked. (C) This paper is then slid to the required position within the limits of surgical possibility and the tracing is completed (D).

decision taken by bony cephalometric analysis may be reviewed with the tracing and reevaluated. The surgery is diagrammatically and proportionately duplicated over the tracing. Another tracing paper is placed over the first tracing . The immovable parts are traced first. The movable parts are traced after sliding this sheet appropriately. Soft tissue movements with their limitations are translated and the prediction tracing is completed.

Model Surgery

Model surgery is a complement to prediction tracing. This helps to understand the postsurgical relationship of the arches and the dentition. This relationship has got substantial influence on the postoperative stability. For proper stabilization and fixation and for maintaining the pre-planned interarch relationship, splints are advisable.



Figures 8-21A and B: This is another simple and easy method of prediction tracing. Subnasale perpendicular is drawn to assess the position and relationship of features in the facial profile. In the above case the mandible is anteriorly placed (prognathic). Prognathism can be quantified and the amount of retropositioning required is calculated. The same is marked on the profile tracing and cut off. The starred area is slid backward to simulate the surgery.

Surgery on the models helps in fabricating splints. Models give the surgeon the quantitative data that are useful during surgery.[3]

Studies have described how errors in planning of the postocclusions can be caused by inaccurate recording of the center of mandibular rotation. Patients who have had substantial discrepancy between centric occlusion and centric relation require the planning after the models are mounted in anatomical articulators.[13,16,17,23,28] Usually for single jaw surgery ordinary hinge articulator may be sufficient. But when two jaw surgery is performed anatomical articulator is more appropriate. Movements of the jaws are transferred to the articulator by "Face bow transfer". Horizontal and vertical reference marks are made on the models. The pre planned surgery is mocked on the model and the segments are moved appropriately and the splint is fabricated. In two jaw surgery the sequence of the surgery is to be followed in the mock surgery. After the model surgery of the first jaw is completed and segments repositioned, an 'intermediate splint' is fabricated. Now, model surgery of the second jaw is done, and the final splint is fabricated. Semiadjustable articulators and face bow transfer records are advantageous, when maxilla is repositioned anteriorly, posteriorly or vertically. It can also be used when two jaw surgeries are planned and intermediate splints are required.[7,12]

In Le Fort 1, the amount of superior repositioning required in the anterior region can be calculated precisely by cephalometric analysis and clinical parameters. The extent of superior repositioning required in the posterior region can be better calculated by model surgery. Model surgery should always be complementary to prediction tracing.

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Chapter

9

Tojan Chacko

Introduction

Orthognathic surgery is a team approach wherein two specialists, the orthognathic surgeon and the orthodontist, have major roles to play. The team approach lasts from patient examination, through treatment planning, presurgical orthodontics, and surgical procedure, to postsurgical orthodontics.

Orthognathic surgery is intended for patients who have got skeletal deformities which are not amenable to routine orthodontic management or orthodontic camouflage.

Diagnostic records models, photographs and lateral cephalogram should be assessed before diagnosis and treatment plan are finalized.

During orthognathic surgery the reposition of basal bone naturally jeopardizes the occlusion. Orthodontic treatment is mandatory to achieve good interarch relationship and aesthetics. Orthodontic treatment can be divided into 2 phases—presurgical orthodontics and postsurgical orthodontics. The primary objective of presurgical orthodontics is to achieve proper alignment of the maxillary and mandibular teeth by decrowding, space closure, ideal axial inclination and angulations of teeth, to ensure long term stability, and thus to help the surgical procedure to achieve the desired facial aesthetics and function.

Skeletal malocclusion is usually presented with natural dental compensations. It is mandatory from an orthodontist's point of view to identify the natural compensations already taken place in a case of malocclusion. Natural compensations appear to reduce the severity of the skeletal deformity. Before the surgical procedures, naturally compensated teeth should be decompensated. Decompensation of the teeth helps to reveal the extent of skeletal deformity.

Decompensation of teeth may worsen the appearance of the face. Patient should be informed well in advance about the treatment procedures. Patient counselling regarding the facial changes after the presurgical orthodontic treatment and after the surgical procedures would help to maintain a good rapport.

Decompensation of teeth is done presurgically, to maintain the teeth in the basal bone of maxilla and mandible in ideal positions, to achieve proper balance and harmony postsurgically.

Class II Skeletal Malocclusion

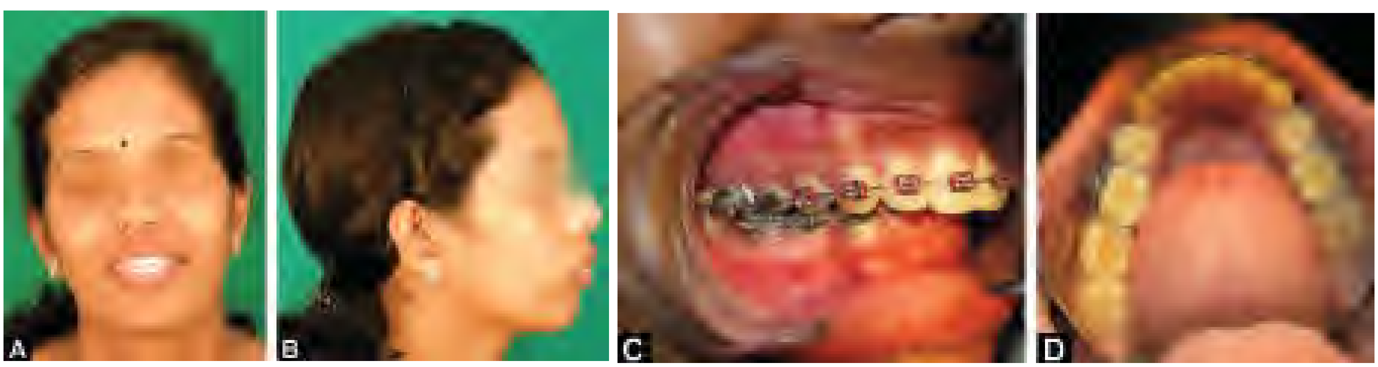
Class II skeletal malocclusion presents itself either as prognathic maxilla with normal mandible or normal maxilla with retrognathic mandible or a combination of both. Exact cause of the malocclusion can be assessed clinically, cephalometrically or by means of computer imaging. Clinically the maxilla will appear constricted transversely with increased overjet and overbite. Maxillary anterior teeth appear upright in the basal bone or may be naturally compensated by mild palatal tipping. Mandibular anterior teeth are naturally compensated by proclination and spacing between the teeth. At times mandibular teeth appear proclined without spacing **(Figure 9-1)**.

Presurgical Orthodontic Approach

Presurgically maxillary and mandibular teeth should be handled separately. Our aim should not be to achieve functional occlusion at this stage but should aim at achieving ideal positions of maxillary and mandibular teeth in their respective basal bones.

In maxilla, fixed orthodontic treatment should be started without extraction. Mild palatal inclination of the anterior teeth if present can be corrected by uprighting. Constricted arch form should be corrected by orthodontic expansion to achieve proper arch form.

Figures 9-1A to E: Class II skeletal malocclusion. (A) Front view, (B) Profile view, (C) Intraoral view, (D) Maxillary arch, (E) Mandibular arch.



Figures 9-2A to D: Class II skeletal malocclusion after decompensation. (A) Front view, (B) Profile view, (C) Intraoral view, (D) Mandibular arch.

In mandibular arch, naturally compensated anterior teeth should be retracted to occupy ideal positions. If compensation is by means of proclination and spacing, space closure along with retraction can be done simultaneously. If proclination is without spacing, extraction of teeth should be considered to gain space for retraction.

Once the maxillary and mandibular teeth are decompensated, patient should be maintained in larger size archwire. Preadjusted edgewise appliance system with slot size 022 is preferred over 018 slot for surgical cases because of the freedom to engage higher gauge wires in the archwire slot. In the slot size 022, 091× 025 niti wire be placed as the final wire before surgery **(Figures 9-2A to D)**.

Surgical correction can be carried out six weeks after placement of the final wire. One week prior surgery the final wire is removed, and impressions are made for surgical splint. By this time the wire become passive inside the archwire slot, so that unnecessary tooth movements can be avoided after impression making. Mock surgery is performed on the models. A wafer thin acrylic occlusal splint of not more than 2 mm thickness is constructed, with the models placed in the proposed positions. Surgical splints placed interocclusally at the time of surgery can be removed only at the time of active postsurgical orthodontic treatment. Time duration for the pre-urgical orthodontics is around 6-12 months **(Figures 9-3A and B)**.

Figures 9-3A and B: Postsurgical. (A) Front view, (B) Profile view.

Class III Skeletal Malocclusion

Class III skeletal malocclusion can present itself clinically as retrognathic maxilla with normal mandible or prognathic mandible with normal maxilla or a combination of both. Underlying cause of the malocclusion can be assessed clinically, cephalometrically, or by means of computer imaging. Clinically reverse overjet is present. Maxillary anterior teeth are naturally compensated by proclination with mild crowding or spacing. Mandibular anterior teeth are presented with lingual inclination. At times mild constriction in the mandibular arch is noticed **(Figures 9-4A and B)**.

Presurgical Orthodontic Approach

Lingually inclined mandibular anterior teeth should be decompensated orthodontically by uprighting. Constricted mandibular arch can be expanded to achieve a good arch form. Maxillary anterior teeth if proclined with spacing, space closure can be done along with retraction. If the maxillary anterior teeth are proclined with crowding, extraction of the premolars should be considered to create space for retraction of the anterior teeth. This results in increasing in reverse overjet considerably. Once the maxillary and mandibular teeth are well aligned in the ideal axial inclination and angulations, patient can undergo surgical procedure within a period of one month. Existing light wires should be changed to rigid wires, as mentioned earlier **(Figures 9-5A to 9-6B)**.

Figures 9-4A and B: Class III skeletal malocclusion. (A) Front view, (B) Profile view.

Cleft Lip and Palate

Cleft lip and palate patients clinically appear with retrognathic maxilla and prognathic mandible. Permanent teeth may be missing in the cleft region (usually lateral incisors). Moderate to severe crowding may be noticed in the maxillary arch. Transpositioning of teeth can be noticed in the maxillary arch. Transverse constriction of the maxillary arch is another clinical feature.

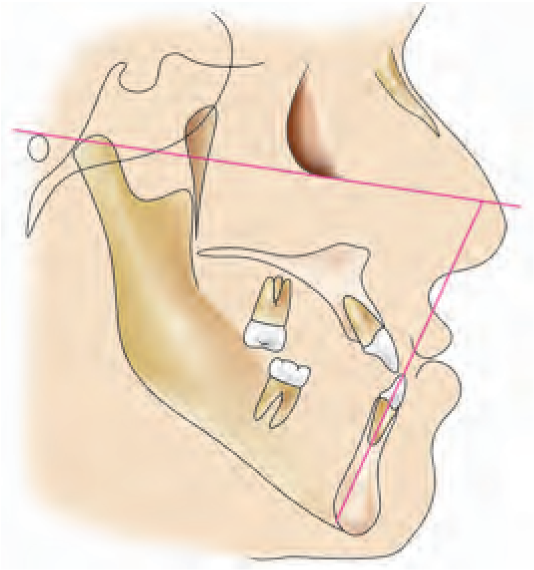


Figure 9-5A: Diagrammatic representation of natural compensation in class III: Pre-treatment position of upper and lower anterior teeth.

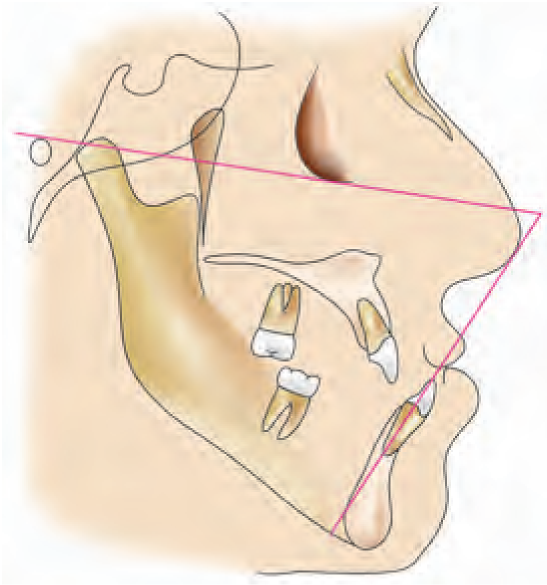


Figure 9-5B: Diagrammatic representation of decompensation in class III: Positions of upper and lower anterior teeth after decompensation.

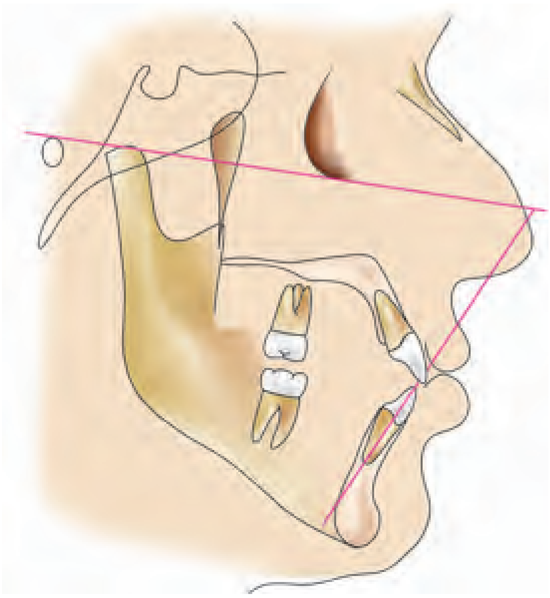


Figure 9-5C: Diagrammatic representation of decompensation in class III: Post-treatment position of upper and lower anterior teeth.

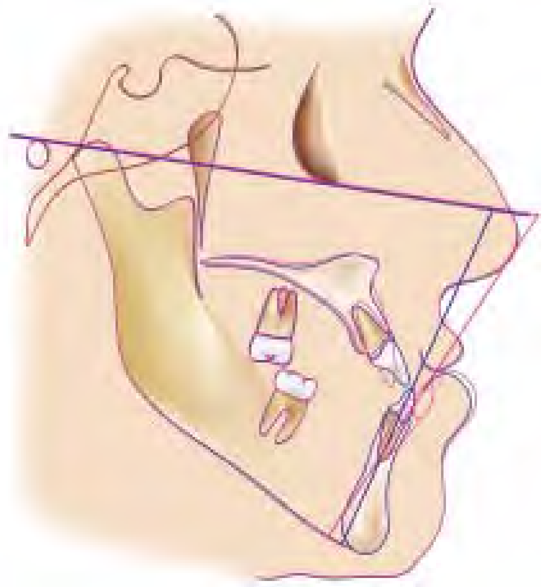


Figure 9-5D: Diagrammatic representation of decompensation in class III: Superimposition of pre-treatment and decompensated positions of upper and lower anterior teeth. Blue—Pre-treatment and red—after decompensation.

Figures 9-6A and B: (A) Class III post-treatment front view, (B) Class III post-treatment profile.

Before the growth is completed, growth modification appliances may be attempted for transverse as well as anteroposterior expansion of the maxillary arch.

Once the growth is completed, if any skeletal change is required in the maxilla or mandible, orthognathic surgery is the only treatment option **(Figures 9-7A to C)**.

Presurgical Treatment Approach

In the maxilla, orthodontic treatment is initiated to achieve proper alignment of teeth. All the teeth in favorable position should be brought to alignment. Any malposed tooth, if present in unfavorable position, should be extracted.

In the transverse direction if expansion is required rapid maxillary expander may be placed. Once the desired maxillary expansion is achieved, the expansion device has to be maintained in place for at least a period of 3 months for ossification at mid-palatal area.

Once the teeth are aligned and the optimum expansion have been achieved, light archwire should be changed to rigid wire before surgery.

Postsurgical Orthodontics

Surgery is basically quantum movements while orthodontics is nano movements. Postsurgical orthodontics is

Figures 9-7A to C: Patient who was treated at young age for cleft lip and palate. (A) Front view. (B) Profile view. (C) Intraoral view.

Figures 9-8A to C: (A) Front view, (B) Profile view, (C) Intraoral view.

aimed at final finishing by minute movements, to achieve stable occlusion and aesthetics.

Segmental osteotomies of the maxilla or mandible to some extent disturb the arch form and alignment. Post-surgical orthodontics can correct minor discrepancies that may occur as an inevitable sequel of surgical procedure. For example about 1-2 mm of bone has to be left around the tooth for proper periodontal health, and this leaves some space at the osteotomy site. Postsurgical orthodontics is essential to close such spaces.

Limitations of surgery may sometimes cause discrepancies in the interarch relationship. This may require skeletal movements to achieve good functional occlusion. This can be achieved by using heavy elastics for callus distraction provided semirigid fixation was used during osteotomy.

The objective of postsurgical orthodontic treatment is to settle the teeth in good occlusion and alignment. Post surgical treatment may be started 2 weeks after the surgical treatment. Once the surgical splint is removed the rigid wires can be changed to light wires, preferably 016 SS round wire. This will bring about more play in the arch wire slot and easier teeth movement. Interarch elastics can be given for proper intercuspation of the upper and lower teeth. Delay in achieving proper occlusion could lead to functional shift of the mandible while clenching the teeth. Once proper occlusion is achieved, minor corrections can be carried out. The total time taken for postsurgical orthodontic treatment is around 6-8 months **(Figures 9-8A to C)**.

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Chapter

10

Model Surgery

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Introduction

A conceptual treatment planning involving movements of both jaws in all three planes of space is critical to the success of orthognathic surgery. Regardless of whether the planned maneuver is simple or a complex asymmetric correction, it is imperative that the operator plans and executes these movements in the laboratory using analytical model surgery and thereafter transfers this movement to the patient with a surgical splint.

The success of orthognathic correction of a dentofacial deformity largely depends on the stability of the final functional and aesthetic outcome and this requires that one takes into consideration establishment of a stable occlusion with appropriate seating of the condyles within the glenoid fossa. In addition, repositioning of the jaws in a multiplanar dimension to correct the structural deformity within the confines of the soft tissue curtains must also be considered.

There may be multiple ways to achieve the same outcome, be it in ultimate surgical strategies or in model surgery depending on the operator's preference. While most model surgery techniques have not been validated[4] to be able to be directly transferable in actual surgery, they all provide a "road map" to navigate through the variables that present themselves in surgery. The techniques, however varied, all provide one method or another to allow the operator to position the jaws in a pre-planned position as outlined by his preoperative database, cephalometric prediction and laboratory model surgery.

According to Perciaccante and Bays, the purposes of preoperative model surgery are to: (1) mark the models to facilitate three-dimensional measurement of the pre- and postoperative positioning: (2) place the jaw models into the desired positions based on all of the database including three-dimensional clinical assessment (the most important), radiographic analysis, model studies and patient desires; (3) evaluate the feasibility of the planned surgical moves using the measurements and make necessary adjustments; (4) determine the vertical change that will be achieved at the time of surgery in such a way that it can be accurately duplicated intraoperatively; and (5) construct the surgical splint(s).[7]

Presurgical Database

A good presurgical database must include:

- Clinical examination of the dentofacial structures
- Cephalometric measurements – lateral and antero-posterior
- Mounted models
- Clinical photographs
  - Frontal in repose and smiling
  - Lateral
  - Occlusal—maxillary, mandibular arch forms, anterior intercuspation, lateral views of intercuspation bilaterally
- Panoramic radiographs
- Periapical radiographs when indicated (interdental osteotomies).

In an ideal circumstance, one must obtain these databases prior to commencement of the orthodontic therapy and at the immediate preoperative visit.

Clinical Examination

A standardized clinical examination of the orofacial region with emphasis on maxillomandibular relation at rest and in function often helps the clinician to deconstruct the dentofacial deformity not only for diagnosis but also for treatment planning.

Such a database would have to be simple, concise, and practical.

Table 10-1 depicts the least minimal components of a presurgical clinical database.

Table 10-1: Presurgical clinical database

Orthognathic Database	*Date*
Transverse	
Maxilla-Face	
Mandible-Maxilla	
Chin-Maxilla	
Occlusal plane cant	
Mandibular angles	
Arch width	
Vertical	
Crown length	
U-lip rest	
U-lip speech	
U-lip smiling	
Open bite	
Anteroposterior	
Overjet	
Nasolabial angle	
Nasal contour	
Labiomental fold	
Chin	

This clinical examination will consider a three dimensional appreciation of the deformity.

It is important to understand that much like in the world of avionics, the jaws move in all three dimensions once separated from their basilar structures.

All measurements must be done with the patient sitting up straight, with a caliper or a small millimeter ruler.

The transverse measurements include the evaluation of the midlines—maxilla to mandible midline as well as maxilla to face midline and chin point to maxilla. It should be noted that occasionally in patients with a notable deviation in their nasal structures or in those with hemifacial asymmetries there may be errors in evaluating midlines. In these instances, making a glabellar mark with a skin marker and holding a perpendicular string or dental floss from this mark, helps to measure dental and facial midlines. Caution must be exercised to avoid errors in judgment of soft tissue landmarks in significant asymmetries.

A cant is an asymmetry of the occlusal plane in the 'roll' dimension.

Occlusal cant is measured at least at the maxillary canines and if possible at the first maxillary molars. It is measured against the interpupillary line as a reference, with two rulers or tongue blades **(Figure 10-1)**. While occlusal cant is often a function of the maxilla with the mandible reciprocating it, rarely there may be an isolated mandibular cant. Another measurement of the asymmetry in this plane is the measure of mandibular angles **(Figure 10-2)**.

Figure 10-1: Measuring occlusal cant.

Figure 10-2: Measuring mandibular angle symmetry.

The measurement of maxillary and mandibular arch-widths is done both intraorally and on study models. Often a number may not denote this measurement but it is described as narrow/ok/wide, and specific mention of dental crossbite is important.

The vertical measurements are mostly made in the maxilla. The maxillary central incisor is the key to treatment planning in orthognathic surgery. Its preoperative position must be assessed in wide smile, function and in repose. In addition the length of the crown and a gingival show must be noted. Upper lip support can also be assessed by placing a roll of wax in the labial vestibule to estimate the amount of tooth show that may present after a maxillary advancement. In addition any open bite in the area of the central incisor must be measured preoperatively.

Overbite, whether positive or negative, should be noted following orthodontic decompensation. In significant anteroposterior maxillomandibular discrepancies, this is often a key measurement in predicting the movement that is required to correct the deformity. In addition, the nasolabial angle and the labiomental fold often help assess the soft tissue draperies that accompany the jaw relation discrepancies. One must also be mindful of the nasal contour while planning upper jaw procedures. Concomitant nasal procedures can be done to correct significant nasal functional and aesthetic concerns.

The position and structure of the chin play a major role in the final aesthetic perspective of most patients. While model surgery may or may not reveal the final position of the chin, cephalometrics certainly can help predict chin movement. Thus a preoperative assessment of the chin position is important.

Controversy reigns supreme in understanding the role of occlusion in TMJ function and whether orthognathic surgery corrects or worsens existing TMJ symptoms await a meta-analysis in the literature for conclusive evidence.[8] Until such proof presents itself, one must assume that altering occlusion and jaw relations can affect the TMJ. Hence a preoperative functional evaluation of the TMJ is imperative.

Table 10-2 depicts the minimal components of a preoperative TMJ exam.

The focus of this chapter is not cephalometric and other radiographic treatment planning. Hence the details will not be discussed. Nevertheless, the utilization of cephalometrics in treatment planning cannot be left unmentioned. The most important corelation that must be made between a cephalograph and mounted models is establishment of a common reference plane.

Multiple analyses have been constructed for measuring various aspects of dentofacial deformities. In addition, most ethnic groups have variations in their norms and averages.[6]

A few analyses such as the Delaire analysis do not rely on such averages and measures craniofacial architecture based on every patient's face to skull measurements and are useful in treatment planning more than others.[2]

Table 10-2: Components of preoperative TMJ exam

TMJ exam	*Date*		
		R	L
1. Muscle palpation			
Masseter			
Temporalis			
Pterygoid			
2. Capsule palpation			
Tenderness			
Click			
3. Joint noise			
Click			
Rec click			
Crepitus			
4. Lateral excursion			
5. Max opening			

Most surgeons use a combination of analyses as listed below to first measure angles and quantitative measurements of the patient's cephalograph for diagnosis and thereafter to make prediction tracings. These 'trial surgeries' with either acetate overlays or computer software allow the surgeon to test treatment options **(Table 10-3)**.

Impressions, Models, Face-bow Transfer

Stone models are a 1:1 representation of the patient's dental structures. Hence it is crucial that good impressions are taken and good working casts prepared from these impressions especially for the final preoperative work-up.

The casts should be poured in dense dental stone, devoid of air bubbles and undistorted. It is important that the casts include all dental structures in the oral cavity. The soft tissues are not as crucial in presurgical casts as they would be in prosthodontic treatment planning.

The bite to interdigitate the casts and to help mount the models should be recorded in centric occlusion. In patients with a preoperative CR/CO slide both these bites have to be registered, and must be accounted for in planning final occlusion.

In order to accurately record a spatial and functional relationship of the maxilla to the skull base a face bow is utilized **(Figures 10-3A and B)**.

The accuracy of face bow transfer and its clinical relevance has been argued in the past.[3]

Table 10-3: A comprehensive and practical cephalometric analysis

Cranial Base			
N-S-Ba		129 ± 4 [137 ± 5.8]	
SN-FH		7 ± 4 [9 ± 3.4]	
Maxillary Position			
SNA		81 ± 4 [84 ± 4]	
A pt To Na Perp.		1 ± 2 mm	
CO to ANS (Harvold)		100 mm (M), 93 mm (F)	
Mandibular Position			
SNB		80 ± 3 [80 ± 4.7]	
Pog to Na Perp.		-2 ± 4 mm	
SN – MP		32 ± 10 [29 ± 5.8]	
FH – MP (MPA)		22 ± 6	
Co to Pog (Harvold)		127 mm (M), 119 mm (F)	
Intermaxillary Relation			
ANB		2 ± 2 [4.2 ± 3]	
Wits (A pt perp to B pt perp)		-1 mm [=0.4 mm]	
PP - MP		20± 5 [27.6]	
Harvold difference		27 mm (M), 29 mm (F)	
Dentoalveolar			
U1 – SN		104 ± 4	
L1 - MP		90 ± 5 [93 ± 7]	
L1 – NB / Pog – NB (Holdway)		1: 1	
Inter-incisal angle		131 ± 10	
Vertical Dimensions			
UFH (N – ANS)		58 mm (M), 53 mm (F)	
LFH (ANS – Me)		74 mm (M), 67 mm (F) [80± 6.2 mm]	
UFH/ LFH		0.78	
U1 – ANS		30.5 mm (M), 27.5 mm (F)	
U6 – PP		26 mm (M), 23 mm (F)	
L1 – Me		45 mm (M), 40 mm (F)	
L6 – MP		38 mm (M), 38 mm (F)	
Soft Tissue			
E plane to Upper Lip		-3 mm	
E plane to Lower Lip		-2 mm	
Nasolabial Angle		100 ± 10	
Upper Lip to U1		2 mm (M), 4 mm (F)	

Measurements for Caucasians listed with African American averages in parentheses.

In most cases, an arbitrary face bow transfer is utilized without compromising the results.

Figure 10-3A: Face bow measuring maxillary relationship to skull base.

Figure 10-3B: Face bow parallel to Frankfort horizontal plane.

Mounting and Measuring Models

Orthognathic surgery even at its best does not require the use of a fully adjustable articulator.[5] However a strong case can be made for mounting most cases and making use of a semiadjustable anatomic articulator.

In mounting models for surgery, the first step is to perform a face bow transfer. Thus an anatomic articulator that allows for accommodation of a face bow is important.

In isolated mandibular surgery, often there is no role for such elaborate hinge-axis transfer. However a lot of clinicians make a strong case for using hinge axis transfer in all cases involving maxillary surgery, whether isolated or in combination with mandibular surgery. Errors in mounting will manifest themselves as errors in cant, midline, vertical position of the central incisor or antero-posterior position of the maxilla. This of course is a moot point if one chooses to arbitrarily position the maxilla intraoperatively in all three planes of space. While this may be common practice, errors are prone even in the most experienced clinician when proper treatment planning is not translated on to the operating table.

The practitioner and student with minimal experience in model surgery are urged to mount all cases make all measurements in order to get a concept of spatial movement and appreciate maxilla-mandibular interaction. Also, it helps to understand the translation of model surgery to the operating table and how these changes co-relate. One can use a barn door hinge when one feels comfortable with these concepts for single jaw cases!

It is only a matter of time when this whole process of treatment planning will be done virtually using CAD-CAM technology.

A few technical points on mounting: The base of the mounting and the cast are best separated by application of a layer of separating medium at the time of mounting. They are also best done in two separate colored gypsum products. For instance the model may be poured in yellow stone and the mounting may be done in white dental plaster.

The base must be smooth and parallel to the base of the cast so that measuring marks can be made easily and smoothly.

Measuring Mounted Casts

Once the maxillary and mandibular casts are mounted and dried, marking and measuring can commence. It is best to use a flexible ruler, or a caliper to measure and two different colored pencils, one for preoperative measurements and one for postoperative measurements. It also helps to scribe the points and lines with a blade and paint them with a clear paint or clear acrylic nail polish to avoid erasing these during the process of remounting for the final or intermediate splints.

Regardless of the methods used for measuring, the principles remain the same.

1. Obtain pre-cut vertical, transverse and anteroposterior measurements.
2. Ensure these measurements are reproducible and minimize parallax errors
3. The absolute numbers rarely matter, the difference between pre-cut measurements and post-movement measurements is what matters.

The Model platform and the Model block **(Figure 10-4)** (Great Lakes Orthodontic Products, Ltd., Tonawanda, NY) are widely used in the United States for measuring and marking models. This is an orientation block on which a caliper is attached that allows for marking and measuring models to an accuracy of 0.01 mm. The major advantage of using the block is avoiding parallax error.

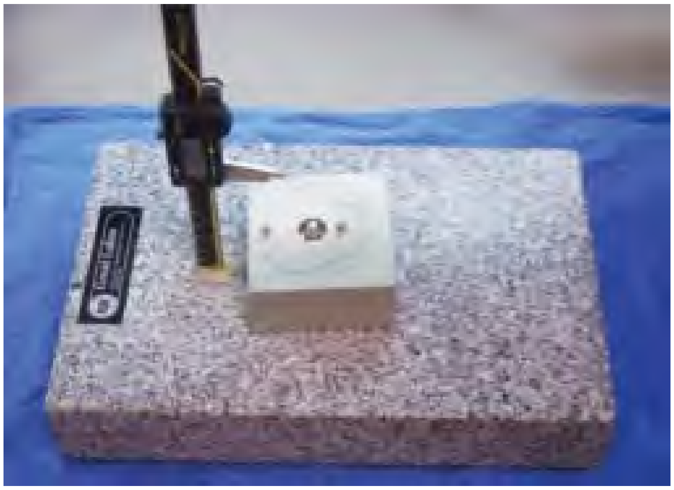


Figure 10-4: Model block and measuring platform.

Measuring the Maxilla

Midline marking is the first step in marking models. This can be done making lines parallel to the articulating pin on either side of it from a frontal view avoiding paralleling errors. This step is done on both maxilla and mandible mounted together in the presurgical occlusion **(Figures 10-5 and 10-6)**.

A mounted maxillary model requires measurements in the anteroposterior, vertical and transverse planes. This can be done with the maxilla removed from the articulator or while on it, either using a caliper or a flexible ruler.

A-P measurements are made at the central incisors and the arbitrary anterior nasal spine on the base of the cast to a point on the pin of the articulator to which all measurements should be consistently made. While making this measurement, keep in mind that the ruler remains parallel to the base of the articulator **(Figure 10-7)**.

Vertical measurements of the maxilla are made at both the central incisors at pre-marked points, both the canine cusp tips, mesiobuccal cusp tips of first molars. In addition the heel of the cast at both tuberosities should be measured **(Figure 10-8)**.

Figure 10-5: Measuring maxillary and mandibular midlines avoiding paralleling error.

Figure 10-6: Midline marked parallel to pin, but not visible from frontal view.

In the event of maxillary movements, one must ensure that the heel of the casts do not "fish-tail" with movements anteriorly. The points on the teeth to which the measurements have been made are marked so that the measurements can be reproduced without error. In addition, the ruler has to be kept parallel to the long axis of the tooth when making these measurements.

Transverse measurements are particularly important when considering segmental maxillary osteotomies. They must be made between vertical long axes lines of teeth between which the osteotomy is proposed. Also,

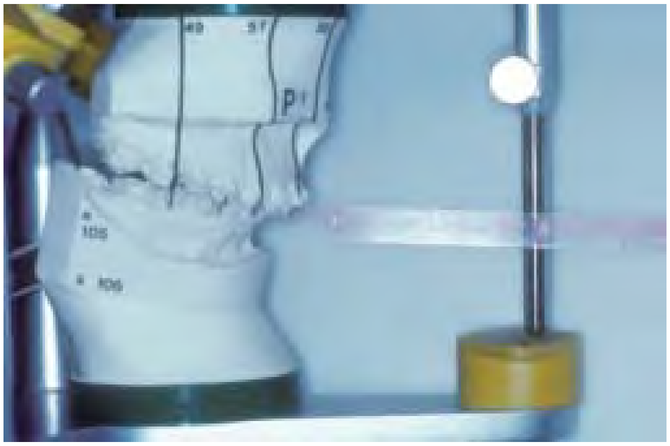


Figure 10-7: Measuring A-P distance of Maxillary central incisor to pin.

Figure 10-8: Measuring vertical distance of maxillary canine, molar and heels to the base.

measurements are made between canine cusp tips and at the heel of the maxillary casts that will help make post-operative measurements on the segmentalized cast.

Measuring the Mandible

Midline marking for the mandible is done at the same time as marking the maxillary midline.

The only practical measurement of the mandible is in the A-P dimension. This is measured to the fixed point keeping the ruler parallel to the base of the articulator. Both central incisors are measured to the pin from a marked reproducible point on the cast. In addition, an arbitrary menton is marked on the base of the cast that will conceptually deliver movements of the chin **(Figure 10-9)**.

At the posterior mandible, bilaterally two points are measured one at the superior border and one at the inferior border. These measurements are important especially when considering differential movements **(Figures 10-10 and 10-11))**.

Figure 10-9: A-P Measurement of anterior mandible to pin

Figure 10-10: A-P measurement of posterior mandible to pin. This is done at superior and inferior borders to measured rotation.

Figure 10-11: Marked and measured final mandibular cast.

The occasional time that mandible needs to be widened in the transverse plane; this can be measured at any cusp tip preferably the canine.

It is important to have a standard form on which these measurements can be recorded. A sample form is given on page 91.

Co-relating the Database, Cephalometric Tracing and Model Surgery

Once the clinical database that includes photographs, radiographs and cephalometric tracing has been obtained, clinical decision making should be based on all of the data collected and be influenced by every one of them.

The most important factor to influence the final treatment plan must be the patient's chief complaint and perception of surgical outcome. If the patient's perception of the issue appears far removed from reality then it is the clinician's responsibility to concede and communicate the reality of the outcomes with the patient. Software programs that superimpose prediction tracings with clinical photographs have significantly improved in their accuracy and make good tools in patient education.[1]

The true basis for maxillary model surgery in bi-maxillary cases is the placement of the maxilla in three planes of space based on decisions made from co-relating the clinical database and cephalometric tracings. The mandibular movements in bi-maxillary surgery are then determined by best intercuspation. This holds true even in case of large maxillomandibular advancements for correction of sleep apnea as well.

Most treatment planning takes into account the sex, age and race of the patient and the aim of the surgeon is to make changes in the osseous structures that will then reflect in the soft tissue drapery, for every patient to meet the acceptable esthetic norms for that age, sex and race. These moves must also consider limitations imposed by the dentition as well as stability in the long term.

After the clinician has decided on the kind of osteotomy that may be required to correct the patient's dentofacial deformity, then the model surgery can be performed and surgical splints may be constructed that will then allow for transferring these movements precisely in the operatory.

Treatment Schemes

Single Jaw Surgery

Mandibular Surgery Alone

Mandibular osteotomy by itself is utilized for correction of mandibular anteroposterior deficiency or excess. While considering mandibular surgery alone, it is accepted that the maxillary position is ideal and that it will now serve as a template for mandibular positioning.

Road Map

Oral and Maxillofacial Surgery

Name: ______________________ Surgery Date: ______________

Dr: ______________________ Surgery Planned: ______________

Orthodontist: ________________ Resident: ________________

Orthognathic Physical Exam

Date: ________________

Transverse

Mx-Face: ________________

Md-Mx: ________________

Chin-Mx: ________________

Occlusal Plane: ________________

Md Angles: ________________

Arch Width: ________________

Vertical

*Crown Length

U-Lip Rest: ________________

U-Lip smiling: ________________

Openbite: ________________

*A-P

Overjet: ________________

NLA: ________________

Nasal Contour: ________________

LMF: ________________

Chin: ________________

MIO: ________________

Planned Maxilla Movements

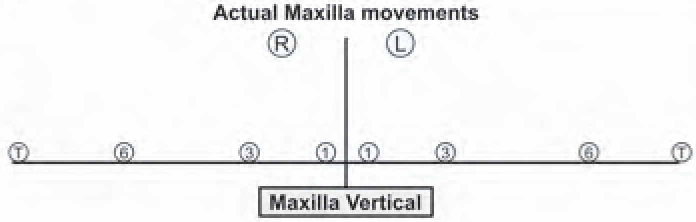
Incisors A-P: ______________ Cant Correction: ______________

Incisors Vertical: ______________ Midline Correction: ______________

Tuberosity Vertical: ______________ Palatal Expansion: ______________

Segmental Pieces and Cuts: ________________________________

Actual Maxilla movements

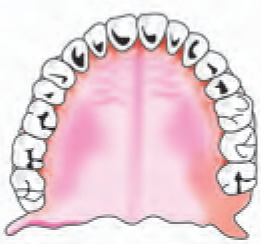


Equilibrate: ______________________

R3 ________mm

R6 ______mm

A-P

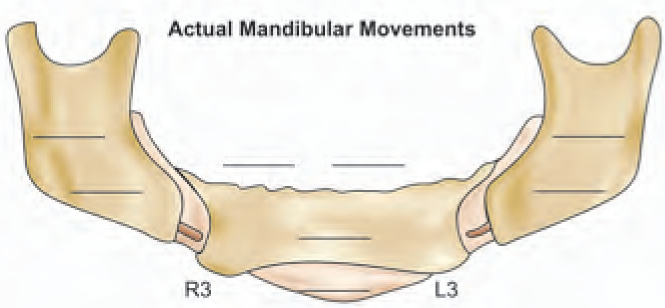


L3 ________mm

L6 ______mm

Transverse

Actual Mandibular Movements



R3 ______ L3 ______

For the purpose of discussion we shall consider a Class II malocclusion case where the mandible should be advanced into a class I relation. While a simple hinge articulator can be used for simple single jaw cases, the authors prefer to teach trainees with a semi-adjustable articulator for reasons cited earlier.

The models are articulated as per standard mounting technique. The incisor pin is not changed at all during the case. Standard measurements are made, scribed, and recorded. The mandibular cast is now separated from its base and placed in its intended position and a new base is created. The anteroposterior measurements are recorded again and the final road map is created. A final splint is made to this new position.

Occasionally one resorts to interdental osteotomies and a subapical osteotomy in the mandible, and while the basic concept remains the same, these variations are easily incorporated into the models prior to construction of the splint.

Maxillary Osteotomy Alone

In this scenario, the mandible will serve as a template for final position of the maxilla. An acceptable clinical situation to consider for the sake of discussion would be a single piece Le Fort I maxillary osteotomy for correction of maxillary posterior hyperplasia in a skeletal class I open bite malocclusion.

At least a semi-anatomic articulator if not a fully adjustable articulator is recommended for these cases, especially if the maxillary movement involves correction of a cant. The advantage of using such an articulator is that it simulates the appropriate arch of autorotation of the mandible when properly mounted. With maxillary shortening, the incisal pin will be shortened.

The models are articulated as per standard mounting technique. The incisor pin is not changed at all during the case. Standard measurements are made, scribed, and recorded.

The maxillary cast is now separated from its base, maxilla is positioned appropriately to interdigitate with the mandibular cast and a layer of wax or compound is added to the gap between the base and the model.

Any anteroposterior changes are usually limited by the mandibular position. The new measurements are recorded and the road map is prepared. A final splint is made to this occlusion.

Double Jaw Surgery

The model surgery for dual arch surgery will depend on the order of osteotomies that the surgeon prefers to perform. Some surgeons prefer to operate on the maxilla first, fixate it against the un-operated mandible using an intermediate splint and then tackle the mandible to this new maxillary position for the final maxilla-mandibular relation. Some others prefer moving the mandible first, and then the maxilla.

If the mandibular osteotomy performed is a sagittal split osteotomy, the authors prefer to cut, but not split the mandible first, and then osteotomize the maxilla, use an intermediate splint to fixate it in the new position, and then split the mandible and fixate it, using the position as dictated by the final splint.

The model surgery in this scheme would consider single piece maxillary surgery alone. Segmental surgery is considered as a separate entity.

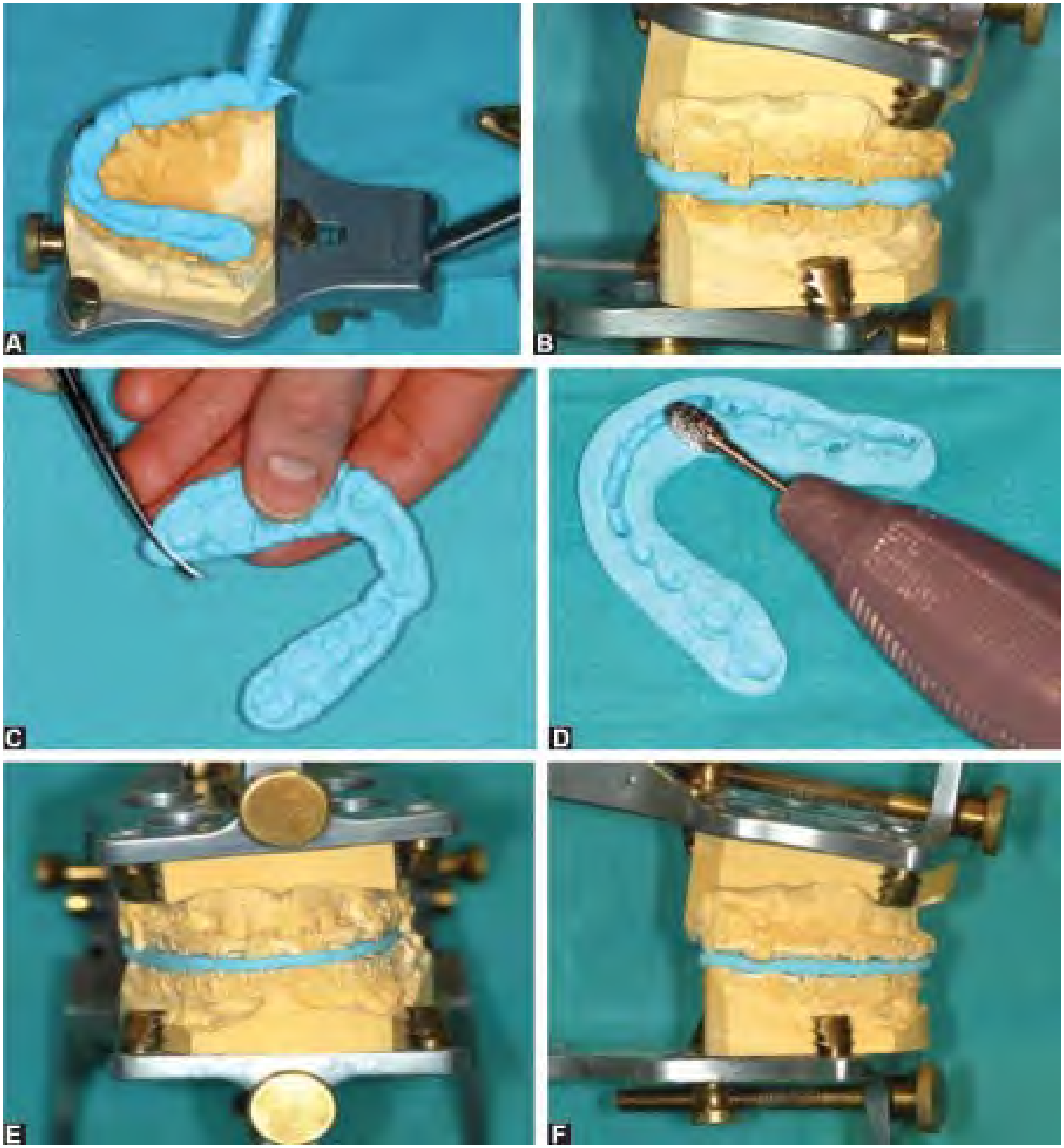
Assuming that the maxilla is the first jaw to be mobilized in surgery, the following steps are considered in the model surgery.

The models are articulated as per standard mounting technique. The incisor pin is not changed at all during the case. Standard measurements are made, scribed, and recorded.

The maxillary cast is then separated from the base. The base of the cast is trimmed sufficiently to accommodate either an intrusion or other movements. The new position of the maxilla must be considered in all three planes. Midline has to be matched. Any cant correction is achieved by correcting vertical measurements that may be unequal first. For instance if on clinical exam, the maxillary left canine is 2 mm lower than the right canine, this is leveled in the final position of the cast. Co-relating the clinical database and cephalometric prediction tracing, the maxilla is then moved in an anteroposterior dimension to the prescribed position.

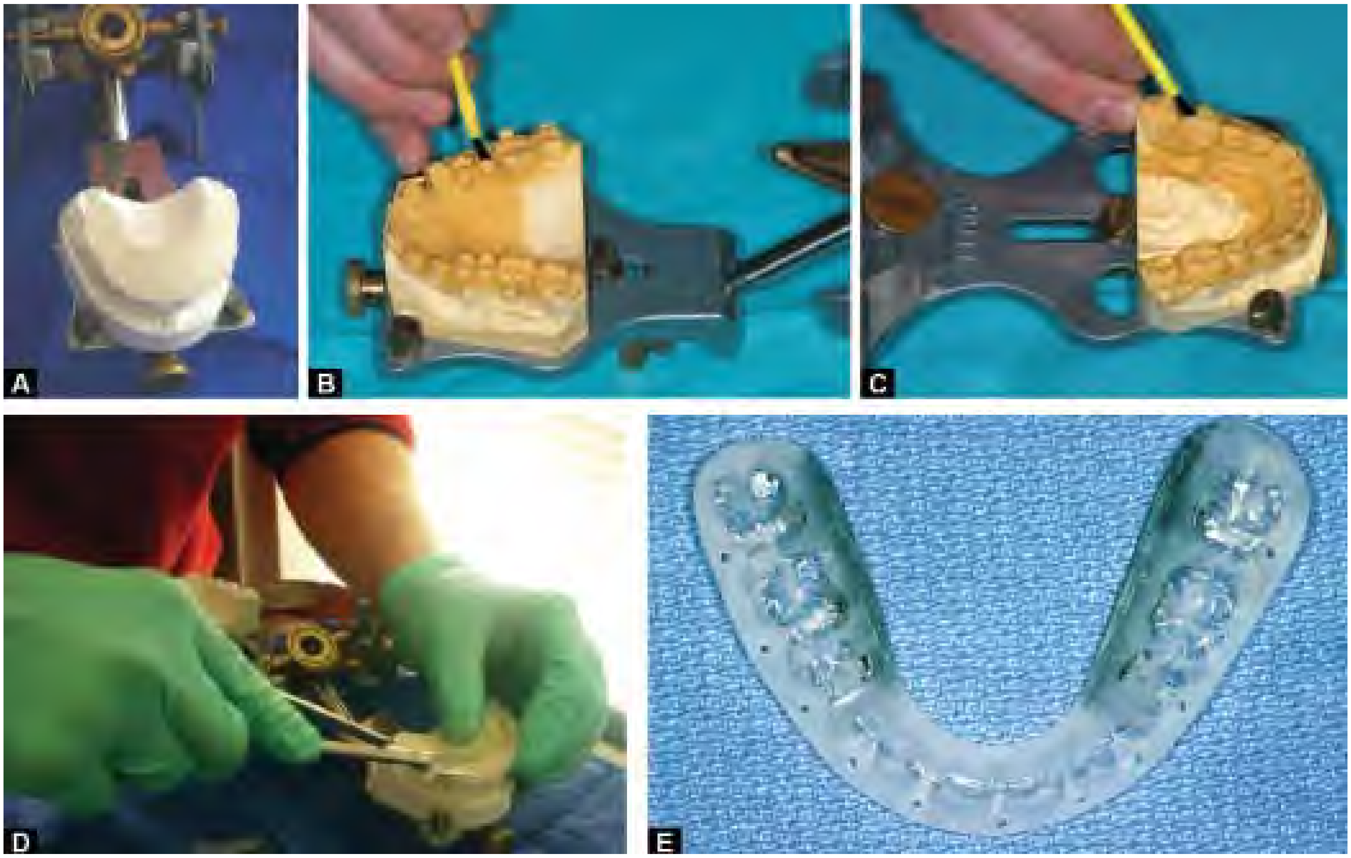
Any method can be used to hold the cast while making the movements. The author prefers to use three dollops of red sticky wax during the 'move and measure' phase and then melts yellow wax in between model and the base to secure it in that position. Some clinicians use dental plaster while yet others resort to a glue gun for the same purpose.

Caution must be exercised while making multi-dimensional movements to constantly re-evaluate the measurements in all planes and also ensure that the heels of the cast are not kicked off in one direction or another. This is especially possible while attempting to correct the midline. As the anterior part of the cast moves to one side or another, it is easy for the heels to 'fish tail' in the opposite direction. This can be avoided by changing the fulcrum of rotation as anterior as possible.



Figures 10-12A to F: Blu-Mousse® splint making.

With the maxilla secured in its desired position, it will provide us with the position it will take in relation to the unsplit mandible. One could attempt to make an intermediate splint at this time. However it is prudent to reserve this until later. In the event that the process of fabrication of a splint causes any damage to the master casts, this could significantly jeopardize the final positioning, interdigitation, and fabrication of the final splint.



Figures 10-13A to E: (A) Application of acrylic template, (B) Application of separating media, (C) Application of separating media, (D) Trimming the splint, (E) Final splint, trimmed, polished and holes made for passing wires for intraoperative fixation

Hence, following the placement of maxilla in its new prescribed position, the mandibular cast is separated from its base, placed in a position that allows maximum intercuspation, and a new base is created for it, preferably in a stone of a different color as opposed to the original mounting. This will be the final position of the mandible.

A final splint is fabricated first in this position. Once that splint is complete, the mandibular model can be repositioned on the initial base and the intermediate splint is constructed. All postoperative measurements are recorded on the road map for surgery.

When a segmental maxilla is utilized for achieving a good postoperative result in dual arch surgery, a composite splint is required. The composite splint involves a final interocclusal wafer that forms its upper half. The lower half represents the intermediate splint. The upper part of the splint attaches to the maxilla and is placed first intraoperatively. Following placement of this splint, the intermediate splint is placed and wired on, which will then assist with proper maxillary positioning taking into consideration the specific rotation axis of the mandible to the osteotomized maxilla.

In the event that the maxillary procedure involves segmental surgery, then the final splint often has a palatal strap that is incorporated to the occlusal aspect of the splint that helps to maintain transverse stability of the arch as it heals.

Splint Making

Most surgical splints are made with cold cure acrylic material. An ideal splint must be thin, strong, be devoid of interferences, air bubbles and imperfections. Other materials can be used to make splints as well. Thixotropic vinyl polysiloxane(Blu-Mousse®) is a popular material that often replaces the classic acrylic splint **(Figures 10-12A to F)**.

Most clinicians prefer coverage of the splint till the first molar tooth; some prefer a splint that involves only anterior teeth **(Figures 10-13A to E)**.

Summary

There are multiple ways of achieving the same results through model surgery.

While the absolute movements from model surgery may not translate millimeter per se to the operating table, the exercise gives the practitioner a concept of the expected movements in three dimensions. Systematic analysis of information gathered from clinical cephalometric and occlusal examinations from both a functional and a spatial stand point helps make the treatment decisions related to multidimensional placement of maxilla and hence the mandible.

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Chapter

11

Krishnan Pisharody

Introduction

Orthognathic surgery has gained wide popularity over the past two decades. Surgeries are performed on the maxilla or mandible either for cosmetic purpose or for improvement in the occlusion of teeth, or both.

Patients coming for these procedures are usually well motivated, young and healthy. The common procedures for which patients come are Le Fort I osteotomy, Sagittal split osteotomy, Genioplasty, etc.

Anesthetic Considerations

- Sharing of the airway between the surgeon and the anesthesiologist
- Intraoperative bleeding
- Intermaxillary fixation—postoperative management of the airway, if it is used
- Postoperative management of the patient.

Preoperative Assessment and Planning

A detailed clinical examination should be done. If there are any medical problems, they should be investigated and adequately controlled prior to the surgery.

Airway should be assessed as for any other surgery with special emphasis on patency of nostrils, because the intubation has to be done through the nasal route. In patients with deviation of nasal septum, help of an ENT surgeon can be sought to decide the nostril through which intubation can be carried out. Difficulty of airway management should be anticipated in patients with cleft palate, micrognathia and previous history of trauma. A plan for difficult intubation has to be made, if indicated by history and clinical examination.

Preoperative investigations should include blood and urine examination to rule out any systemic illnesses, coagulopathies and screening tests for HIV, HBs Ag and HCV. Blood group and Rh should be known prior to surgery.

A written consent for the procedure should be obtained. Patient and relatives have to be explained about preoperative and postoperative events, they would go through. Assurance is given to relieve the anxiety and fear of the patient.

Orthognathic surgery can produce blood loss during the intraoperative period. Planning for perioperative blood transfusion should be done prior to the surgery. Packed cells and fresh frozen plasma should be arranged separately, as whole blood transfusion is not preferred. Autologous transfusion is another alternative. However, due to improvements in surgical techniques and anesthetic management, perioperative blood transfusion can be avoided in most cases.

A plan for postoperative care of the patient should also be made at this stage.

Preparation of the Patient and Premedication

A 6 to 8 hours of starvation is advised prior to the start of the surgery. The patient is given a nasal decongestant for 1-2 days prior to surgery. Xylometazoline 0.1%, 3 drops three times a day can be prescribed for this purpose. Tab. Diazepam 10 mg, given 6 hours before surgery is useful in reducing anxiety. Pre-emptive analgesia is very effective in managing pain intra- and postoperatively, before the onset of surgical pain.

One method is to give Paracetamol 650 mg sustained release, 2 tablets 3 hours prior to surgery and a narcotic analgesic ½ hour before surgery. This is also helpful in successful management of induced hypotension in the intraoperative period. A β-blocker (e.g. Tab. Atenolol 12.5 mg) is given 12 hours prior to surgery, if it is not contraindicated. This will prevent increase in the heart rate during the surgery and aid in the proper management of induced hypotension, a description of which will be followed. A proton pump inhibitor like Pantoprazole 40 mg and antiemetic Ondansetron 8 mg slow IV bolus are administered preoperatively to reduce the chances of postoperative nausea and vomiting. IV access with a 16 G or 18 G cannula is secured and maintenance fluid is infused during the starvation period. A large bore cannula is extremely useful in administering fluids or blood at a fast rate if required. Inj. Dexamethasone 0.1 mg/kg IV bolus is given to reduce the postoperative edema. Blood can be drawn from the patient for autologous transfusion and acute normovolemic hemodilution. A description of this technique will be given at the end of the chapter.

Induction of Anesthesia

In the operation theater the patient is connected to ECG, Pulse oximeter, Noninvasive blood pressure, End-tidal CO_2 and temperature monitors. Invasive arterial pressure monitoring can be used wherever facilities are available. A urinary catheter should be inserted if the expected duration of the surgery is more than 3 hours. Temperature monitoring is very useful to detect hypothermia in prolonged surgeries especially when cold saline irrigation is done at the surgical site during osteotomy.

A balanced anesthesia technique is to be followed. Glycopyrrolate 0.2 mg IV bolus is given before induction. Midazolam, 0.1 mg/kg IV bolus can be given to reduce anxiety and for initial sedation. 1% Propofol is the choice of induction agent. This is given at a dose of 2 mg/kg IV bolus. The drug is used for maintenance of anesthesia as well.

The fast recovery from anesthesia, assistance in controlled hypotension, easier ICU care, reduction in duration of ICU stay and reduced contamination of the operation theater by inhalational anesthetic agents are some of the major benefits of using Propofol for induction and maintenance. Nasotracheal intubation is done under succinyl choline paralysis. Nasal RAE tubes which have preformed curves are used. Kinking of endotracheal tubes in the intraoperative period can be avoided by the usage of these endotracheal tubes. Once endotracheal intubation is confirmed, a roller gauze throat pack is inserted, to prevent collection of blood and saliva above the cuff of the endotracheal tube and probable pulmonary aspiration.

Positioning

A sand bag is placed under the shoulder to produce extension of neck. A head ring is placed for stabilizing the head. An upward tilt of the operation table of about 20-30° is given. By doing so, the site of surgery can be kept higher than the level of heart, to facilitate venous drainage away from the site of surgery. This step is very important to reduce bleeding from the site of surgery. Pressure points are adequately protected. Fixing the endotracheal tube at the tip of the nostril should be done carefully. Excessive pressure at this point can lead to decreased blood flow and ulceration of the skin, especially when controlled hypotension is used. Correct position of the endotracheal tube is confirmed once again after positioning.

Maintenance of Anesthesia

Maintenance of anesthesia is done by using oxygen, nitrous oxide, Inj. Propofol 2 mg/kg/hour and longer acting muscle relaxants. A narcotic analgesic of choice can be supplemented intraoperatively.

Controlled hypotension is started immediately after positioning. Nitroglycerine is the drug commonly used. 50 mg of nitroglycerine is added to 500 ml of 5% dextrose and infusion rate is adjusted according to the monitored blood pressure. The infusion has to be started immediately after induction of anesthesia, as it takes some time to reduce the blood pressure to the desired levels. The mean blood pressure is brought down by 20 to 30% of the baseline measurement. Mean blood pressure is not brought down below 30% of the baseline pressure. Care is taken to have normal blood volume by infusing crystalloids, so that cardiac output is optimal. Oxygenation of blood has to be closely monitored. The blood pressure can be maintained at a higher point where a bloodless field is achieved and intraoperative blood loss is minimal. Reduction of blood pressure is done gradually so that the brain, heart, kidneys and liver have enough time for compensatory mechanisms to develop to maintain optimal blood flow. Some general measures that help controlled hypotension are, posture, deep plane of anesthesia, good analgesia and liberal use of local anesthetics at the site of surgery. 2% lignocaine with 1: 2,00,000 adrenaline is used for infiltration.

Since controlled hypotension is used routinely, intraoperative blood loss is minimal. Blood loss is estimated by measuring the amount of blood in the suction bottles, the number of soaked mops, approximately calculating the amount of blood on the wet drapes. Transfusion is given either using packed cells or autologous transfusion. If the estimation of blood loss indicates only a single unit transfusion, blood transfusion is better avoided. Hemoglobin percentage and packed cell volume can be estimated postoperatively to decide whether transfusion has to be given or not. Autologous blood is transfused back, in the postoperative period irrespective of the blood loss. Towards the end of the surgery, the BP is brought back to the baseline by gradually decreasing the rate of nitroglycerine infusion. The temperature in the operation theater is also brought back to normal to make sure that the patient's temperature is normal at the time of reversal.

The throat pack is removed before reversal from muscle relaxation is planned. With the improvements in bone fixation techniques with plates and screws or wires, intermaxillary fixation is not done nowadays. Once the patient has recovered adequately from the effects of anesthetics and muscle relaxants, and is conscious enough to maintain and protect the airway, extubation is done. Extubation is done in the operation theater in most cases. The endotracheal tube can be retained in the postoperative period, if there is persisting bleeding from the surgical site or if the recovery from the anesthetics is inadequate. The endotracheal tube is also retained in case IMF is done. The patient is shifted to the postoperative intensive care unit. Lateral position is maintained during the shifting and also in the ICU. Throat suctioning should be given immediately after shifting to the ICU because collected blood from the paranasal sinuses can flow into the pharynx in Le Fort I osteotomies. Oxygen supplementation is given by mask till the patient is fully awake.

Autologous Transfusion

Autologous transfusion describes administration of any blood component which has been donated by the intended recipient. During a surgical procedure which produces bleeding, the initial problem is hypovolemia. But it can be managed with the use of crystalloids or colloids and the patient's normal compensatory mechanisms will lead to recovery without transfusion of blood. Hemorrhage is well tolerated till PCV reaches 25 to 30%. Once it is below 25%, oxygen delivery to the tissues is affected. It is at this point, homologous blood transfusion is considered. But there are some risks involved when homologous transfusion is given. Some of them are

1. Disease transmission, e.g. HIV, HBsAg, HCV, cytomegalovirus, syphilis, malaria.
2. Allergic reactions.
3. Alterations in the host immune function.

These complications can be avoided by the use of Autologous Transfusion.

Methods of autologous blood transfusion:

1. Predeposit donation or storage for defined need.
2. Acute normovolemic hemodilution.
3. Intraoperative cell salvage.
4. Postoperative collection.

Contraindications for autologous transfusion:

a. Acute bacterial infection.
b. Patients with cardiac disease.
c. Pregnant patients.
d. Anemia.

Acute Normovolemic Hemodilution

This is one of the safest methods of conserving patient's own blood prior to surgery, and transfusing it back after the procedure. This technique can be done about one hour prior to surgery. Usually one unit is drawn with all aseptic precautions. One liter of ringer lactate or 500 ml of hydroxyl ethyl starch is infused while blood is being drawn. This is done to maintain normal blood volume.The drawn blood is labelled and kept at room temperature in the operation theater if the surgery is expected to finish in less than six hours from the time of collection.

Once hemostasis is achieved and surgery is completed, the blood is transfused back. This technique is especially useful in patients with rare blood groups. This is a simple procedure and can be done in any set up.

Chapter 12

Varghese Mani

Introduction

Surgical treatment of maxillofacial deformity has become prevalent since the latter half of the last century. An array of surgeons have contributed to this field and developed new techniques. Before 1965, most of the procedures done on the mandible were extra oral. But the pioneering and challenging work by Kole, Walker, Obwegeser and others helped to develop intraoral techniques for the treatment of mandibular procedures. Basic surgical principles are applicable to orthognathic surgery and they are to be adhered to strictly.

Any change in the appearance of the face is not easily accepted either by the patient or by the kith and kin, whether it is good or bad. Postoperative sequelae like swelling, pain and restricted movements can have a negative effect on the patient. The patient and the relatives are to be cautioned about the postoperative sequelae and the possible complications.

Bone heals by repair and regeneration. This quality of the bone is favorable for osteotomy. Maxillofacial bones have a better blood supply than the bones in the rest of the body. So the healing is faster. The basic principle is to cut the bone into appropriate fragments and to realign it so that the pre-planned architecture is achieved.

Principles of Surgical Treatment

Strict adherence to the surgical principles is an inevitable requisite for the success of surgery.

Blood Replacement

Since most of the patients who undergo orthognathic surgery are healthy individuals, the requirement of blood transfusion is minimal. Blood loss can be reduced by hypotensive anesthesia. Autologus blood transfusion is ideal if transfusion is required.

Studies show that 8 gm/dL of hemaglobin or a hematocrit value of 24% is more than sufficient to meet oxygen demands, provided appropriate compensation is effected by crystalloid or colloid solutions to maintain necessary cardiac output. The surest way to avoid complication related to blood transfusion is to resort to autologus blood transfusion. One or more units of blood are removed a few weeks prior to surgery. Iron supplementation is started two weeks prior to withdrawal of blood, stopped on the day of surgery and continued after 3 days.[36, 189] Predeposit of autologus blood can be done as late as 72 hours prior to surgery. However iron (325 mg $FeSO_4$) replacement is important to minimize anemia.[36] Hemodilution can be done by bleeding the patient immediately prior to surgery. The hematocrit value can be brought down to 30%. The loss is compensated by colloids and crystalloids. The collected blood is transferred immediately after the surgery.[109]

Candidates for preoperative hemodilution include those whose total blood loss will probably fall in the range of 1 to 2 liters. They should have a preoperative hemoglobin level greater than 12 gm/dL and should not be suffering from coronary heart disease, lung disease, renal disease, hypertension, liver disease or clotting abnormalities.[109]

The major disadvantage of autologus blood transfusion is the inconvenience to the patient and the risk of development of anemia prior to surgical procedure. These disadvantages however are probably outweighed by the advantages of autologus transfusion when compared with homologous transfusion.[104]

Psychological Preparation of the Patient

It is essential that the patient and relatives be informed about the postoperative result of the surgery as well as the problems involved during the postoperative recovery period. They should be aware of the difficulties in normal activity that are likely to be encountered in the 4-6 week postoperative period. Patient satisfaction from orthognathic surgery is related to the changes that the patient has expected. When surgery changes the features, the patient has not identified as deformed, patient dissatisfaction may result even if it is technically adequate.[102] Unanticipated postoperative events like bleeding, infection, IMF, postoperative depression, etc. can cause patient dissatisfaction.[52, 83, 84, 163] Overall satisfaction seems to be unrelated to the presence or absence of functional problems.[52,83,84] Long-term satisfaction is primarily related to the aesthetic outcome of the case.[52, 83, 64]

Patients may have to subsist on soft or liquid diet. However, the nutritional value of the food intake is very important for proper healing. Postoperatively high calorie high protein supplementation is necessary. Weight loss and loss of protein adversely affect the nutritional support during healing.[81]

Maintenance of oral hygiene is of utmost importance. Patients have to brush the teeth after every food intake. Postoperative swelling and pain should be discussed with the patients. Swelling usually starts subsiding after three or four days. However, it completely subsides only after the patient resumes proper jaw movements. Occlusal disturbance associated with surgery, during the immediate postoperative period, should be briefed to the patient.

A patient who has been briefed and prepared psychologically turns out to be a very cooperative patient. Most of the patients can return to their routine activities by the second week of surgery.

Maintenance of Blood Supply

One of the most important aspects in orthognathic surgery is the proper maintenance of blood supply to the mobilized fragments. This is achieved by maintaining proper soft tissue pedicles to the osteotomized segments. Experimental studies by Bell, Nelson and others have helped proper understanding of the perfusion of blood. Bell was the one who first identified the exact nature of blood vessels in the osteotomized maxilla.[17, 23]

When an adequate soft tissue pedicle remains attached, collateral circulation opens vascular channels to the bony segments **(Figure 12-1)**. The ischemia at the osteotomy site is only transient. Bell's research helped to establish the biologic basis for orthognathic surgery. Their study involved both histologic and microangiographic data.[17,19,23]

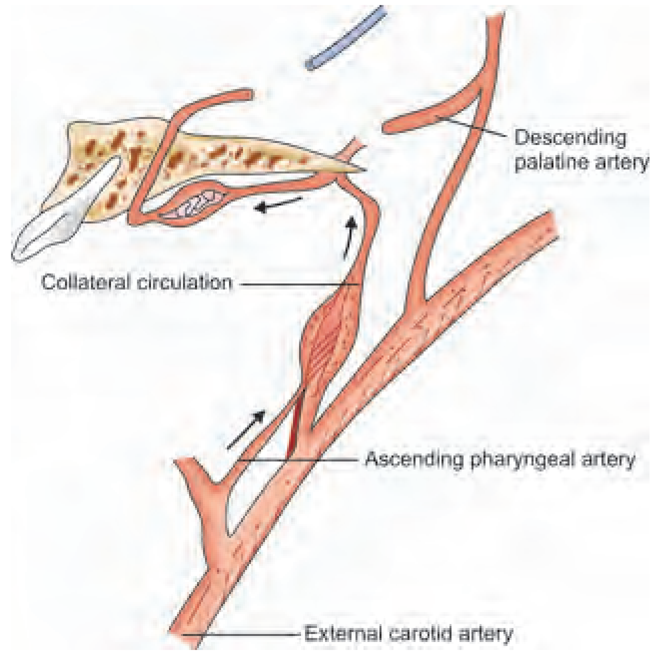


Figure 12-1: Rich blood supply to the maxilla from the various branches of the external carotid artery takes care of the perfusion of the maxilla even if the descending palatine artery is transected in Le Fort osteotomy.

It is not advisable to segment a single jaw into more than four fragments as multiple fragmentation reduce the blood supply. Though it is possible to do individual tooth osteotomy, it is always better to have a minimum of three teeth per segment.

The vessels entering the bone from the elevator muscles inserted to the mandible are important. Therefore when ramus surgery is done it is advisable that muscle stripping is kept to a minimum.

Control of Blood Loss

Three principal benefits of hypotensive anesthesia are reduction of intraoperative blood loss, improved visibility in the surgical field and reduced operative time.[39, 171] Brain has the ability to regulate blood flow down to mean pressures of 50 to 60 mmHg in patients who are normotensive preoperatively.[171, 174] Hypocarbia complements the reduction of central blood flow produced by hypotension.[2,107] The heart tolerates hypotensive anesthesia well. After-load reduction sharply cuts myocardial oxygen requirements.[27] By achieving hypotensive anesthesia of 20% below normal, bleeding can be significantly reduced, increasing visibility and decreasing the operating time.[45]

Care of the Nerves, Vessels, Teeth and Bones

The nerves of importance which may get involved in surgery are the facial nerve, inferior alveolar nerve and infraorbital nerve. The extra-oral submandibular incision is designed in such a way that the marginal mandibular nerve is spared.

It is important to protect both the inferior alveolar and the mental nerves, as injuries to these nerves result in numbness of the lower lip. The procedures which can cause injury to the inferior alveolar nerve are sagittal split osteotomy and body osteotomy. During maxillary surgery, care should be taken to protect the infraorbital nerve.

Vascular supply of the teeth can be preserved by making the osteotomy at about 3 to 5 mm away from the apices of the teeth **(Figure 12-1).**

Complication due to vascular ischemia following Le Fort I include delayed healing, loss of teeth and loss of bony segments.[14, 94, 182] Studies indicate that palatal soft tissue pedicle and the labial buccal gingiva are adequate to maintain blood supply for single stage total maxillary osteotomy.[16,17,20,23] If basic principles are followed transection of descending palatine artery on both sides may not adversely affect blood supply in Le Fort I osteotomy. This is due to the rich vascular anastomosis of the branches of the ECA, in the oropharyngeal area from the branches of the External Carotid Artery.[17, 40]

If the periodontal ligament is involved in the bony cut, it may result in ankylosis of the tooth. Tipping the roots away from the osteotomy site by orthodontics facilitates interdental osteotomy without injury to the periodontium.[53, 158] It is important to maintain the contour of the alveolar crest. Violation of this principle may result in periodontal pockets with bone loss **(Figure 12-2).**

While using rotary instruments or saws, copious saline should be used to irrigate the region to prevent thermal damage of the bone.

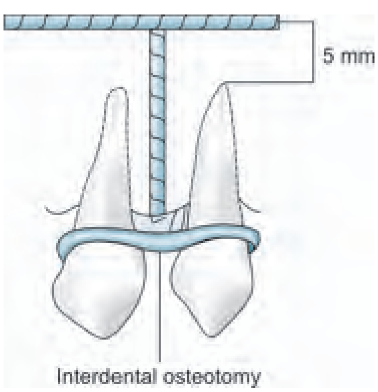


Figure 12-2: The osteotomy should be 3 to 5 mm away from the apex of the root. As far as possible step defect at the interdental osteotomy is avoided.

Whenever a bone defect is created, bone grafting may be done. Though autogenous or allogenic bone grafts can be used, they serve only as a scaffold. The patient's own bone replaces the graft as healing progresses. Autogenous bone is more dependable when rapid healing is required and when augmentation of the facial contour is the aim of the surgery.

After orthognathic surgery, immobilization of the jaw for a period of five to six weeks is required to prevent movement at the osteotomy site, if wire osteosynthesis is used. Movements at the site of osteotomy may result in fibrous union which is not desirable. Rigid internal fixation (RIF), using screws and plates, facilitates jaw function without movements at the osteotomy site.

Prevention of Relapse

Certain surgical principles are to be observed to prevent relapse in orthognathic surgery. Of this the most important is to prevent stress and strain on the soft tissues. Advancement procedures in maxilla and mandible produce strain, and chances of relapse are high. Stability is greatest when the soft tissues are relaxed after surgery and least when they are stretched.[76] Rigid fixation is the appropriate method of osteosynthesis in such cases. Osseous gaps can also contribute to relapse. Therefore such gaps are grafted, preferably with autogenous bone.

Displacement of the condyle from the glenoid fossa while doing intermaxillary fixation is another reason for relapse. There is a tendency for the maxilla to slide forward when superior repositioning of the maxilla is done after Le Fort I osteotomy. In such cases, mandible gets dragged forward while doing an intermaxillary fixation. After releasing the intermaxillary fixation the condyle may go back to its normal position in the fossa and create an open bite. This can be prevented by ensuring the position of the condyle in the fossa by using finger pressure at the ramus to push the mandible upward and simultaneously pushing the mandible backward by thumb pressure. It is generally accepted that relapse tendency is almost proportional to the displacement of condyle from its fossa **(Figure 12-3)**.[124,191]

Postsurgical Period

The general principles followed after orthognathic surgery, as the same as those observed for any other surgery. These include balance of fluid intake and output, and control of infection, edema and pain. Maintenance of oral hygiene is very important. The patient should be encouraged to clean the mouth after every intake of food.

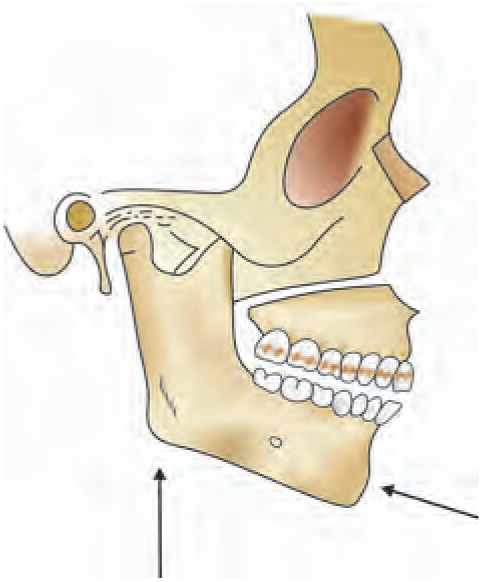


Figure 12-3: Displacement of the condyle is one of the main causes for relapse. This can be prevented by making sure that the condyle is in the fossa while positioning the maxilla.

Though not statistically significant, prophylactic antibiotic has reduced the incidence of infection.[130] Many factors like pre-existing health problems, surgeon's experience, duration of surgery, surgeon's past rate of infection, etc. should be considered. If prophylactic antibiotic therapy is indicated the surgeon should consider giving a pre-operative dose sufficiently before the surgery to provide good tissue levels and supplement it in periodic intervals of the surgery.[148] Administration of Methylprednisolone before, during and after surgery has resulted in reduction of facial edema after Le Fort I and ramus osteotomies.[150] Steroid therapy makes it possible to do extubation soon after surgery. Moreover early extubation eliminates the potential complications of laryngeal injury, pharyngitis and nasal irritation.[197]

Early ambulation is advised postoperatively as it reduces the chances of developing pulmonary problems, and enables the patient to regain energy faster. Good nutrition is essential to promote good healing. A normal patient requires 1500 to 2500 ml of water/day to make up for losses composed of 800 to 1500 ml through urine, 300 ml through the lungs by breathing, and 400 ml through the skin. On the basis of these losses a normal 70 kg man requires 2100 ml of fluid/day.

Maxillary Surgery

Osteotomy of the maxilla was first described in 1859 by Von Langenbeck for the removal of nasopharyngeal polyps.[92,166] David Cheevar did maxillary osteotomy in 1867 to treat a complete nasal obstruction.[33] In 1959 Schuchardt used posterior maxillary osteotomy to correct dentofacial deformity.[155] Midface osteotomies have been classified anatomically to coincide with Le Fort fracture classification.[98]

Common osteotomies performed in the maxilla are the Le Fort osteotomies, anterior maxillary osteotomy and the Posterior subapical osteotomy. These procedures can be combined and modifications can be done depending on the clinical requirement.

Le Fort I Osteotomy

The first total Le Fort I osteotomy was performed by Wassmund in 1927 to correct a skeletal open bite.[187] Axhausen in 1934 did the first maxillary advancement at the Le Fort I level.[11] Bell established the biologic basis for Le Fort I osteotomy by extensive animal and human studies.[17,20]

In 1901 Le Fort published his classic description of the natural planes of maxillary fracture.[99] In 1927 Wassmund first described the Le Fort osteotomy for the correction of midface deformities.[61, 71, 188] In 1942 Schuchardt advocated the separation of pterygomaxillary junction.[156] Moore and Ward in 1949 advocated horizontal transection of the Pterygoid plates for advancement.[113] Willmar reported severe bleeding where Pterygoid transection was done.[192] In 1965 Obwegeser advocated complete mobilization of the maxilla so that repositioning could be achieved without much tension on the soft tissue.[122]

Le Fort I osteotomy generally simulates the Le Fort I fracture of the maxilla. The entire maxilla below the zygomatic level is osteotomized and down fractured. The fractured maxilla can be moved upward, forward and to some extent downward and backward. It can be rolled, pitched or yawed. In short the maxilla can be moved in all the three dimensions **(Figure 12-4).** The main indications for Le Fort I osteotomy are vertical excess of maxilla and sagittal deficiency or excess of maxilla. Le Fort I can be used for most of the maxillary deformities.

Surgical Technique

At the beginning of the procedure, 2% lignocaine hydrochloride with 1: 200,000 epinephrine is infiltrated into the buccal tissues of the maxilla on both sides. Palatal infiltration is not advised since it can compromise the palatal perfusion of blood to the maxilla. Before surgery the head end of the table is tilted up by about 15°. This

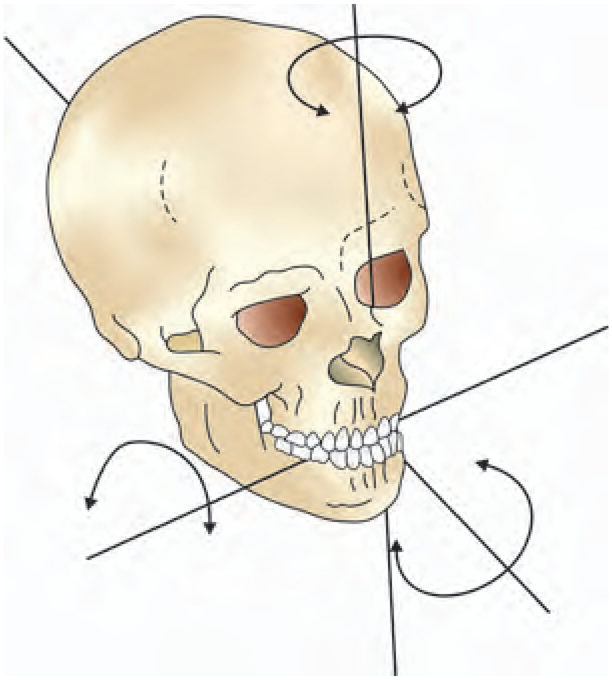


Figure 12-4: Maxilla can be moved in all the three dimensions.

helps to reduce the bleeding. Hypotensive anesthesia technique is preferred. These techniques are mainly intended to reduce the intraoperative bleeding.

Incision

Sulcus incision is extended from the zygomatic buttress region above the first molar to the midline on both sides **(Figure 12-5).** A broad pedicle of buccal tissue remains attached to the maxilla on the alveolus. It is desirable to have the posterior aspect of this tissue wider than the anterior part.

Figure 12-5: For Le Fort I osteotomy the incision is extended from one buttress region to the opposite buttress region.

The incision is carried through the mucosa, muscle and periosteum to the bone. The maxilla is exposed by reflecting the tissue subperiosteally from the buttress region to the anterior nasal spine. Superiorly, the dissection is carried up to the infraorbital foramen taking care not to injure the infraorbital nerve. The dissection is carried out posteriorly, strictly adhering to the bone (subperiosteally) towards the maxillary tuberosity and inferiorly to the pterygomaxillary junction. Superior dissection at the junction is avoided to prevent excessive bleeding and injury to the nerves **(Figure 12-6)**.

Figure 12-6: Incision is deepened to the bone and subperiosteal dissection is done posteriorly to the pterygoid region and the nasal cavity and the nasal mucosa is reflected.

In the anterior region, nasal aperture is exposed along the rim of the pyriform aperture and dissection is extended to the lateral nasal wall below the inferior turbinate. Mucosa from the floor of the nose is elevated, and the anterior nasal spine is exposed.

Osteotomy/Ostectomy

Anterior nasal spine is exposed and separated from the nasal septum. Using a septal chisel, the septum is separated from the palatal crest. It is extended backward to the vomer. Care should be taken not to carry the cut too far backward for fear of cutting the endotracheal tube. By doing septal osteotomy as the first step, retraction of nasal mucosa becomes easier. This gives a better exposure of the lateral wall of the nasal cavity, and risk of injury to the nasal mucosa is reduced **(Figure 12-7).**

Horizontal reference marks are placed in the anterior and buttress regions depending on the amount of bone to be removed, in case of superior repositioning of the maxilla **(Figure 12-8).** Vertical position of the maxilla can

Figure 12-7: The nasal septum is separated using a septal chisel.

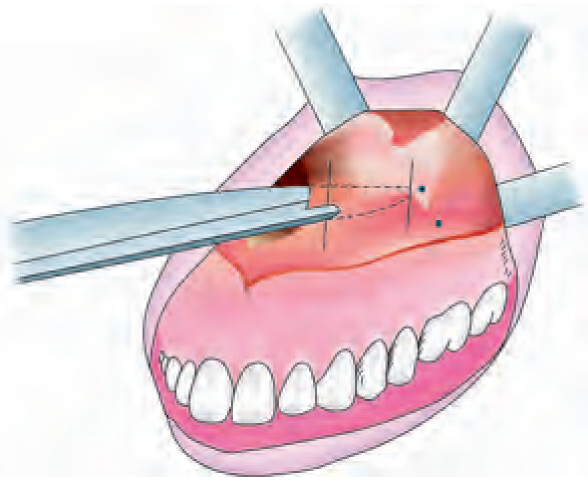
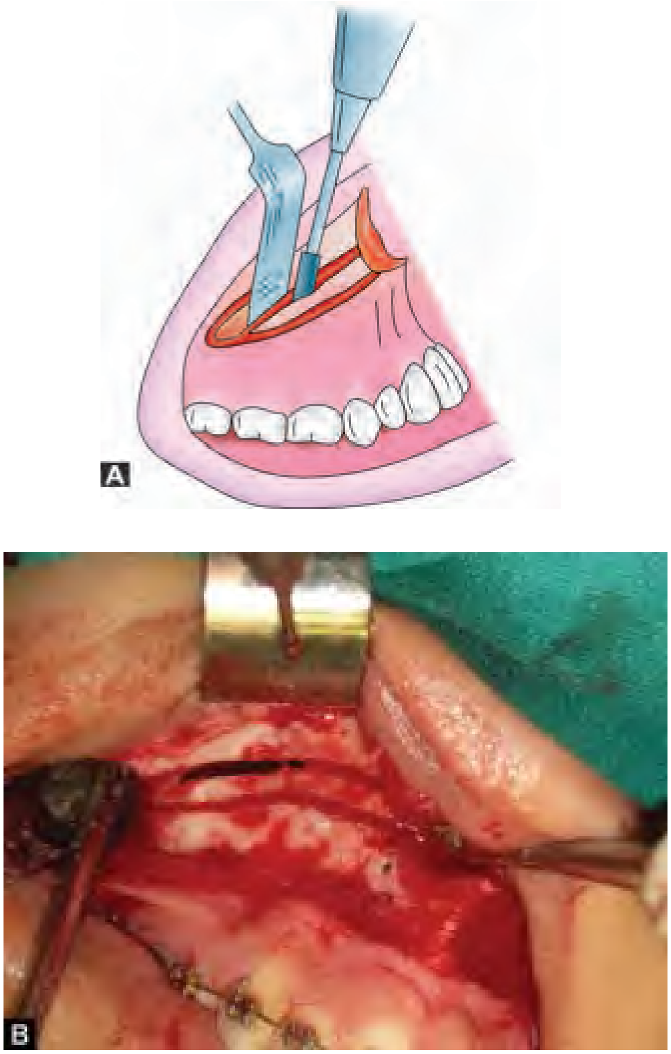


Figure 12-8: Preplanned vertical marks are made on the lateral wall of the pyriform aperture to indicate the amount of bone to be removed to achieve the desired vertical reduction.

be determined intraoperatively by several methods. Reference holes placed above the osteotomy site can be used in the canine and first molar regions to determine the entire maxillary vertical position.[21,46,63,77,181]

Model surgery gives an approximate idea of the amount of bone that has to be removed at the lateral border of the pyriform aperture and at the buttress region. However it is ideal to cut less than what is required. Precision adjustments can be done by trimming.

Osteotomy is started at the zygomaticomaxillary buttress. Cut should be made about 5 mm above the root apices, to ensure blood supply to the teeth. It is preferable to make the cut about 35 mm above the occlusal plane, (the length of the posterior teeth is 25 to 30 mm). Most surgeons agree that 5mm is adequate distance from the root apex to osteotomy **(Figures 12-9A and B)**.[23,196]



Figures 12-9A and B: The bony cut is made about 35 mm above the occlusal plane of the maxillary teeth: (A) Diagram, (B) Photograph of the osteotomy.

Cut is taken anteriorly to the pyriform rim using a reciprocating saw or a fissure bur in a micromotor. Osteotomy should always be designed in such a way that the cut is made in the inferior part of the pyriform aperture, below the inferior turbinate. This will minimize the risk to the nasolacrimal system. Nasal mucosa is protected by using a periosteal elevator while cutting the pyriform rim. Thickness of the lateral maxilla is more at the anterior region. The marked part of bone (in case of superior repositioning) is removed using the saw or bur.

Traditionally lateral maxillary cut slants downwards posteriorly. Modification of this may become necessary depending on the desired outcome.[24]

The next step is to cut the posterolateral wall of the maxilla. A retractor is placed subperiosteally extending to the pterygomaxillary junction. This protects the buccal soft tissues from the bur or saw. Injury to these regions and breach of periosteum can cause troublesome extrusion of buccal pad of fat. If it occurs, wet gauze is used along with the retractor, to protect it. Posterior to the zygomatic buttress, bone cutting is done from inside out. The cut is angulated downwards and posteriorly to the pterygomaxillary junction. According to Epker, the cut may be made anterior to the junction in the maxillary tuberosity area. Downward angulation reduces the risk of injury to the maxillary artery and its terminal branches.

If third molar is not impacted and fully erupted, the tooth is extracted, and osteotomy can be carried out through the socket. This technique could prevent excessive bleeding and makes the down fracturing easier. If an impacted third molar is present, the osteotomy design is not altered and the third molar is removed after the maxilla is down-fractured.

When the bone cuts are complete the region is packed with moistened gauze. The same steps are repeated on the opposite side.

The next step is to section the lateral wall of the nasal cavity. A small flat osteotome is used for this purpose. The cut is made inferior to the inferior turbinate. It is directed towards the perpendicular plate of the palatine bone. During cutting, the lateral nasal mucosa is protected by using a periosteal elevator. The lateral wall of the nasal cavity is very thin; so sectioning can be done with minimal resistance. Resistance, with an audible difference in sound while malletting, is felt when the osteotome reaches the palatine bone. Only a partial sectioning of the perpendicular plate of the palatine bone is sufficient. Too far posterior sectioning may injure the descending palatine vessels causing haemorrhage. The vessel at greatest risk for hemorrhage is the descending palatine artery.[65,95,119,161,178] Severe bleeding after Le Fort I maxillary osteotomies has been reported. In most of these cases the vessel implicated is the descending palatine artery. The opposite lateral nasal wall is sectioned, similarly. Complications associated with Le Fort I osteotomy are mainly vascular and can be significant **(Figure 12-10)**.[96]

Sectioning of the palatine bone may cause injury to the descending palatine artery. However, complete sectioning is advocated by some authors, for fear of inadvertent fracture while down fracturing, which may extend to the orbit and even cause visual disturbances.[96] After all the five walls are sectioned, attention is directed to freeing the maxilla from the pterygoid plates. A curved osteotome or pterygoid chisel is used to separate the maxilla. Robinson has suggested the use of a small sharp curved osteotome instead of the traditional wide pterygomaxillary osteotome, because the reduced surface area of the former limits the fracture.[145] Osteotome is directed medially and inferiorly to the lowest part of the pterygomaxillary junction. Index finger is placed at the hamular notch in the palate. This helps to direct and orient the cut. The osteotome is malletted to achieve the separation which can be felt at the index finger kept at the palatal region **(Figure 12-11)**. Same steps are repeated on the opposite side.

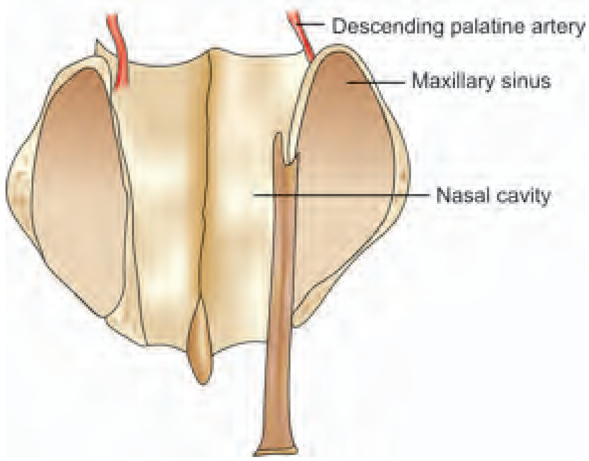


Figure 12-10: While cutting the medial wall of the maxillary sinus, care should be taken not to injure the descending palatine artery which may cause excessive bleeding.

When all the bony cuts are over, the maxilla is down-fractured. Standing at the head end of the patient the

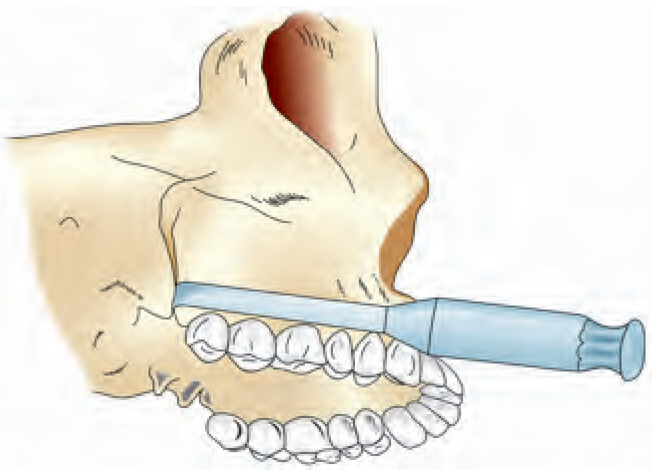


Figure 12-11: A curved pterygoid chisel is used to separate the maxilla from the pterygoid plate.

Figure 12-12: Down fracturing the maxilla using thumb pressure, hooking the zygoma with the middle fingers. Down fracturing can be achieved only if all the walls are cut and the pterygoid disjunction is achieved.

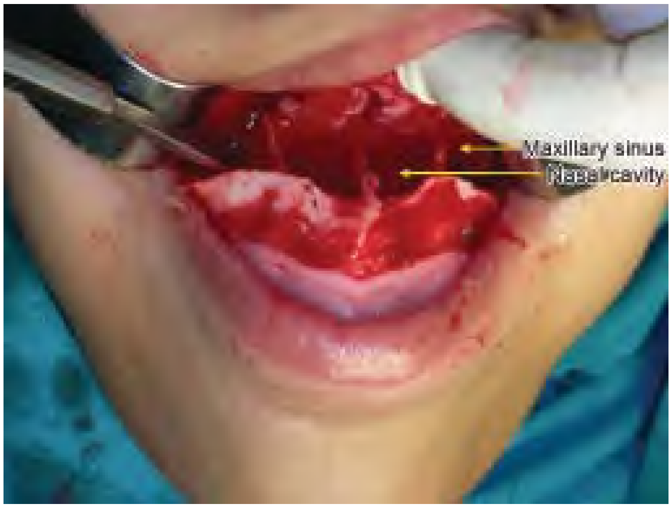


Figure 12-13: Maxilla can be mobilized using a lever technique by protecting the thin wall of the maxilla with the broad surface of a cheek retractor.

middle fingers are hooked on the zygoma on both sides and thumbs can be used to press down the anterior part of the maxilla. The nasal mucosa is dissected to elevate it from the nasal floor **(Figure 12-12)**.

A Smith spreader can also be used at the posterior region to effect the down fracturing. Since the lateral wall of the maxilla is thin care should be taken not to splinter the bone. Another method is to use Rowe's disimpaction forceps to disjunct the maxilla.

Mobilization can be achieved by several methods. The widely used technique is to use the disimpaction forceps. Another method is to use a sturdy chisel to engage the posterior part of the maxilla and mobilize the maxilla anteriorly by using the upper stable part of the zygomatic buttress area as the fulcrum, protected by a cheek retractor to prevent splintering of the bone. This technique has the added advantage that the pressure applied is well controlled. Maxilla can be brought forward by about 1 to 1.5 cm without much resistance. Since the chance of relapse is high, rigid fixation is the rule in maxillary advancement **(Figure 12-13)**.[132]

Maxilla can also be mobilized using 'Hayton Williams' forceps or 'Rowe's Disimpaction' forceps **(Figure 12-14).**

Using a Rongeur forceps and burs the excess bone is removed from the nasal crest, vomer, the medial wall of the maxillary sinus, etc. **(Figure 12-15)**. Anterior nasal spine is removed only if the maxilla is to be repositioned superiorly. Maxilla is mobilized and any remaining bony attachments in the posterior region are removed. Any bony interference is removed using bone Rongeur.[21, 144] All potentially damaging sharp bone edges are eliminated to prevent bleeding due to injury to the vessels.

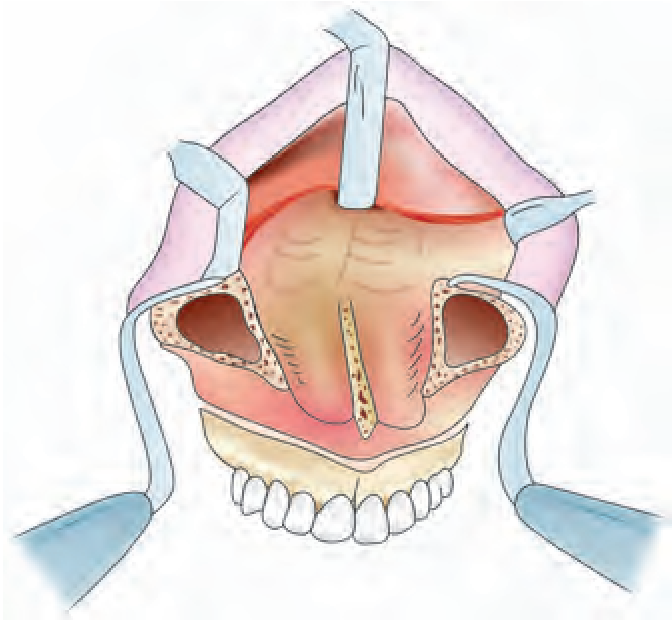


Figure 12-14: A mobilizer can also be used to mobilize the maxilla.

Sequentially eliminating the hindering points of bone in Le Fort I osteotomy ensures better bony contact.

Intermaxillary fixation is done using 26-gauge wire after placing the prefabricated occlusal wafer splint. Care should be taken not to displace the condyle inferiorly. When the maxilla is repositioned the pyriform rim is in apposition with the bone and the posterior aspect is telescoped in. Buckling of the nasal septum must be avoided. This can be achieved by removing adequate bone from the nasal crest of the maxilla and cutting off the inferior portion of the septal cartilage **(Figure 12-16)**. If the inferior turbinate interferes with repositioning of

Figure 12-15: After down fracturing, the excess bone may be removed using Rongeur forceps, and the sharp ends are trimmed.

Figure 12-16: It is easy to expose the nasal septum after down fracturing the maxilla. In superior repositioning of the maxilla adequate amount of the septum is removed to prevent kinking of the septum.

the maxilla, it may be trimmed with a Rongeur or scissors after exposure through the nasal mucosa.[180]

Some authors advocate a "U" shaped cut on the floor of the nasal cavity leaving the nasal floor attached to the palatal tissue, if the repositioning is more than 5 mm superiorly. The purpose is to prevent the reduction of the nasal space while the maxilla is superiorly repositioned. The author recommends this technique only if the superior repositioning is more than 1 cm **(Figure 12-17A).**

Nasal airway problem can be corrected at the time of orthognathic surgery. Some of the procedures which can

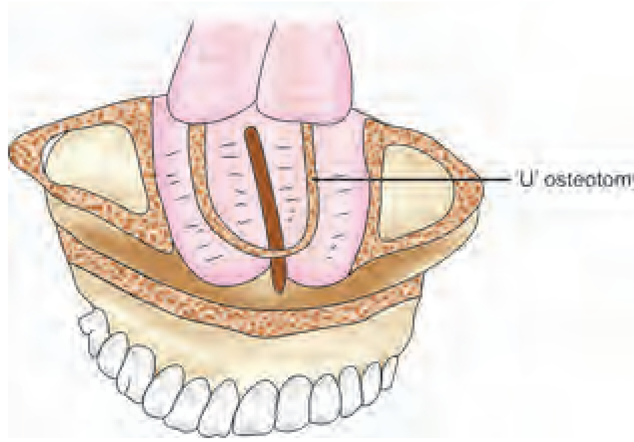


Figure 12-17A: 'U' shaped cut on the floor of the nasal cavity can prevent the reduction of the nasal space.

be done along with orthognathic surgery are septorhinoplasty, partial turbinectomy, nasal polyp removal, etc.[35,185] When Rhinoplasty is to be combined with orthognathic surgery, the former may be done after orthognathic procedure.[151]

The base of the nasal pyramid is the maxilla, and if rhinoplasty is done before orthognathic surgery, stability of the nose will be lost.

Mucosal tears should be repaired with resorbable sutures. This reduces the risk of postoperative nasal bleeding.

As mentioned earlier maxilla can be moved forward, downward, backward, upward, transversally or rotated. Maxillary advancement is required in maxillary deficiencies. Incidence of relapse is high in maxillary advancement. This is due to the stretch of the soft tissues during advancement or any lengthening procedures. Tendency of the tissue is to go back to the original position. Restraining force is more in scar tissue which is present in repaired cleft palate cases. To counter this, proper mobilization is mandatory. More the mobilization less is the relapse. Inferior repositioning of the maxilla is challenging since there is increased tendency for relapse.[54,62]

If slanted 'Z' osteotomies are used, inferior repositioning of maxilla may not require bone grafting. [13, 142] The tendency for relapse may be due to tipping movements of the segments. Torque control of the segments may minimize tendency for relapse **(Figure 12-17B)**.[132]

In cleft patients maxillary advancement may cause velopharyngeal dysfunction resulting in postoperative velopharyngeal insufficiency and subsequent hypernasal speech.[153,157] There are several methods to assess the velopharyngeal function. By Cinefluroscopy, escape of radiopaque substance into the nose during speech can be

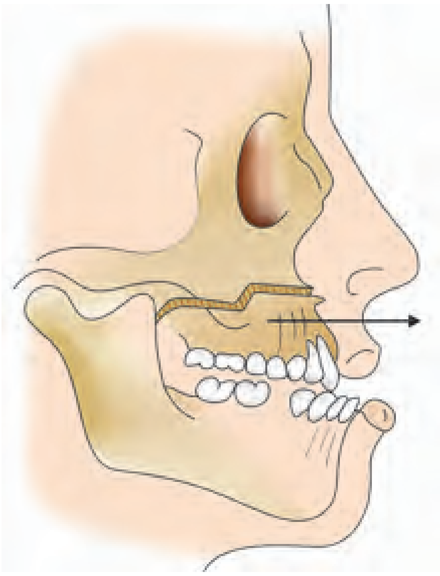


Figure 12-17B: 'Z' osteotomy of the maxilla.

Figure 12-18: Maxilla can be pushed backward by about 0.5 to 1 cm by doing pterygoid osteotomy or ostectomy of the maxillary tuberosity.

observed. Through fiberoptic nasopharyngoscopy velopharygeal closure can be observed, and the velopharygeal competence can be gauged in lieu of the soft palate movement and pharyngeal wall movement.[12] In patients without clefts, maxillary osteotomies may not produce change in speech.[28, 149]

Inferior and anterior repositioning of maxilla increases distance between posterior nasal spine and posterior pharyngeal wall. Bone grafting to enhance stabilization was advocated by Willies and Howe in 1954.[50] Obwegezer advocated grafting of pterygomaxillary junction.[183]

By Le Fort I, pushing the maxilla backward is rather difficult as the pterygoid plates prevent the backward movement of the maxilla. However, there are a few techniques by which a total push back of the maxilla can be achieved **(Figure 12-18).**

If the posterior osteotomy to separate the maxilla is done through the socket of the last molar tooth, after down fracturing the maxilla, the bone can be removed from the socket and the tuberocity area and the maxilla can be pushed back. Another method is osteotomy of the Pterygoid plates. This is done at the level of Le Fort I, much below the cranial junction using a sharp 6 mm osteotome. This procedure not only helps to push the maxilla backwards but also helps in superior repositioning of the posterior parts of the maxilla. Total push back of the maxilla can be resorted to in the following situations:

1. Marginal class II cases where the push back required is less than 5 mm. For more than 5 mm push back segmental osteotomy of the anterior maxilla in conjunction with the Le Fort I is the preferred method.
2. Skeletal cases of maxillary excess which have been already treated orthodontically by extraction of the premolars, which require superior repositioning and/or push back.

Segmental Osteotomy

Posterior repositioning of the maxilla achieved by Le Fort I alone is very minimal (1-2 mm). Further push back of the maxilla can be done by pterygoid osteotomy or ostectomy of tuberosity. However if the push back is more than 5 mm, anterior segmental osteotomy is preferred at the level of the premolars. First premolars (14 and 24) are extracted and anterior segmental osteotomy is done. The segment is repositioned posteriorly to achieve the preplanned retrusion. Care should be taken not to section the buccal soft tissue pedicle and the palatal tissues **(Figure 12-19)**.

Immobilization

Immobilization of the fragments is very important to achieve good and fast healing of the bone.

Transosseous wires are placed at the pyriform rim and zygomatic buttress regions where the bone is comparatively thick. 26 gauge SS wire is used for this purpose. Skeletal suspension from the pyriform rim to the mandible is also helpful to prevent the movement at the osteotomy site.

Rigid internal fixation has revolutionized the technique of fixation. Rigid fixation was described by Herster and Luhur as early as 1980 and 1981 respectively.[41,72] Bone plates fixed with screws can stabilize the maxilla. Usually two bone plates are placed on each side, one at the

Figure 12-19: Le Fort I osteotomy can be combined with anterior segmental osteotomy and mid-palatine osteotomy. Anterior segmental osteotomy is meant for push back, while mid-palatine osteotomy is for correcting minor transverse discrepancies.

zygomatic buttress region and the other at the pyriform rim region **(Figure 12-18)**. Bone plates are secured after intermaxillary fixation. IMF is used as a guide to proper positioning of maxilla and mandible in a feasible occlusal relationship. Rigid fixation prevents telescoping and resorption of interfacing bone due to mobility.[97, 160] Some surgeons prefer wire fixation, since it is easier to correct imperfect occlusion with postsurgical elastic traction and studies show no significant difference between wires or plates and screws.[136] (Wires may be used only in cases where there is good apposition of bone. If the bone apposition is not proper after osteotomy, tightening of the wires may produce occlusal cant and occlusal gaps) **(Figure 12-20)**. While rigid fixation has many advantages, occlusal problems are more with it, than with skeletal suspension or wire fixation.

Figure 12-20: Fixation of the maxilla is done after intermaxillary fixation and ensuring the position of the condyle in the glenoid fossa. Wire osteosynthesis may be done only if the bone apposition is excellent.

Maxilla moves forward relatively during superior repositioning, by itself, and also to compensate for the rotation of mandible. So while doing IMF there is a tendency for the mandible to get distracted forward and condyle comes downward and forward from the glenoid fossa which may be prevented by pushing the mandible backward and upward at the ramus region.

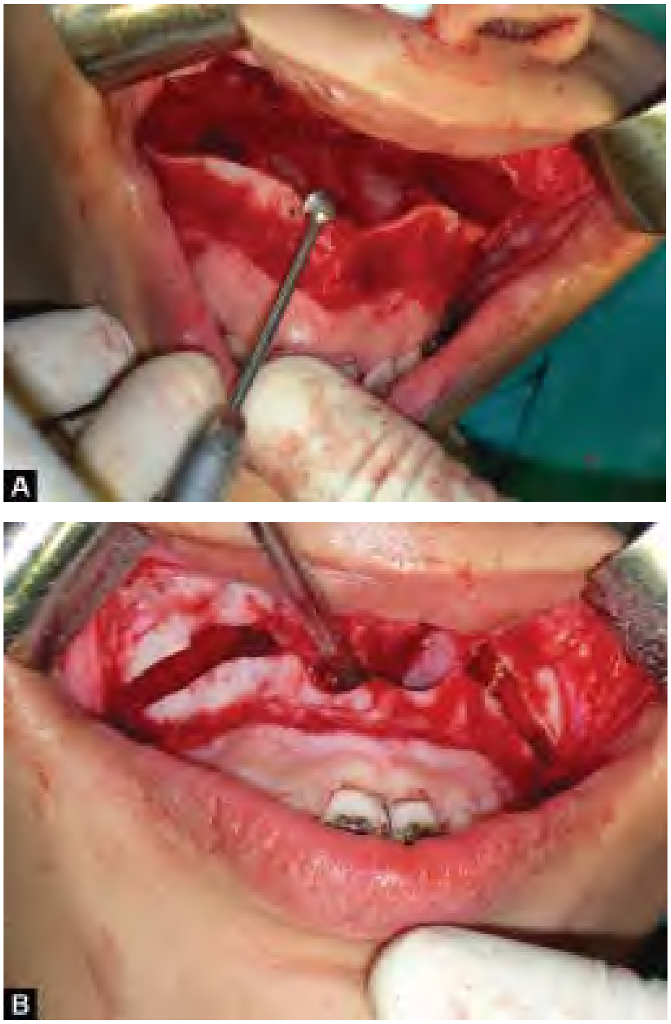
However, in a few situations proper occlusion may not be possible due to occlusal factors and postural changes. Postsurgical orthodontics is mandatory to establish proper occlusion. It is hard to move the bone postsurgically if a rigid fixation is employed. In wire osteosynthesis the fixation is semirigid, and elastics and even occlusal forces could adjust the relationship by callus malleability. Hence many surgeons resort to wire osteosynthesis, and, if plating is used, the plates are restricted to the anterior region only, while the post zygomatic buttress region is fixed using 26 guage S.S wires.

Another important pre-requisite for wire fixation is proper apposition of the bone ends. In superior repositioning, if the bone removal is excess, over correction may take place. Excess bone removed on one side may produce occlusal cant. Care should be taken to maintain proper bony apposition. An ideal method is to use bone trimmer to the requirement after down fracturing the maxilla. Plate fixation is indicated if bone apposition is not adequate.

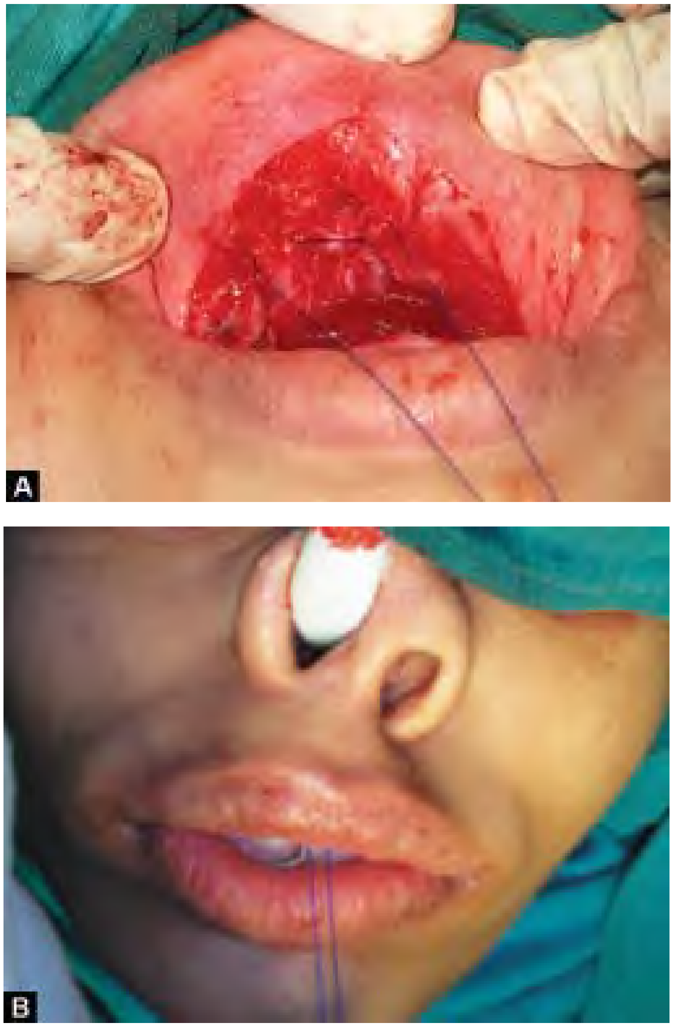
Bone grafts are to be used when the maxilla is advanced or inferiorly repositioned and where bone apposition is not present. The grafts should be properly supported so that these are not dislodged into the maxillary sinus. Dislodged grafts sequestrate in the maxillary sinus and result in foul odor. If it lasts for more than 2 weeks the piece has to be removed from the maxillary sinus.

Autogenous bone grafts are more reliable than allogenic grafts or alloplasts. Chances of osseous union are best with autogenous bone grafts. Ileum, rib and cranium are the common autogenous bone donor sites. Advancing the maxilla always produces tension on the surrounding musculature and the chance of relapse is much higher. Rigid fixation is the rule in such cases since it affords better stabilization and relapse is minimized.

Reduction of the vertical dimension of the maxilla reduces the vertical dimension of the pyriform aperture as well. Moreover removal of the anterior nasal spine also may become necessary for nasolabial aesthetic harmony. Retaining of the anterior nasal spine may cause upturning of the nasal tip, deviation of the nasal tip and reduction in the nasolabial angle. Excision of the ANS makes the sill of the pyriform aperture flat. A pyriform plasty by



Figures 12-21A and B: (A) A round or oval bone trimmer is used to trim the sill of the pyriform aperture into shape. (B) The sill of the pyriform aperture is trimmed to shape.



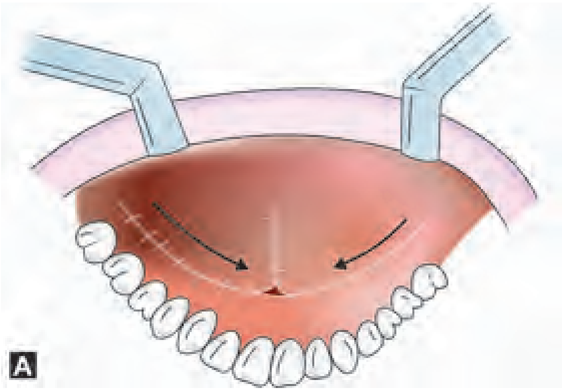
Figures 12-22A and B: Cinch suturing of the alar base is often done to prevent the flaring of the nose, while doing a superior repositioning of the maxilla.

trimming the bone from the rim of the aperture helps to reinstate the vertical dimension of the aperture, reduce the flaring of the ala and reduce the acuteness of the nasolabial angle **(Figures 12-21A and B)**.

Wound Closure

It is a frequent phenomenon that the alar base gets widened after the superior repositioning of the maxilla. This is attributed to the change in the bony architecture supporting the alar base. Alar base cinch suture reorients perinasal musculature and helps to prevent alar base widening **(Figures 12-22A and B).**[57] The skin of the nasolabial fold is pulled laterally, flaring the alar rim. If this maneuver improves the ease of breathing and facial aesthetics permit, the surgeon may decide to allow alar flaring to occur. This test is called 'Cottle test'.[82] After anterior or superior repositioning, nasal tip rotation is generally increased.[146] Nasal tip and alar movements do not correlate quantitatively to the magnitude of maxillary repositioning.[103] External widening of the alar base may be accompanied by increase in the width of the nasal valve, decreasing the nasal resistance.[135]

Lip shortening is another adverse effect usually observed, and this is attributed to excessive scarring. Suture technique which minimizes scarring is advised. White suggested a muscle suturing technique to reduce lip shortening. Musculoperiosteal 2-0 chromic catgut or vicryl sutures (2 on each side) are placed diagonally in such a way that, when tightened, they pull the lip medially. Suturing the transverse nasalis muscle is important. 'V' -'Y' closure of the mucosa helps to maintain the lip length and the height of the exposed vermilion (**Figures 12-23A and B).** It is observed that the vermilion



Figures 12-23A and B: Scar contracture could shorten the lip. V-Y closure of the circumvestibular incision can prevent the shortening of the upper lip.

height and alar width are better maintained by this technique.[154] Intrinsic quantitative and qualitative characteristics of the upper lip will get modified in response to maxillary surgical repositioning. Thin lips tend to follow the movement of the hard tissue more closely than thick lips.[125] Inferior repositioning of the maxilla increases vermilion exposure.[131] V-Y closure helps to prevent the flattened appearance of the lip after superior and posterior maxillary positioning.[49,172] V-Y closure helps in advancing lip projection in advancement surgery.[32]

Postoperative Considerations

Facial edema maybe expected after the surgery especially during the second and third postoperative day. This resolves in 10 to 14 days' time. However, it takes 6 to 12 months for the facial muscles and lips to adapt to the new position. An altered sensation on the lip is felt by most of the patient, but it gets restored to normal, in due course.

Postoperative bleeding is usually rare. However, if excessive bleeding occurs, measures should be taken to control the same. Complications associated with Le Fort I are almost vascular and can be significant.[96] If the routine measures like local application of vasoconstrictors and packing are not helpful, the patient should be examined under GA to locate the site of bleeding; and measures should be taken to control it. Ocular dysmotility is a rare complication occurring following Le Fort I osteotomy. Newlands et al feel that the etiology is inadvertent fractures extending towards the base of the skull and posterior aspect of the orbit. Associated fractures can also involve the internal carotid artery resulting in 'Carotid Cavernous Sinus Fistula' formation. Fracture of the optic canal resulting in permanent blindness and ocular palsy, following Le Fort I, is also reported.[118]

As long as the maxilla remains attached to a broad soft tissue pedicle, the healing is excellent even if it is segmented to several pieces. The soft tissue of the palate, lateral pharyngeal walls and buccal mucosa provide the vascular network that permits healing. The rich, freely anastomosing vasculature of the face is responsible for this healing capability.[17,116] Maxillary sinus disease following surgery is very rare. Wire sutures may contribute to persistent sinusitis. If so, removal of the wire sutures helps to alleviate the condition.

The space in the nasal cavity is reduced by superior repositioning of the maxilla. However, nasal airway resistance is not increased and in many cases the nasal breathing improves. When the base is widened the nasal airway opens better. Studies have indicated that superior repositioning of maxilla does not compromise the nasal airway.[101,179,186] Esthetic considerations should not be sacrificed to decrease the nasal breathing resistance. If any septal deviation is detected postoperatively, the same should be corrected. The septum can be repositioned on the first or second postsurgery day by using septal forceps. In cases, where the vertical dimension of the septum is more, simple repositioning is not enough and surgery may have to be performed to reduce the vertical dimension.

Technique of Anterior Segmental Osteotomy

Segmental osteotomy is a planned procedure. Before performing Le Fort I osteotomy the premolar is extracted and the palate is tunnelled subperiosteally from one side premolar region to the opposite side. Since the periosteum is firmly attached to the bone, osteotomy may injure the periosteum and jeopardize the blood supply. Sub-

Figure 12-24: Subperiosteal tunnelling at the premolar region.

periosteal tunnelling helps to prevent the injury of the mucoperiosteum **(Figure 12-24)**.

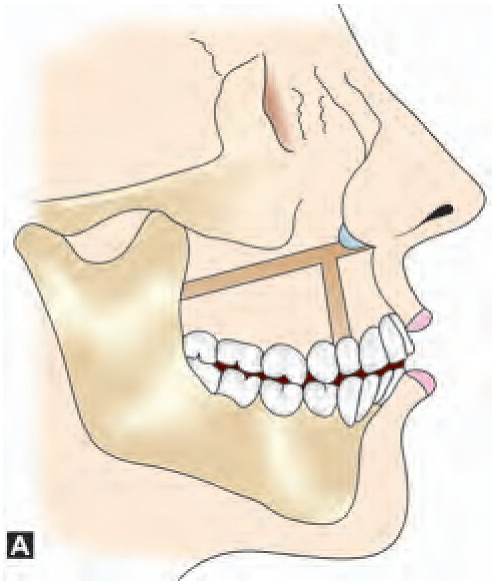
Bone cutting is done from one premolar socket to the opposite premolar socket. The osteotomy can be done by direct vision after down fracturing the maxilla **(Figures 12-25A and B).**

High Level Osteotomies

The quadrangular Le Fort I osteotomy was first described by Obwegezer in 1969 **(Figure 12-26)**.[123] In 1970 Converse et al described a Le Fort II Osteotomy which involved the premaxilla and the nasal complex.[35a] But it was not taken up by later surgeons. Steinhauser in 1980 published a review article and proposed three types of Le Fort II osteotomies based on anatomy of the midface. They were anterior, pyramidal and quadrangular.[162] Quadrangular was first described by Kufner in 1971 and by Headerson and Jackson in 1973.[66, 90] Steinhauser suggested that Le Fort II quadrangular osteotomy is more indicated than the rest, and also opined that skeletal stability is better in this procedure. They have also shown the feasibility of doing Le Fort II intraorally **(Figure 12-27)**.[29,162] Obwegeser has shown that it is possible to combine Le Fort I with either II or III osteotomies as a single procedure.[123] Axhausen in 1934 did the first maxillary advancement at the Le Fort I level.[11]

Anterior Maxillary Osteotomy

Segmental surgery in the maxilla was reported about half a century ago in the European literature. Blood supply was of great concern during the early days. So initially, the anterior maxillary osteotomies were done as two stage



Figures 12-25A and B: Anterior maxillary osteotomy in conjunction with Le Fort I osteotomy: (A) Diagram, (B) Photograph.

procedures. The first reported anterior segmental maxillary osteotomy was performed in 1921 by Cohn-Stock. Cupar, Kole and Wunderer presented modified techniques for anterior maxillary osteotomy which had more direct access, still maintaining the blood supply.[37,47,137]

Wassmund and Wunderer in 1935 and 1963 reported the surgical techniques which were widely accepted, and are still followed with minimal modifications. These techniques are known after them.

Anterior subapical maxillary osteotomy is a reliable surgical technique especially for maxillary protrusion, if the vertical excess of the maxilla is minimal. This proce-

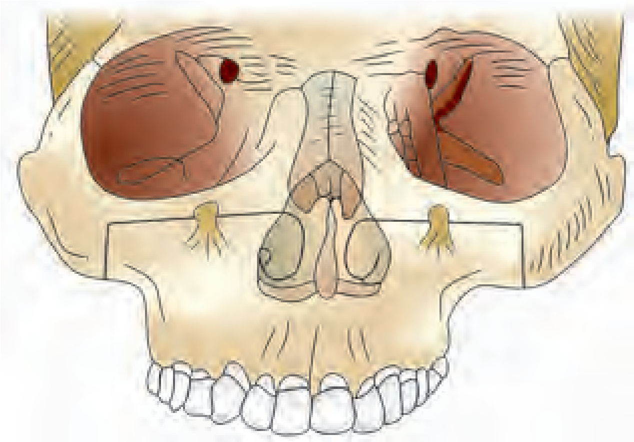
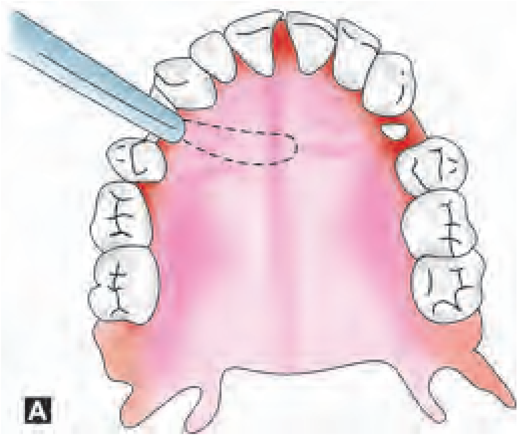


Figure 12-26: Diagram of high Le Fort I osteotomy.

Figure 12-27: Diagrammatic representation of Le Fort II osteotomy.



Figures 12-28A and B: Palatal tunneling at the premolar region to protect the mucoperiosteum from injury.

dure is used in conjunction with anterior subapical osteotomy of the mandible in cases of bimaxillary protrusion.

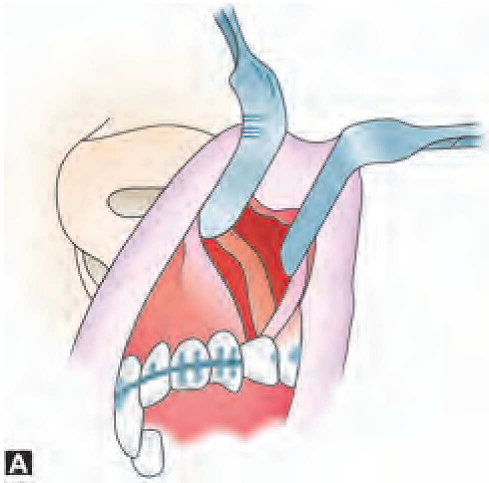
It is not possible to advance the anterior segment due to the lack of soft tissue coverage but, the posterior and superior repositioning of the anterior maxilla is possible. For anterior maxillary osteotomy an acceptable posterior occlusion is desired.[147] In the Wassmund technique more soft tissue pedicle is maintained, thereby ensuring better blood supply. In the Wunderer technique the palatal flap is reflected, making it easier to perform the surgery. Radioactive microsphere technique to assess blood flow in macaque monkeys indicated that blood supply to the anterior segment can be maintained by labial, buccal or palatal tissues independently.[117]

Wassmund Technique

Buccal sulcus of the upper arch is infiltrated with lignocaine containing 1: 2,00,000 epinephrine. Palatal side is not infiltrated. Upper first premolars are extracted. Palatal mucosa is reflected by tunneling at the level of the first premolars. Care is taken not to injure the anterior palatine vessels **(Figures 12-28A and B)**. Vertical incision is made between the canine and the premolar, extending to the nasal floor. Mucoperiosteum is reflected posteriorly and superiorly. While reaching the apical region of the canine, the reflection is carried to the inferolateral border of the nasal pyriform aperture. Mucoperiosteum of the pyriform aperture is reflected using a freer elevator **(Figures 12-29A and B)**.

Bony cut is made on the buccal aspect of the alveolus at the retracted area using the bur or reciprocating saw. The cut is taken vertically upwards and turned medially to the pyriform aperture so that 3 to 5 mm of intact bone remains above the apex of the canine tooth.

1 to 2 mm of bone around the adjacent teeth may be left intact to prevent periodontal involvement. Throughout the bony cutting, cold saline irrigation is provided to prevent thermal injury. No more than the required amount of bone should be removed.

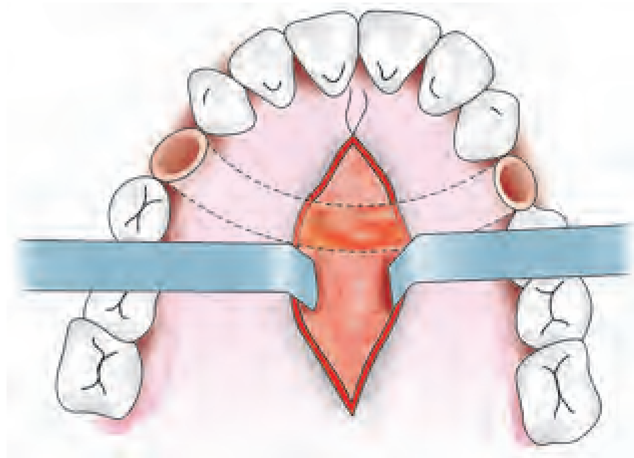


Figures 12-29A and B: Vertical incision is placed on the canine area, the flap is reflected and the bony cut is made from the first premolar region to the lateral border of the pyriform aperture, well above the root apex of the canine.

The next step is the removal of the palatal bone from the alveolus to the midline. This is done using the bur or saw. Care should be taken not to injure the palatal soft tissues. Towards the midline the palatal bone is hard to cut due to difficult access and increased thickness of the bone. This region can be cut through a midpalatine incision in the anteroposterior direction (blood supply is not compromised by this incision) **(Figure 12-30)**.

A similar osteotomy is performed on the opposite side. Next step is the separation of the nasal septum from the segment. Occasionally this can be disarticulated by finger pressure. A vertical incision is placed over the anterior nasal spine. The mucoperiosteum is reflected from the nasal spine and the inferior aspect of the cartilaginous nasal septum. Using a nasal osteotome the septum is separated from the anterior maxillary segment.

The dentoalveolar segment can be split in the midline, at this stage, if required; and is useful for closure of



Figures 12-30: Sagittal midline incision is given to access the palate for osteotomy.

diastema and minor adjustments in the apposition of the canine and the premolar.

Now, the dental component has to be fitted into the occlusal splint. Any bony hindrance should be removed. The teeth are fixed to the splint. The folds on the soft tissue are checked to ascertain that there is no hindrance to proper blood flow. The soft tissue is closed using 2-0 catgut or 3-0 vicryl.

Wunderer Technique

Wunderer technique is suitable especially when the second premolar tooth is the one to be extracted. The labial approach for the surgery is the same as that for the Wassmund technique. In Wunderer technique a transverse cut anterior to the planned osteotomy site is made. Before this procedure is started the surgeon should make sure that the labial pedicles are intact and sufficient to provide proper blood supply to the osteotomized segment. Soft tissue is raised posteriorly, a little behind the planned osteotomy site. The osteotomy / ostectomy is now performed. In the midline the bone is a little harder. In this technique access to the palate is very good and the cut can be done as far posteriorly as the second molar **(Figure 12-31)**.

Once the cuts are completed, the anterior segment can be mobilized and separated from the nasal septum. It is then positioned and fixed using prefabricated occlusal splint, and soft tissue closure is done.

Epker's Anterior Maxillary Osteotomy (Figures 12-32A to C)

Local anesthetic with 1:200,000 epinephrine is infiltrated to the labial sulcus. The first or second premolars are extracted. A transverse incision is made in the depth of

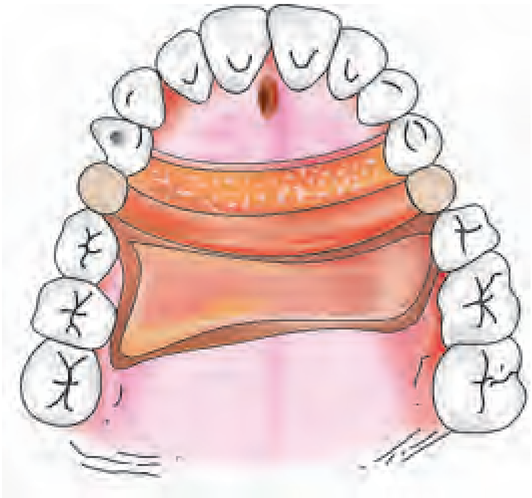


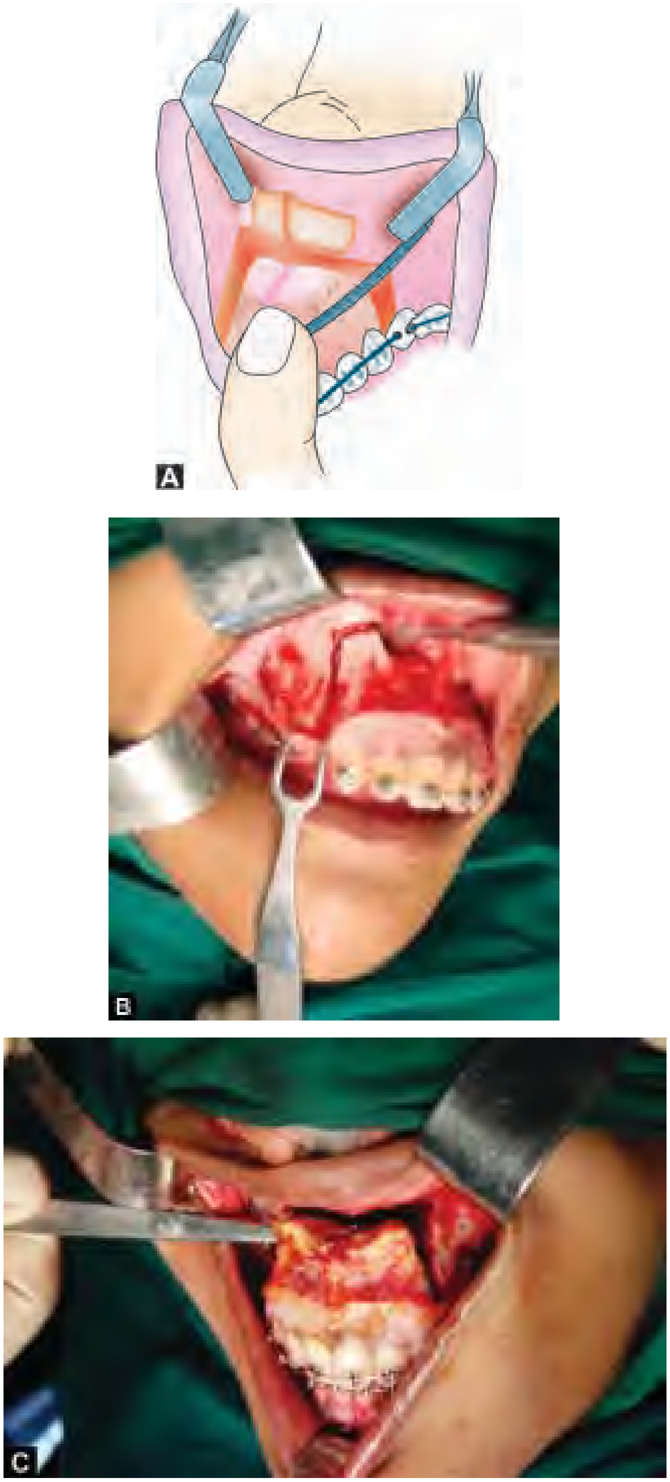
Figure 12-31: Palatal tissue is reflected to get access to the palatal bone. This affords better vision of the palate. Blood supply to the anterior segment is to be ensured by the labial pedicles.

the sulcus from behind the planned osteotomy site to the opposite side. Subperiosteal dissection is done superiorly. Inferior dissection is avoided. Pyriform aperture is exposed. Nasal mucosa is dissected on the lateral wall and floor. The cartilaginous nasal septum is elevated from the vomerian groove in the anterior nasal crest of the maxilla. Dissection is carried out for about 15 mm posteriorly. Osteotomy or ostectomy is done at the preplanned site and the cut is designed as per the model surgery. The osteotomy / ostectomy is extended to the nasal cavity, protecting the nasal mucosa with periosteal elevators (There should be 3 to 5 mm of healthy bone above the apices of the canines). Osteotomy is done after tunnelling the mucoperiosteum at the interdental area. Care should be taken to minimize the elevation of the mucoperiosteum in the anterior region. When the alveolar osteotomy is performed, avoid injury to the palatal tissues; placing a finger in the palatal area helps to feel the bur perforating the bone. Enough margin of alveolar crestal bone is maintained around the teeth adjacent to the osteotomy site, so that the peridontium is not exposed.

After completion of the subapical and alveolar osteotomy on both sides, a midline osteotomy is done if necessary. This is required if there is a midline diastema and in cases where the intercuspid distance is to be increased.

About 15 mm of the anterior portion of the nasal crest of the maxilla is removed. This helps better visualization while doing the transpalatal osteotomy.

With a straight osteotome transpalatal osteotomy is completed, anterior maxilla is down-fractured. Palatal mucoperiosteum is carefully separated from the part of the palate posterior to the osteotomy. Using a large round bur (mastoid bur) the required trimming is done.



Figures 12-32A to C: Osteotomy plan in Epker's technique of anterior maxillary osteotomy.

All osteotomy sites are inspected for bony protuberances, which, if present, are removed before aligning. The segment is placed into the prefabricated occlusal splint and wired into proper position. Usually there is no need of any intermaxillary fixation. Pyriform aperture wires or miniplates are used for better stabilization. Soft tissue closure is done, taking care of the alar base and lip esthetics.

Stabilization and Fixation

Intermaxillary fixation (after the teeth are positioned into the occlusal splint), if required, is done for a period of one or two weeks only. Later the arch wire and the splint on the maxillary segment can maintain stabilization satisfactorily. Interdental wiring and transosseous wiring of the pyriform rim at the osteotomy site are often sufficient for stability. The use of a mini palate gives rigidity to the fixation.

Postoperative Sequelae

Postoperative edema is a usual sequel. Edema of the lips is usually due to abrasion and traction. This can be minimized by reducing the injury to the lips by the use of petrolatum or steroid cream. Edema subsides rapidly and disappears within 2 weeks. However, normal activity and movements of the lips, cheeks and orofacial muscles become harmonious by six months only.

Sensory supply to the teeth in the segmented part is reestablished within a period of six months to one year. If proper bony margin is left at the apex of the teeth, the blood supply to the teeth is not jeopardized.

Complications

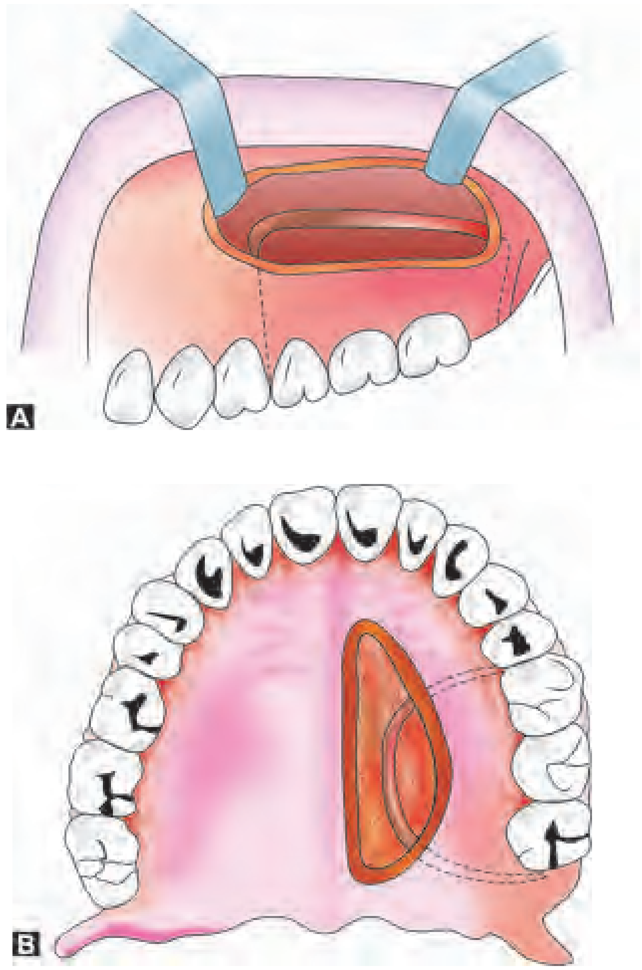
Complications associated with anterior segmental osteotomy of the maxilla are rare. Of them the most common is the non-vitality of the teeth with its sequelae (discoloration and apical abscess). This problem can be managed endodontically.

Necrosis of the bone is a rare occurrence. In case the wound gets infected and breaks open, proper debridement is done and the area is kept clean. If bone is exposed the area is dressed with peripads.

Posterior Subapical Osteotomy of Maxilla

Schuchardt in 1959 described the posterior segmentalization of the maxilla.[155] This procedure is usually done in isolated cross bites of the maxillary teeth. Rarely this is used for superior repositioning of maxillary segment when the opposing mandibular teeth are lost and the maxillary teeth are over erupted.

Infiltration of local anesthetic with epinephrine, at the height of the maxillary vestibule, is done 5 minutes prior to incision. The incision is made at the mucoperiosteum from the canine region to the zygomatic buttress region. Mucoperiosteum is reflected upwards. Removal of teeth, if planned, should be done at this stage. Osteotomy is 3 to 5 mm above the root apices. The cut is extended to the maxillary sinus. Vertical cut is made at the required interdental area, with minimal disturbance to the mucoperiosteum. Palatal mucoperiosteum should not be torn. When medial repositioning of the segment is planned, ostectomy of the palatal bone is considered. For palatal ostectomy, palatal incision is done medial to the planned bony cut extending from the canine region to the molar **(Figures 12-33A and B)**. Mucoperiosteum is reflected to the minimum, and the osteotomy is done.



Figures 12-33A and B: Diagrammatic representation of the posterior segmental osteotomy plan. (A) Buccal view, (B) Palatal view.

If the entire posterior segment is to be repositioned, the same has to be detached from the pterygoids using a pterygoid chisel as is done in Le Fort I osteotomy.

The segment is repositioned into the pre-planned position, preferably using a prefabricated occlusal splint.

A palatal parasagittal osteotomy can produce a three piece maxilla and accord differential movements of the maxilla. This also leaves the central part intact.[60, 195] Presently most surgeons prefer a total maxillary osteotomy to the parasagittal one.[190]

Stabilization and Fixation

The ideal method is to use an arch wire, an occlusal splint and a bone plate. The bone plate provides a rigid internal fixation.

Mandibular Surgery

Ramus Osteotomies

Movement of the mandible in the anteroposterior direction is usually achieved by ramus osteotomy. Limberg reported subcondylar oblique osteotomy in 1925.[100] Thomas, Robinson, Shira and others described buccal osteotomy which involved the ramus. Later, Caldwell and Letterman (1954) described vertical subcondylar osteotomy by extra-oral approach, which became very popular.[31] This technique minimized trauma of the inferior alveolar neurovascular bundle. Though the primary indication was mandibular prognathism, many surgeons advocated vertical osteotomy and certain modifications like inverted 'L' osteotomy **(Figure 12-34),** and 'C' osteotomy for advancement of the mandible. Bone grafting has to be done to fill the gap created.

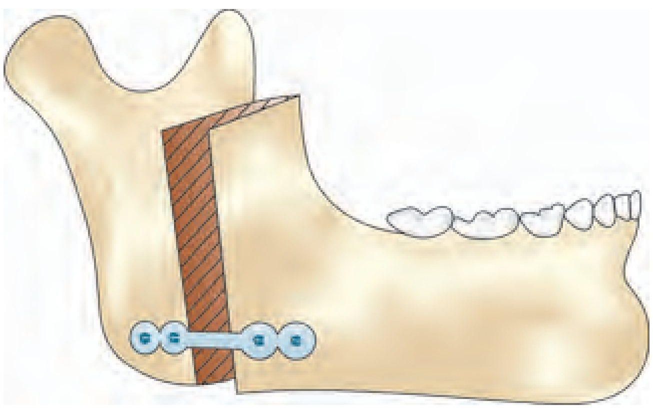


Figure 12-34: Inverted 'L' osteotomy of the ramus. Usually used for advancing the mandible.

In 1927 Wassmund described the inverted 'L' osteotomy.[188] Caldwell and co-workers described 'C' and inverted 'L' osteotomies for advancement.[30] In 1937 Lane described a sagittal osteotomy. Obwegeser modified the Lane's technique in 1955 and the technique of sagittal split osteotomy is credited to him. Sagittal split is a versatile technique and has the following superiority over others.[121] It gives great flexibility in repositioning the distal tooth bearing segment. There is better cancellous bone contact which enhances healing. The alterations in the position of the condyles and muscles of mastication are minimal. There is no extraoral scar. Injury to the marginal mandibular nerve is avoided. However, chance of injury to the inferior alveolar neurovascular bundle is there.

DalPont made the modification to sagittal split by a vertical cut through the lateral cortex.[38] Hunsuck extended the medial cut only to a point above the lingula. This minimised trauma to overlying tissue.[75]

Extraoral Vertical Ramus Osteotomy

This was one of the most popular procedures for correcting mandibular prognathism. Rigid internal fixation techniques and certain modifications like 'C' osteotomy and inverted 'L' osteotomy have been used for advancement of the mandible. After 'C' or 'L' osteotomy the gap created while advancing or rotating the distal segmental is filled with bone graft.[140] The major disadvantages are the external scar and the possible injury to the marginal mandibular branch of the facial nerve. With judicious care these problems can be minimized. Good visibility is the major advantage **(Figure 12-35)**.

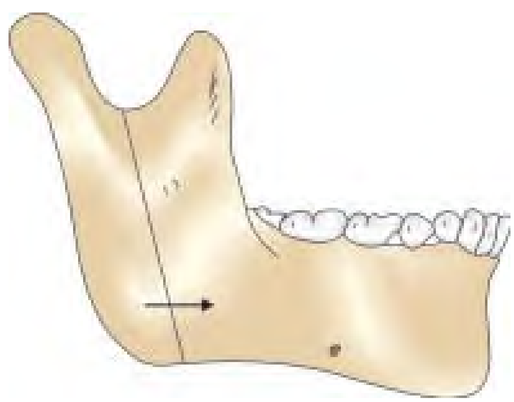


Figure 12-35: Subsigmoid vertical osteotomy was the most popular technique before the introduction of sagittal split osteotomy. This technique is used for shortening the mandible.

Surgical Technique

Submandibular skin incision is placed, about 1.5 cm below the angle of the mandible. The incision is taken down to the platysma which is then divided. Marginal mandibular nerve lies below the platysma running parallel to and often below the lower border of the mandible, crossing the facial vessels superficially as it passes upwards. Attempt should be made to identify this structure and preserve it.

After identification and protection of the marginal mandibular nerve, dissection is carried down to the bone. The periosteum is incised over the angle, the posterior and the inferior borders. The periosteum is reflected superiorly to the level of the sigmoid notch on the lateral aspect of the ramus. Coronoid process may be cut in cases when more than 1 cm of posterior movement is required **(Figure 12-36)**.

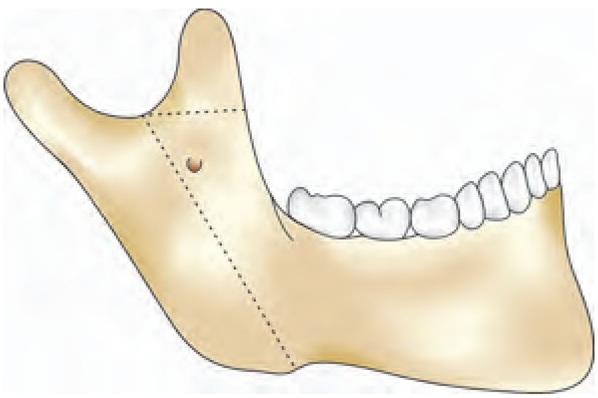


Figure 12-36: When the push back required is more than 1 cm, sectioning of the coronoid process helps in better stability.

Lateral aspect of the ramus is inspected for a small bulge corresponding to the lingula. This helps to identify the mandibular foramen. Osteotomy is performed posterior to the antimandibular foramen bulge so that the mandibular nerve is not injured. A vertical bony cut is made from the sigmoid notch to the lower border near the angle of the mandible. Condylar segment is separated from the rest of the mandible and is detached from the medial pterygoid muscle. The condylar part is laterally placed on the distal segment of the mandible. After packing the wound the same procedure is repeated on the opposite side.

The mandible is repositioned into the desired position with the help of the splint, and intermaxillary fixation is done. The site of surgery is again approached. Some surgeons prefer to leave the condyle as such on the lateral aspect without any transosseous wiring. There is no consensus regarding the decortication of the opposing surfaces.

Removal of bone or decortication may be done if it helps the positioning of the condyle in the glenoid fossa with minimal displacement. Decortication helps better contact of the cancellous bone enhancing healing. Stabilization of the fragments by transosseous wires or screws and plates can be done. Rigid internal fixation eliminates intermaxillary fixation. Except in rigid internal fixation, intermaxillary fixation for a period of 4 to 6 weeks is mandatory. After the fixation is removed elastics may be used to guide the movements.

Wound closure is done in layers. Skin may be closed by monofilament 6-0 or smaller sutures. A pressure dressing is applied for the first 24 to 48 hours. Drain is usually not necessary, and if done, has to be done through a separate stab incision below the main incision. Sutures are removed after 5 days, and the wound is supported by dressing for a period of another one week, if required.

Complications are usually rare. Bleeding may occur due to injury to the retromandibular vein or masseteric artery where it crosses laterally through the sigmoid notch. Bleeding can be controlled by routine methods like pressure packs, ligation, etc.

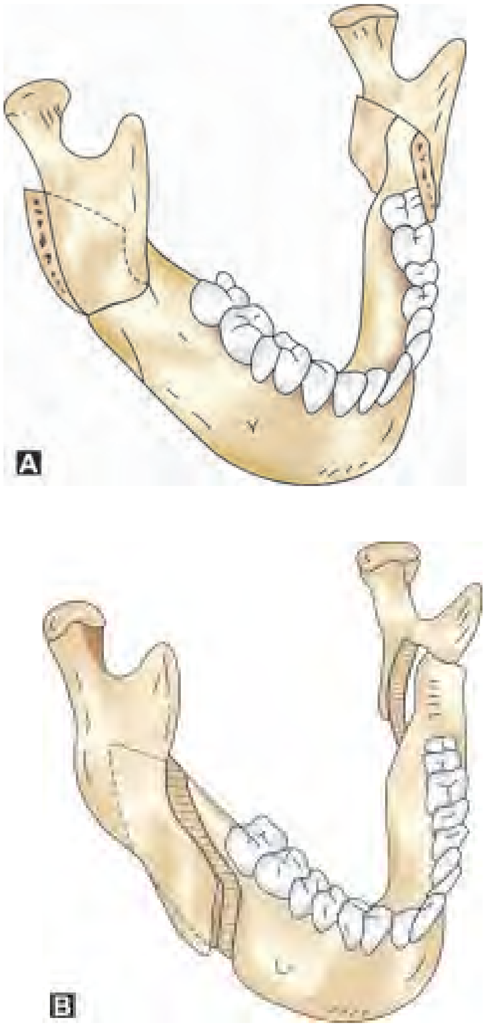
Injury to the marginal mandibular nerve is another possibility. A transitory deficiency in the function of the lower lip may be anticipated due to traction on the nerve. This often recovers completely. In case of sectioning of the nerve, microsurgical repositioning is advised. Placement of the incision well below the mandibular border and adherence to proper tissue planes can prevent injury to the marginal mandibular nerve. The nerve lies below the platysma in the submandibular region. The incision is deepened and dissected upward. The platysma is included in the skin flap. This prevents injury to the submandibular branch of the facial nerve.

If care is taken in closure, and infection is avoided, scar formation is minimal. If scar is formed, revision may be done subsequently.

Sagittal Split Osteotomy

Sagittal split osteotomy can be employed for correcting both retrognathism and prognathism. Modifications by Dalpont, Hunsuck and Epker have made the procedure simpler and more acceptable biologically. Though Schuchardt and Lane described sagittal split osteotomy of the vertical ramus,[67] it was Obwegeser who popularized it. His medial cut was above the mandibular foramen and his lateral cut was below that of Schuchardt's and extended to a part just above the angle, at least 25 mm below the lingual cortical cut. Obwegeser and Trauner described the Bilateral sagittal split osteotomy in 1955.[121]

Dalpont in 1961 advocated the oblique cut to the molar region and the vertical cut through the lateral cortex. Dalpont made a major modification by extending the cut anteriorly and making the vertical cut just below the 2nd molar.[38] Hunsuck in 1968 modified the cut in the medial cortex of the vertical ramus, by extending it just behind the mandibular foramen. Postoperative complications got reduced **(Figures 12-37A and B)**.[75] Bell, Schendel and Epker extended the vertical cut to the lower border of the mandible reducing the incidence of wrong splits.[22, 48]



Figures 12-37A and B: (A) Initially the medial cut in sagittal split osteotomy extended up to the posterior border and when the distal segment was pushed back, the margin used to jut out, which had disadvantages like relapse tendency and injury to the retromandibular tissues. (B) At present the medial cut is taken above the mandibular foramen much short of the posterior border but behind the foramen. The complications are much less.

Incision and Dissection

Incision is placed over the anterior aspect of the ramus to the midramus, running down over the external oblique ridge to the first molar region and curving down to the buccal vestibule.

Initially only the mucosa is incised over the ramus region. Retracting the tissue buccally, before incision, prevents the exposure of the buccal pad of fat, a troublesome interference, during surgery. Sharp dissection at the ramus is continued to the periosteum, using scissors, knife and periosteal elevators.

Periosteal elevation of the lateral aspect of the mandible at the molar region is performed down to the inferior border. On the ramus lateral dissection may be kept minimal but enough to achieve proper visibility and access.

Medial dissection is done very carefully at the medial aspect of the ramus. The level of the lingula and the mandibular foramen is ascertained. This is usually in level with the deepset concavity at the anterior border of the ramus. With a small flexible freer elevator the tissue is dissected taking care not to perforate the periosteum on the medial aspect. Dissection should be above the level of the mandibular foramen. Using a bigger elevator, the medial aspect of the mandible above the lingula is exposed subperiosteally (Perforation of the periosteum not only induces bleeding but may injure the mandibular nerve). Sigmoid notch is identified for better orientation. Subperiosteal dissection should be minimal, but enough to retract the tissues medially without much traction on the mandibular neurovascular bundle.[126]

Osteotomy is initiated by cutting the cortical bone above the lingula on the medial side. This cut should extend behind the mandibular foramen but need not be up to the posterior border of the ramus (about half to two-third of the anteroposterior dimension of the ramus). The cut is taken downward and the external oblique ridge along to the 2nd or 1st molar region. The depth of the cut should be minimal, just enough to reach the cancellous bone **(Figures 12-38 and 12-39).**

Conventionally the vertical cut is made at the 2nd molar region as the bone is thicker there. The CT analysis conducted by Y Tsuji, et al on prognathic mandible demonstrated that the thickness of the mandible

Figure 12-38: The medial cut is taken above and behind the mandibular formen and deepened to the cancellous bone.

Figure 12-39: The cut is extended obliquely through the anterior border of the mandible to the buccal plate and taken downward at the level of the 1st or 2nd molar region, upto the inferior border. Only the cortex need be cut. Deeper cuts could injure the inferior alveolar nerve and may cause wrong splits.

Figure 12-40: A spreader is used to split the mandible at the ramus region.

increased from the mandibular foramen to the mandibular body and the mandibular canal was situated lingually at all sites. They also observed that marrow space on the buccal side is more at the region of mandibular body.[177]

Some surgeons prefer to take the cut more forward to the first molar region. This gives better accessibility for intraoral plating.

When the vertical cut is made, it is mandatory to protect the soft tissue over the inferior border by using a channel retractor. The vertical cut should include the inferior border, so that the direction of the split is controlled. A rotary instrument or a reciprocating saw is used for cutting. Once the cortical cut is completed a small spatula osteotome is malleted to the site beginning from the medial cut to the vertical cut. Osteotome should be directed laterally just beneath the cortical plate so that the neurovascular bundle is not injured. Larger osteotomes are used and slowly the fragments are prised apart using a Smith spreader **(Figure 12-40)**.

As the splitting takes place the neurovascular bundle is visualized and care is taken to maintain it to the medial fragment. If it is attached to the condylar segment the NV bundle is freed with a small periosteal elevator. Next the fragments are pried apart using osteotomes in a wedging fashion or using a spreader.The procedure is repeated on the opposite side.

Sagittal split osteotomy can be used for either advancement or setting back of the mandible. If the mandible is advanced, the Medial Pterygoid muscle is separated from the inferior border of the distal segment with a periosteal elevator. When the mandible is set back, Medial Pterygoid and Masseter may have to be stripped, if needed, to prevent the displacement of the condylar segment posteriorly. Posterior stripping of the pterygomasseteric sling in sagittal split osteotomy should be minimized to the antegonial notch. In excessive stripping, possibility for avascular necrosis increases.[26]

When the tooth bearing segment (distal segment) is pushed back, the buccal plate of the condylar segment (proximal segment) overlaps the distal. This overlapping part is excised and the proximal segment is allowed to rest on the cancellous part without any tension **(Figure 12-41).** Pushing the mandible backward reduces the space

Figure 12-41: Excess of the buccal plate is cut off when the intention is to push the mandible backward.

in the oral cavity. The tongue may not have enough space, and sometimes this induces tongue thrusting, snoring, etc. Some authors advocate reduction glossectomy to improve function related to airway speech and mastication. They also opine that reduction glossectomy improves aesthetics and controls unfavorable mandibular growth.[194]

Stabilization and Fixation

Rigid internal fixation using plates and screws or lag screws is the preferred way of fixation. Rigid fixation has become more popular. Prior to RIF the position of the jaw is adjusted and intermaxillary fixation is done with splint in position. Both fragments are allowed to be in passive position before RIF is performed. Intermaxillary fixation is removed after rigid fixation. However, some surgeons prefer to keep the IMF for a period of one week. For rigid fixation 2.5 mm four hole mini plate with gap is used for push back **(Figure 12-42).** Longer plates are used for advancement. Multiple lag screws can also be used. Skeletal rigid fixation has been shown to reduce relapse following mandibular advancement.[43, 44,152] Rachmiel, et al in their study found improved stability with four hole plate and monocortical screws, with a relapse rate of about 18% only.[138]

Figure 12-42: Rigid fixation after sagittal split osteotomy of the mandible using mini plate.

Based on a ten year experience of using bioresorbable plates in orthognathic surgery, Laine P, et al opine that these devices are safe to be used. Relapse rate with bioresorbable screws is the same as with metal in sagittal split osteotomy.[93]

Other methods of fixation are upper border wiring, lower border wiring and circumramus body wiring. Of these, the circumramus body wiring ensures better apposition of the fragments. If resorting to wiring, intermaxillary fixation has to be kept for 5 to 6 weeks. Maturation of soft and bony tissues continues at the surgical site, and approximates that of non-surgical sites at 12 weeks postoperatively.[17,19, 23]

Wound Closure

Wounds are irrigated well and bleeding is controlled by routine methods. If there is continued bleeding a drain is indicated. It is placed on the lateral surface of the mandible and brought out through a stab incision just in front of the closed intraoral incision. Drain is usually removed after 24 hours. Wounds are closed by 3-0 vicryl sutures.

Postoperative Sequelae

Edema is expected after sagittal split osteotomy. It resolves within two weeks. Edema at the angle is the last to resolve. Suction drainage minimizes tissue edema following mandibular surgeries.[15]

Diminished sensation over the lip is experienced by most of the patients and is mainly due to traction on the neurovascular bundle. If there is no injury to the neurovascular bundle, sensation returns within a few weeks. More than two-third of the patients experience some sensory deficit even after one year. However, most of the patients get adjusted to this altered sensation and are satisfied with the overall result. Limitation of movements of jaw in all direction after osteotomy is often experienced. Sagittal split advancements often cause significant limitation of range of motion.[165] Patients who had sagittal split osteotomies with wire fixation and IMF show significant decrease in maximal opening, while those who had physiotherapy following rigid fixation showed minimal decrease.[6]

Complications

Important complications associated with sagittal split osteotomy are: (1) Wrong split, (2) Injury to the neurovascular bundle, (3) TMJ problems and (4) Excessive bleeding (5) Relapse.

Wrong Split

According to the study of 256 cases conducted by Turvey TA in 1985, 3.1% cases had unanticipated splits. Wrong splits may occur at the lingual cortical plate extending posteriorly and at the proximal segment. Wrong split usually occurs in cases where the last molar is removed at the time of surgery. Hence, it is advised to have the third molar removed (if needed) about 6 months prior to the osteotomy. If the lingual cortical plate is broken, soft tissue separation from the lingual plate should be kept to the minimum, so that the blood supply is not jeopardized.

The major reason for a wrong split on the condylar segment is the use of wrong fulcrum on the lateral segment. Use of a spreader helps to reduce the incidence of wrong splits.

Injury to the Neurovascular Bundle

Care should be taken to maintain the continuity of the neurovascular bundle. If it is transected, ideally the cut ends are microanastomosed. With a repositioned and repaired neurovascular bundle the sensation is recovered though the period it takes is longer. Long lasting neurosensory deficiency (NSD) was underestimated by the surgeons as compared to the patient's subjective symptoms. Long lasting NSD was reported 7.5% (Questionnaire) and 3.8% (Record) after intraoral vertical ramus osteotomy, and as 11.6% (Questionnaire) and 8.1% (Record) after sagittal split osteotomy.[3]

TMJ Problems

Care should be taken while plating the segments. Improper plating can pull or push the condyle to an untoward position. Postoperative X-rays are taken to assess the situation. If needed the displacement has to be corrected by returning the patient to surgery. Displacement of the condyle from the fossa is one of the main reasons for relapse **(Figure 12-43).**[91,152]

In their study Borstlap, et al observed that in sagittal split advancement postoperatively 8% of patients showed postoperative condylar resorption. Patients of relatively low age (≤ 14 years) are at risk of condylar alterations or resorption. Occurrence of pain and TMJ sounds in the first few months postoperatively are highly indicative of condylar changes to occur in the proceeding months.[184] Predisposition in females for condylar resorption after sagittal split osteotomy may be attributed to the modulation of biologic response, by estrogen and prolactin.[7] Mobarak compared the skeletal stability of postoperative changes in low angle and high angle Cl II patients following mandibular advancement. High angle had more horizontal skeletal relapse which is due to condylar movement in a superior direction. Changes in condylar position after orthognathic surgery are a matter of concern.[110] Changes in intercondylar angle and width after BSSO advancement or set back may influence TMJ function.[5, 127] Intercondylar width tends to decrease after mandibular set back and to increase after mandibular advancement. The trend becomes clearer with rigid fixation.[78]

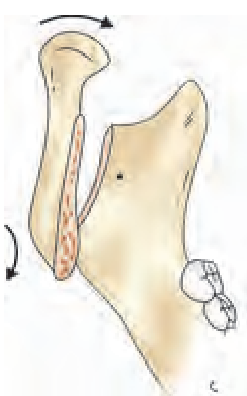


Figure 12-43: Displacement of the condyle is the most common reason for TMJ problems.

Excessive Bleeding

Bleeding can be from inferior alveolar neurovascular bundle, medullary bed, and facial vessels or rarely from retromandibular vein. Bleeding from the former two can be controlled by local measures; but the facial vessels will have to be clamped and tied, for which an extraoral incision may be required. Using the channel retractor with a cup to hold the inferior border and cutting with a Steiger-type bur (this has side cutting and rounded cutting end and cuts bone with minimal injury to the soft tissue) prevents injury to the facial vessels.

Injury to the retromandibular vein is very rare and is due to inadvertent injury to the soft tissues behind the mandible. Bleeding can be controlled by absorbable gelatin sponge. Exessive oozing can cause significant edema, and if oozing is present a drain may be kept.

Vertical Ramus Osteotomy: Intraoral Approach

It was Caldwell and Letterman who developed the intraoral vertical ramus osteotomy in 1954.[31] Later this was described by Moose in 1964[114] and Winstanley in 1968[193] and modifications have been suggested by many others. Intraoral approaches medially and laterally to ramus were described.[114, 193] Herbert and associates in 1970 described the use of special oscillating saw and popularized the intraoral technique to reach the ramus.[61]

The procedure overcomes the disadvantages of extraoral vertical ramus osteotomy. The advantages are the following: (1) external scar is avoided and (2) there is no injury to the marginal mandibular nerve. The advantages over sagittal split osteotomy are that injury to the mandibular neurovascular bundle is avoided. The main disadvantage is the difficulty in access and visualization of the area (**Figure 12-44).**

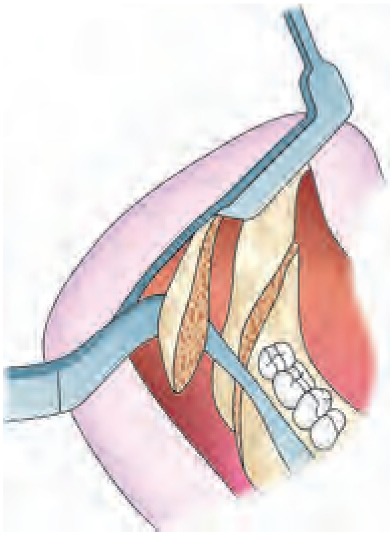


Figure 12-44: Diagram for intraoral subsigmoid vertical osteotomy.

Surgical Technique

A mucosal incision is made along the anterior border of the mandibular ramus. This is extended to the coronoid process and extended laterally up to the 1st molar area and subperiosteally dissected to expose the subsigmoid notch, inferior border and the posterior border of the ramus. Two fibro-optic lit Bauer retractors (left and right) are used - one on the sigmoid notch and the other at the angle area to get excellent exposure of the ramus. An oscillating saw angled at 105° is used to do the osteotomy. The cut is made posterior to the antilingula prominence and directed superiorly to the sigmoid notch and inferiorly to the mandibular angle.

If circum-mandibular wiring fixation is planned the medial aspect of the ramus above the lingula is dissected subperiosteally to the posterior border. The width need only be enough to pass the wires.

Osteotomy, as in the extraoral approach, extends from the sigmoid notch to the inferior border behind the entry of the mandibular nerve to the mandible. The intraoral vertical cut should be made no more than 5 to 7 mm anterior into the posterior border. This will be behind the mandibular foramen.[59] According to some, the use of antilingual prominence as a landmark for identifying the mandibular foramen is not ideal due to its unpredictability.[173]

For better access, as well as visibility and mobility of the fragments, the coronoid process can be separated using a reciprocating saw. The coronoid process is allowed to retract with the temporal muscle.

An appropriate retractor with a cup at the end can be held hooked to the posterior border and the soft tissue is held retracted laterally.

Care should be taken to orient the cut and also to prevent injury to the soft tissues. After the osteotomy the condylar segment is overlapped laterally over the mandible. Medial pterygoid attached to the medial aspect may be stripped in the anterior region of the segment to facilitate tension free positioning of the condylar segment. The same osteotomy is performed on the opposite side, and intermaxillary fixation is maintained for 6 weeks. Extraoral approach for vertical subsigmoid osteotomy is advocated for large mandibular set back of greater than 10 mm.[120,141]

Over correcting the mandibular set back by 2 mm to provide for relapse is also recommended.[56,134] The use of skeletal wire fixation seems to stabilize the initial movement but does not influence the long-term relapse.[87]

Stabilization, Fixation and Wound Closure

Most surgeons use circummandibular or transosseous wires. Rigid internal fixation using plates is rather difficult to place and carries greater risk of injury to the mandibular nerve. Lag screws or mini plates are sometimes used.

Intermaxillary fixation for a period of six weeks is advised, if rigid fixation is not used. Wound closure is done as in sagittal split, adhering to the basic principles.

TMJ Considerations

Radiographically there is an anterior downward and forward movement of the condyle after ramus osteotomy. However, there is a tendency to return to its preoperative position.[134, 143,168] Double contouring of the condyle after 6 months was reported which is attributed to condylar remodelling.[70] Remodelling of the glenoid fossa also has been documented.[169] Complications as well as their management are very much similar to those of sagittal split.

Body Osteotomy of Mandible

This was one of the earlier procedures used for mandibular prognathism. Blair reported a body osteotomy at the premolar level for mandibular prognathism in 1906.[25] Since the advent of the ramus procedures, body osteotomy has lost its popularity. However, in certain conditions, body osteotomy may have to be resorted to.

Surgical Procedure

Depending on the site of osteotomy, soft tissue dissection varies. The basic principle is to reflect the buccal mucoperiosteum down to the inferior border taking care not to injure the mental nerve, but at the same time, exposing it.

The next step is to remove the buccal cortical plate from the mental foramen region backwards to behind the osteotomy/ostectomy site for release of the neurovascular bundle. The tooth at the osteotomy site is extracted.

Using a fissure bur the outer cortical plate is marked and a window is cut. Using curettes and chisels the cancellous bone around the neurovascular bundle is removed. The nerve is released using a nerve hook. Anterior continuation of the inferior alveolar nerve (the incisal branch) is severed. This helps in better retraction of the nerve. The nerve should not be severed of its attachments to the labial soft tissue.

Mucoperiosteum on the lingual aspect is elevated and protected by a periosteal elevator. Osteotomy is completed adhering to the basic principles. The same procedure is repeated on the contralateral side. Body osteotomy at the molar level is almost outdated since the advent of sagittal split osteotomy.

Body osteotomy anterior to the mental foramen can be resorted to in certain specific cases. The main indications of this procedure is lower dentoalveolar protrusion with anterior openbite. A 'V' osteotomy is done at the first premolar region. This will not reduce the total mandibular length, but rotates the anterior segment upward and backward. Maintenance of the arch and occlusion is important. Rigid fixation is mandatory as tendency to relapse is very high due to the pull exerted by the genioglossus and geniohyoid muscles **(Figure 12-45).**

Stabilization is achieved by arch bars or by orthodontic means. Fixation using 2 plates (each plate having a minimum of 4 holes) on each side is advised. Of these, one plate is placed above and one below the neurovascular bundle.

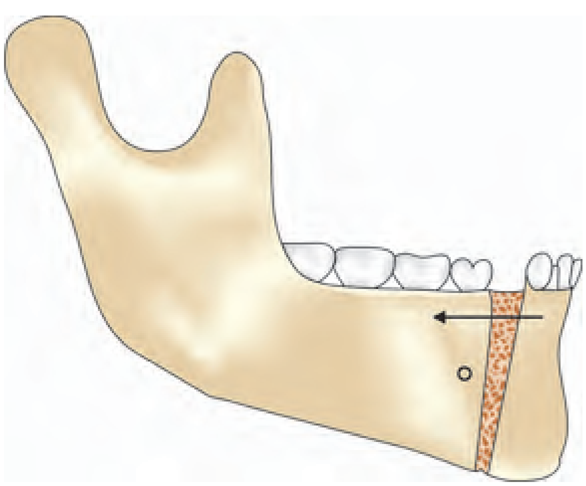


Figure 12-45: Body osteotomy at the level of the premolar region. Diagrammatic representation.

Midline Osteotomy

Midline osteotomy is used either to narrow or to expand the mandible. Expansion is more difficult than narrowing, due to tissue resistance; however, a few mm of expansion can be achieved. Before narrowing the mandible a space must be created in the midline by orthodontic means or by extracting an anterior tooth **(Figure 12-46).**

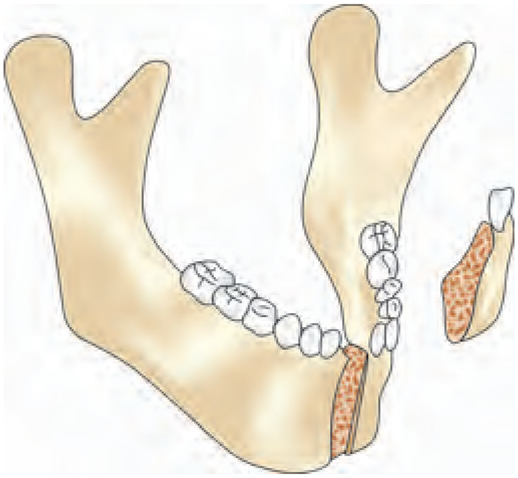


Figure 12-46: Midline osteotomy. Diagrammatic representation

Surgery

Soft tissue dissection is done after infiltration of 2% lignocaine HCl with 1:200,000 epinephrine into the labial sulcus.

A mucoperiosteal flap is reflected from the cervical region of the anterior teeth. Mucoperiosteum on the lingual aspect is tunnelled and protected with a periosteal elevator.

Osteotomy is done by using a fissure bur or reciprocating saw. Rigid internal fixation using plates is preferred one near the lower border and one below the apex of the root tips. Bone grafting to fill the gap is advised in surgery for expansion.

Lower Anterior Subapical Osteotomy

Hullihan performed the first ever anterior subapical osteotomy and published it in 1849.[74] This procedure is widely used in the following conditions:

1. To retrude the lower anterior dentoalveolar segment; often used in conjunction with subapical osteotomy in bimaxillary protrusion.
2. To close minimal anterior open bite.
3. To intrude the anterior segment in deep bite deformity.

Hofer used anterior subapical osteotomy to advance anterior teeth in correction of mandibular dentoalveolar retrusion.[68] Kole used this technique to correct an anterior open bite.[56]

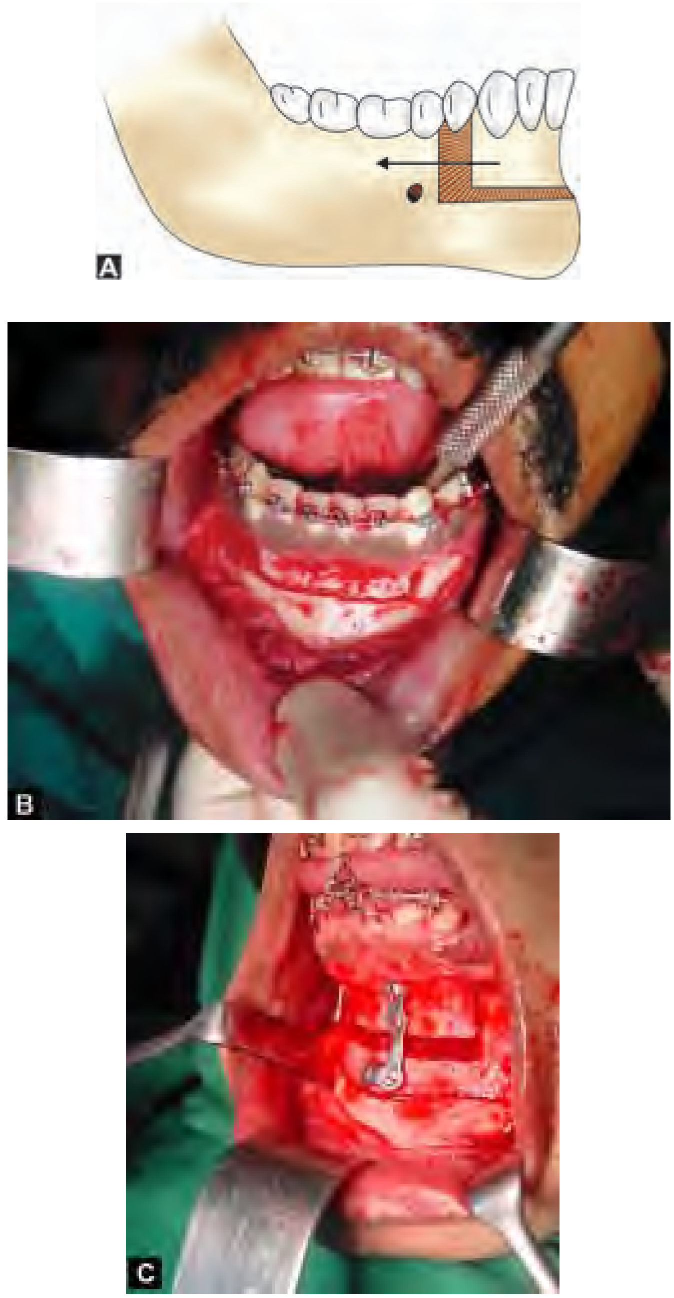
Surgery

After infiltration with a local anesthetic with vasoconstrictor, sulcus incision is made and the mucoperiosteal flap reflected. Subperiosteal tunnelling is done at the lingual aspect of the planned osteotomy site. Extraction of tooth (usually the first premolar) is done if the intention is to retrude the dentoalveolar segment.

Osteotomy or ostectomy is done as planned. Stabilization and fixation are done in the preplanned position using prefabricated occlusal wafer splint or arch wires. Stabilization is done by using lag screws, position screws or wires. Semirigid bone plates are considered superior **(Figures 12-47A to C)**.

In cases where the anterior segment of the mandible is repositioned superiorly, a gap is created at the osteotomy site (subapically). Autogenous bone grafting is advised to fill this gap.

When the osteotomy is planned behind the mental foramen, the neurovascular bundle may be released from the mandibular canal and protected.



Figures 12-47A to C: Lower anterior subapical osteotomy. (A) Diagrammatic representation, (B) Photograph. (C) Lower subapical osteotomy can be combined with genioplasty.

Total Subapical Osteotomy Mandible

Mcintosh in 1974 described total mandibular alveolar osteotomy. In 1942 Hofer described horizontal osteotomy of mandible for horizontal deficiency, excess and asymmetry. It is used mainly for the following indications:

1. For repositioning the entire dentoalveolar segment.
2. When the mandibular length and chin position are compatible with the maxilla and its position, but the deformity is mainly in the dentoalveolar part.

Adequate bone (roughly 10 mm) should be present below the apices of the roots; up to the inferior mandibular border.

Surgery (Figures 12-48A to C)

Mucoperiosteal flap is reflected. The neurovascular bundle is released as described earlier (under Body Osteotomy of mandible).

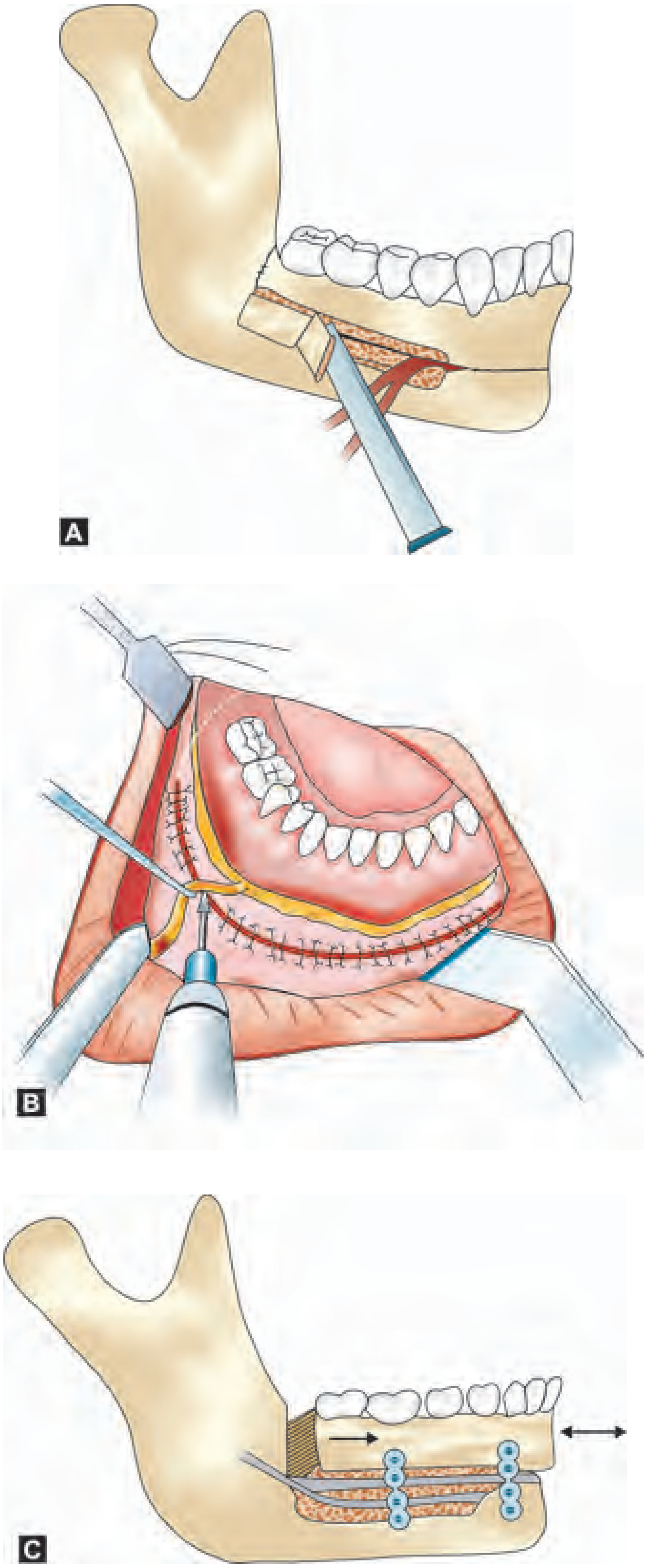
Osteotomy is started behind the most posterior teeth. The cut is made using a reciprocating saw or bur. Care should be taken not to damage the lingual tissues. Osteotomy is continued anteriorly, without injuring the released neurovascular bundle. About 4 mm of bone should be left below the apices of the teeth to ensure proper blood supply.

The dentoalveolar segment is freed and mobilized. Pre planned occlusion is established. Maxillomandibular fixation is aided by wafer splint. The neurovascular bundle is repositioned and secured in position using struts of bone.

Stabilization is done using transosseous wires or rigid internal fixation.

Postoperative sequelae are usually marked by edema which gets resolved in about two weeks' time. Sensory disturbances, though present, usually recover with time. Injury to the neurovascular bundle could cause permanent anesthesia.

Complications are usually rare. The importance of proper blood supply through the lingual pedicle is of



Figures 12-48A to C: Total subapical osteotomy. (A) Neurovascular bundle is released. (B) Osteotomy is done using bur or saw. (C) The dentoalveolar segment is positioned and fixed rigidly.

utmost importance. This is mainly through the mylohyoid, genioglossus and geniohyoid muscle attachments.

Posterior Subapical Osteotomy Mandible (Figure 12-49)

The basic plan of the surgery is not very different from that of total subapical osteotomy. The incision is limited to the posterior area. The decompression of the neurovascular bundle is done and the osteotomy is performed as described earlier.

The main indications are to shift the dentoalveolar segment in question to the required direction in all three dimensions of space, i.e. anteroposterior, vertical or horizontal.

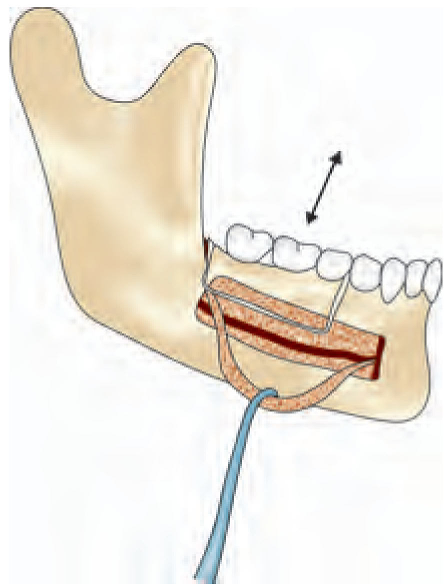


Figure 12-49: Posterior subapical osteotomy.

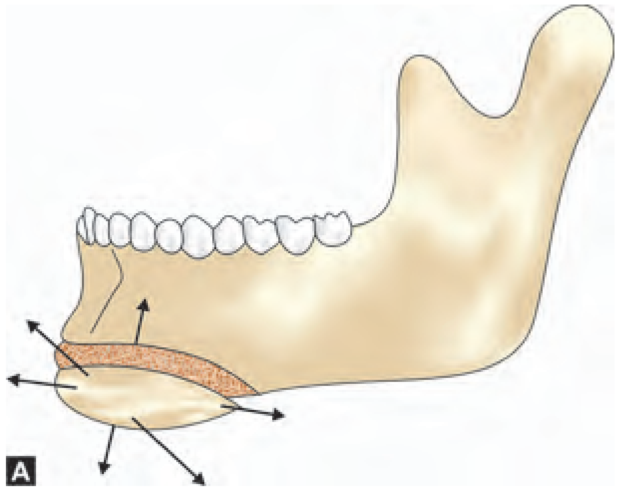
Genioplasty

Genioplasty is used for the correction of deformities of the anterior part of the mandible, the chin. It is possible to reposition the chin in all the three dimensions of space, moving it in anteroposterior, vertical and/or horizontal directions.

Hofer in 1942 introduced horizontal osteotomy of the symphysis.[68] By repositioning the inferior mandibular symphysis, a more stable and natural appearance can be attained.[18]

Surgical Procedure

Incision is made on the labial mucosa on the lower lip after routine infiltration of Lignocaine Hydrochloride 2% with 1:200,000 Epinephrine. It is extended from the pre-



Figures 12-50A and B: (A) Osteotomized chin can be moved in all the three dimensions. (B) Advancement genioplasty.

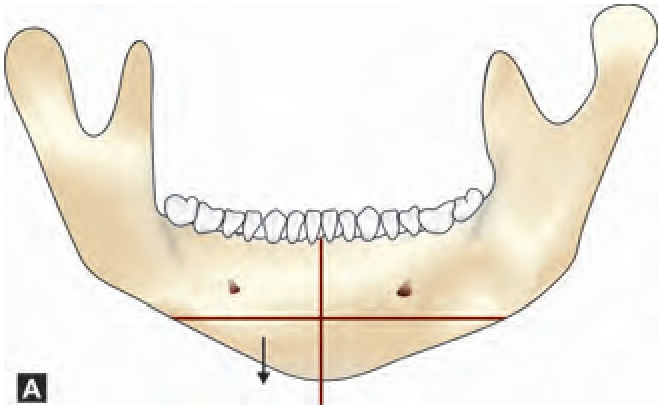
molar region to the opposite symmetrical site. The incision is taken to the periosteum which is cut to expose the bone. Subperiosteal dissection is done to expose the inferior border of the mandible. Mental nerve is identified and protected **(Figures 12-50A and B)**.

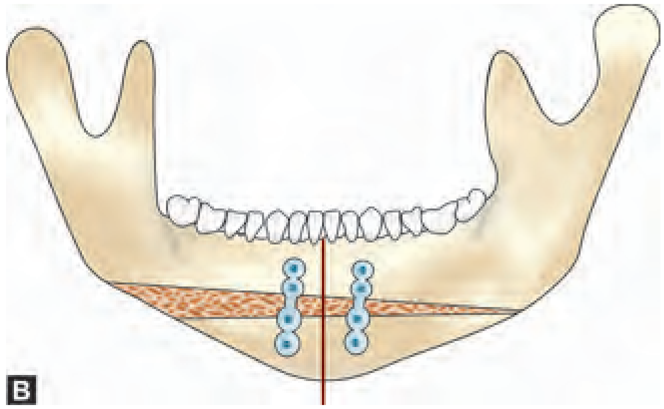
Osteotomy/ Ostectomy

Bony cut is made on the chin about 4.5 mm below the apices of the teeth. The posterior end of the cut should taper to the inferior border, behind and below the mental foramen (This prevents step defects at the site which may be manifested in the soft tissue also).

The segmented portion is freed from the rest of the mandible but remains pedicled to the digastric and geniohyoid. In genioplasty, if the inferior segment is stripped of the periosteum, making it a free graft, intense inflammatory reaction and necrosis may occur.[108, 164] The degree of bone resorption and necrosis is indirectly proportional to the amount of pedicle attached to the segment.[51]

For vertical reduction, another horizontal cut is made below the original cut and the segment of bone between the two cuts is removed. It is not advisable to cut off the bone from the inferior border since such a procedure can imperil the normal contour of the chin. Unilateral vertical reduction can be done for correction of asymmetry, since the chin can be moved in all three dimensions **(Figures 12-51A and B)**.





Figures 12-51A and B: Mild facial asymmetry can be corrected by bone grafting on one side, after osteotomy.

Increase in the height of the chin can be achieved by bone grafting (preferably autogenous) and rigid internal fixation using plates. Unilateral height increase can be done in asymmetry.

Chin can be augmented (augmentation genioplasty) by bringing the cut inferior segment anteriorly and fixing it by the use of wires. Rigid fixation or use of semirigid plates is better than wiring.

For major advancement, stepwise augmentation, slicing the inferior border into more than one horizontal

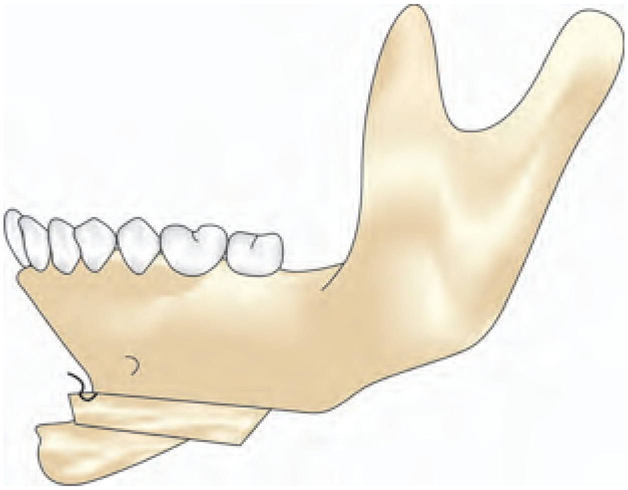
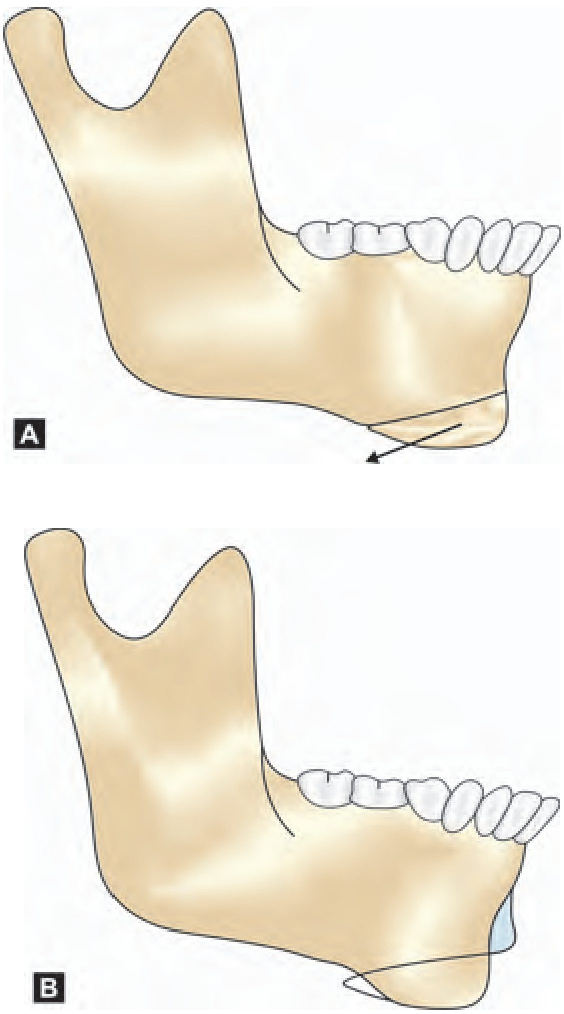


Figure 12-52: Major advancement of the chin can be effected by step osteotomy of the lower border.



Figures 12-53A and B: Reduction of the chin can also be achieved. However, sharp margins are to be trimmed off.

segment is advocated **(Figure 12-52).** Since the advent of RIF the need for multiple sectioning has decreased.

Retropositioning of the chin can also be done, but the soft tissue adaptation following posterior repositioning of the chin is not 100%. While positioning the inferior border posteriorly the labiomental fold may be lost. To prevent this, a concavity may be carved into the anterior surface of the mandible **(Figures 12-53A and B).**

Genioplasty can be used for widening and narrowing the chin in the horizontal direction. In mild mandibular asymmetry the midpoint of the chin may be off the facial midline. By horizontal repositioning of the inferior border, the midpoint of the chin can be brought to the midline of the face and the mandibular asymmetry can be camouflaged **(Figure 12-54).** Stabilization and fixation is usually done using figure of eight transosseous wires. Use of plates and screws for fixation is superior to traditional transosseous wiring.

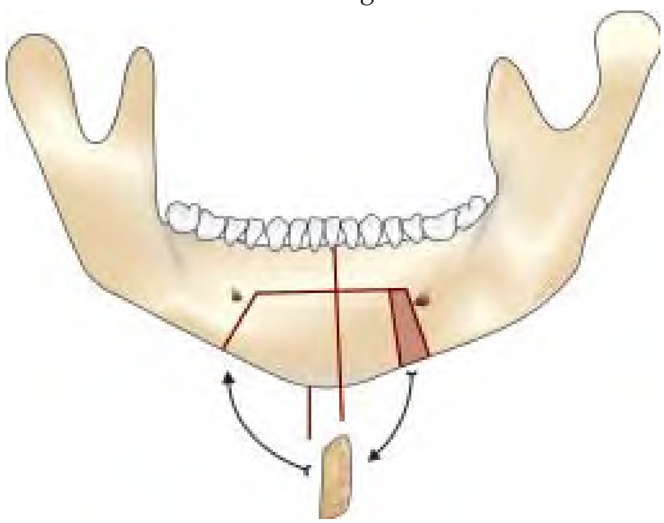


Figure 12-54: Osteotomy plan for mild facial asymmetry pertaining to the chin

Following surgery, the wound is closed adhering to the basic principles. Postoperative edema takes several weeks to resolve. Like in other osteotomies 3 to 6 months are necessary for the lip to adapt to the new position and resume normal function. Complications are rare with this procedure.

Wound dehiscence occurs in some cases. Meticulous irrigation and aseptic measures can reduce the chances of infection. Sensory loss for a period may be noticed due to traction on the mental nerve. Often sensation is regained within a period of 3 to 6 months.

Rigid fixation technique has reduced the chances of shift in position of the repositioned segment. Though the reported relapse rates vary in genioplasty, most authors agree that relapse occurs within the first year.[108,133]

Extended Genioplasty

In extended genioplasty dissection and exposure of the chin, mental nerve and body of the mandible is recommended by a degloving incision. With complete dissection and mobilization of nerves an extended long osteotomy to the antegonial angle may be carried out **(Figure 12-55)**. The long osteotomy ensures proper proportionality between the advanced segment and the posterior mandible.[176] By laterally sliding the lower border facial asymmetry can be corrected. This procedure can be used for hemifacial microsomia and facial deformity resulting from unilateral ankylosis of the temporomandibular joint **(Figures 12-56A and B)**.

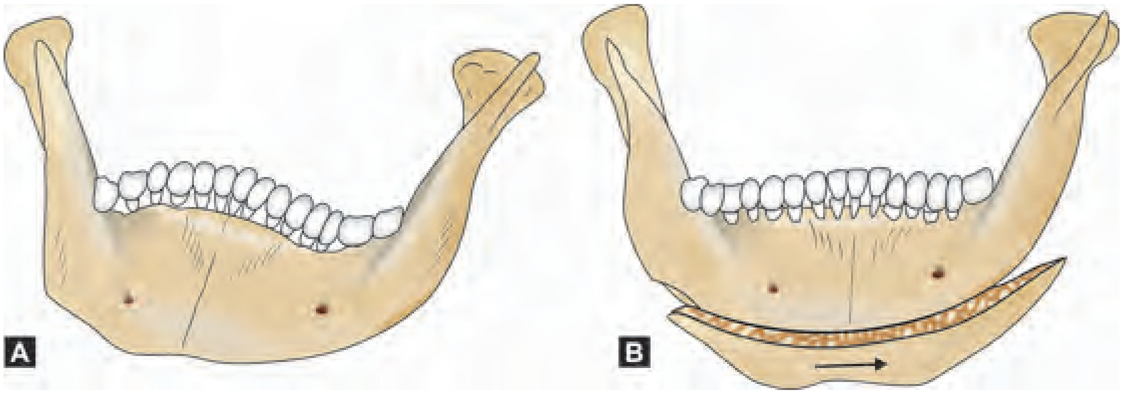
Figure 12-55: After making a degloving incision an extended genioplasty may be done. It is possible to preserve the mental nerve.

Distraction Osteogenesis

Distraction osteogenesis is a recent introduction into the field of orthognathic surgery. This technique has revolutionized the possibilities of orthognathic surgery. It was Illizaro, a Russian orthopedic surgeon, who popularized this technique. The first team to report gradual distraction of human mandible was McCarthy, et al.[106] As bone has got regenerative capabilities, it is possible to create new bone and lengthen the bone in a cut segment by slowly distracting it. The technique is very useful in the management of deficiency of bone in the maxillofacial region as this is an excellent method to increase bone quantity. The spectrum of indications for distraction is widening and innovations are coming up in the field rapidly. During distraction certain important principles are to be followed.

It is advisable to complete the osteotomy and mobilize the segment as far as possible and then put back the segment to its original position and distract it gradually. During distraction directional stability should be ensured, in order to counteract the pull of the soft tissue and the muscles.[139] A new terminology 'Distraction histiogenesis' has come into vogue as not only the bone but the surrounding tissues also get lengthened. Geniohyoid muscle can be lengthened to a maximum of 20% of its resting length.[167] It is possible to distract the inferior alveolar nerve as well.[73] It is important that the distracted tissue is attached to vital tissue to maintain perfusion. Periosteum is rich in osteogenitor cells, and for callus distraction and bone lengthening the periosteum should be intact, and hence it should be preserved.[86]

After osteotomy a latency period of seven days is ideal to provide time for the soft tissue to heal. However other factors like age, stability of fixation, type of operative procedure that affects the formation process during the



Figures 12-56A and B: Major asymmetry of the mandible can be corrected to a great extent by extended lateral sliding genioplasty.

Case Reports

Case 1: Le Fort I, AMO and Genioplasty

A1,2,3: Preoperative photographs

B1,2,3: Postoperative photographs

C1: Preoperative cephalogram C2: Postoperative cephalogram

Complaints: Gummy smile, Incompetent lips.
Findings: Vertical and AP excess of maxilla, Deficient chin
Treatment: Le Fort I superior repositioning with Anterior Maxillary Osteotomy and Augmentation Genioplasty.

Case 2: Le Fort I, AMO and Genioplasty

This 21-year-old girl reported with a complaint of bimaxillary protrusion and difficulty in apposing the lips. Clinical and cephalometric examination revealed vertical and anteroposterior excess of maxilla. Chin was deficient but there was dentoalveolar protrusion of the mandible.

Presurgical orthodontics involved extraction of 34 and 44 and retraction of the lower anteriors to create an overjet of about 1 cm.

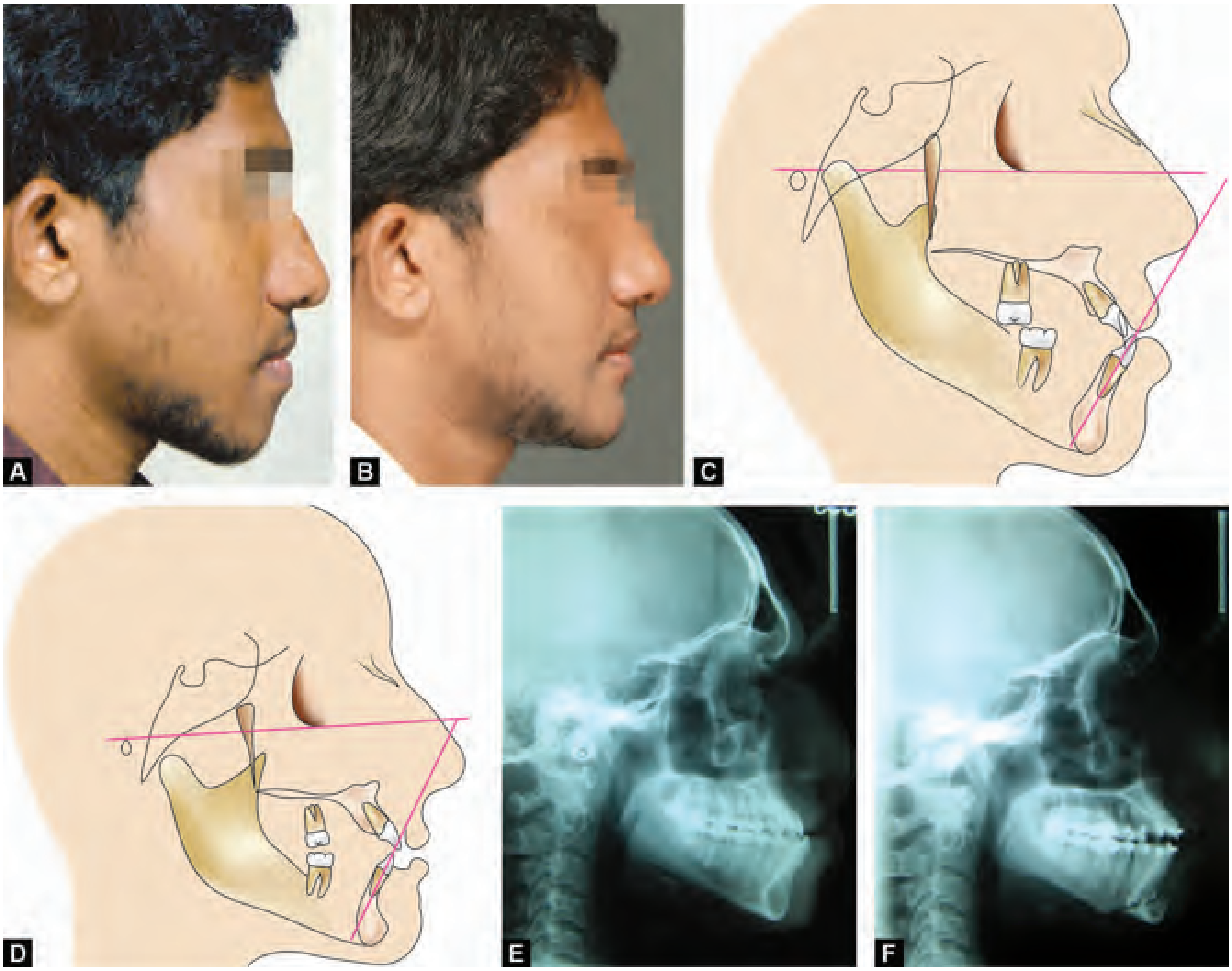
Le Fort I superior repositioning, AMO push back with extraction of upper first premolars and augmentation genioplasty was planned and performed.

A1,A2: Preoperative frontal and profile views. B1,B2: Postoperative frontal and profile views. C1: Preoperative cephalogram. C2: Postoperative cephalogram.

Case 3: Subsigmoid Vertical Osteotomy

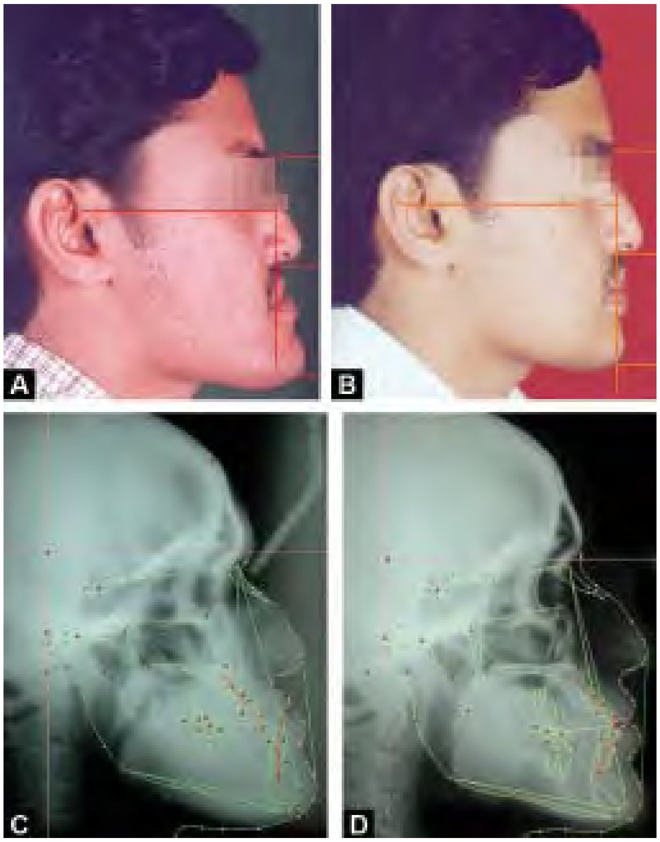
Complaints: Protruded lower jaw.
Findings: Mandibular prognathism with pan occlusal cross bite.
Treatment: Presurgical orthodontics to upright the lower anteriors. Subsigmoid vertical osteotomy of the Ramus on both sides to set back the mandible.
A: Presurgical frontal view. B: Postsurgical frontal view. C: Presurgical profile.
D: Postsurgical profile. E and F: Profile and frontal photographs of the patient 10 years after surgery.

Case 4: BSSO, Genioplasty and Rhinoplasty



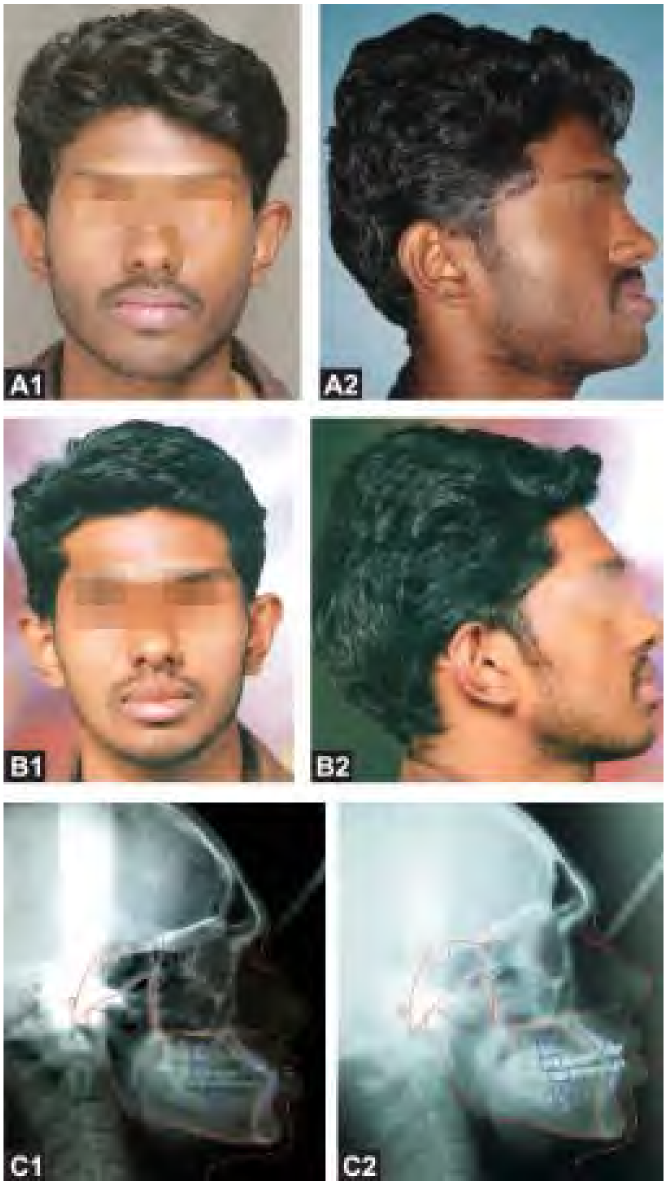
Findings: Mandibular prognathism, hump nose, absent labiomental fold.
Treatment plan: Presurgical orthodontics to decompensate the lower anteriors, and surgery
Surgery: Bilateral sagittal split osteotomy to set back the mandible. Genioplasty to augment the chin and to gain contour of the labiomental fold. Rhinoplasty to reduce the hump on the dorsum of the nose.
A: Preoperative profile photograph. B: Postoperative profile photograph. C: Preoperative tracing. D: Postoperative tracing. E: Preoperative cephalogram. F: Postoperative cephalogram.

Case 5: BSSO (Bilateral Sagittal Split Osteotomy)



A case of mandibular prognathism treated by Bilateral sagittal split osteotomy
A: Preoperative photograph. B: Postoperative photograph. C: Preoperative cephalogram. D: Postoperative cephalogram.

Case 6: BSSO

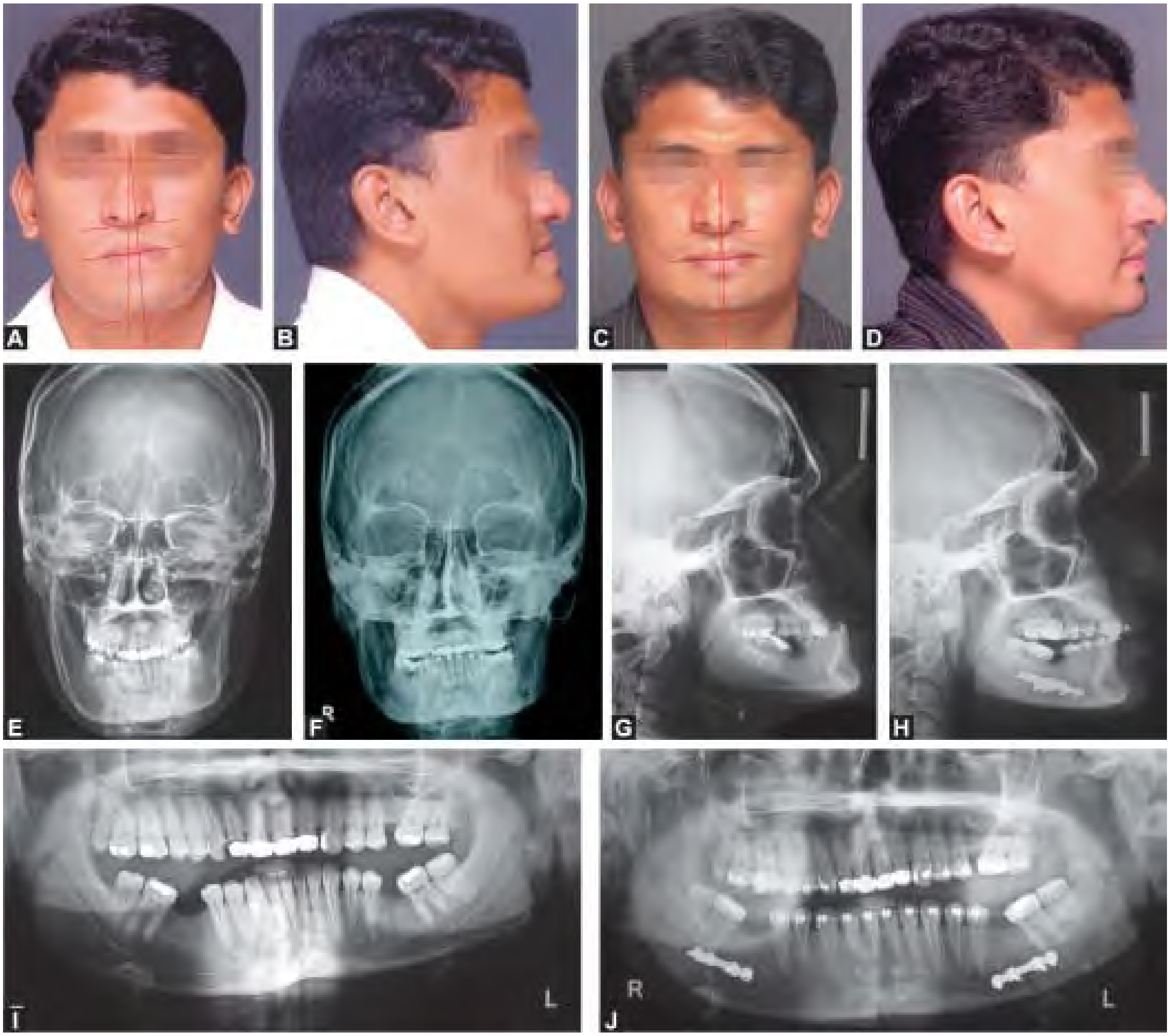


Complaints: Protruded lower jaw, protruded lower lip, improper bite.
Findings: Mandibular prognathism, Anterior cross bite, Cl.III malocclusion.
Treatment plan: Bilateral sagittal split osteotomy to set back the mandible, with rigid fixation.
A1, A2: Preoperative photographs.
B1,B2: Postoperative photographs.
C1: Preoperative cephalogram. C2: Postoperative cephalogram.

Case 7: BSSO with Genioplasty

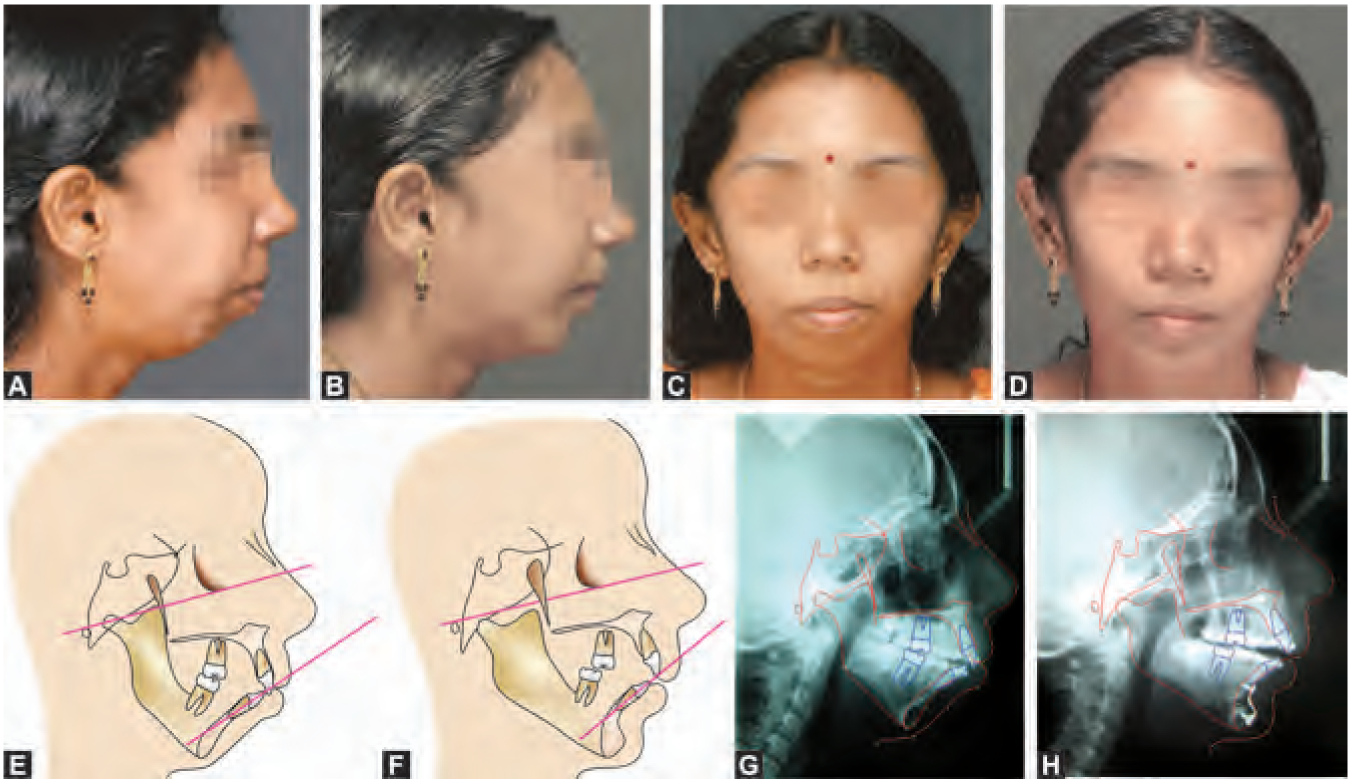
Problem list: Mandibular prognathism, deficient chin, mild anterior open bite, proclined upper anteriors.
Treatment plan: Presurgical orthodontics
Decompensation of the lower anteriors. Retraction of the upper anteriors.
Surgery: Bilateral sagittal split osteotomy with augmentation genioplasty.
A1, A2: Pre- and postoperative frontal view.
B1, B2: Pre- and postoperative profile view.
C1, C2: Pre- and postoperative tracing.

Case 8: Facial Asymmetry: BSSO with Inferior Border Ostectomy



This patient who had hemimandibular hypertrophy with mandibular prognathism and facial asymmetry had undergone bilateral sagittal split osteotomy and inferior border ostectomy of the right side. A and B: Preoperative frontal and profile views. C and D: Postoperative frontal and profile views. E: Preoperative PA cephalogram. F: Postoperative PA cephalogram G: Preoperative lateral cephalogram. H: Postoperative lateral cephalogram. I: Preoperative OPG. J: Postoperative OPG.

Cas 9: Augmentation Genioplasty



This patient had a severely retruded chin and a convex face. Nasolabial angle, overjet and overbite were normal. An extended genioplasty was planned and performed. A and B: Pre- and postoperative profile photographs. C and D: Pre- and postoperative frontal photographs. E and F: Pre- and postoperative tracings. G and H: Pre- and postoperative cephalograms.

initial stages of distraction etc. are to be considered before deciding on the latency period.[1] Certain other studies did not show any difference between no latency period and a latency period of 4 to 7 days.[8, 9, 170, 175]

Four stages are recognized in distraction osteogenesis: (a) Fibrovascular hematoma formation, (b) Formation of collagen fibers parallel to distraction vector, (c) Bone formation and remodeling of new bone, (d) Formation of solid compact bone. In fast distraction collagen fibers may loose contact and bone formation may not take place. In slow distraction, consolidation of bone may occur earlier.[88] Karp et al demonstrated that intramembranous ossification is what occurs predominantly.[80] Distraction of 1 mm per day is the most acceptable rate.[4] Direct current electrical stimulation may be useful in activation and consolidation period.[42,55,58] Insufficient distraction and defective vectors can compromise the final result. These complications can be, to a great extent, managed by manipulating the regenerate bone by the application of orthodontic traction.[69,105,128,167]

Distraction osteogenesis has got an important role in managing sleep apnea, in cases like micrognathia, Pierre Robin syndrome, hemifacial microsomia, Treacher Collin syndrome, etc.[159] In severe cases, in neonatals, tracheostomy may become necessary. Mandibular distraction is an effective method in resolving upper airway obstruction and decannulation of tracheostomy.[112,115,129] Rachmiel A, et al have reported an increase of mandibular volume by 28.4%, increase of upper airway volume by 71.92% and increase in oxygen saturation. This study was conducted in children between 13 months and 7 years of age.[138]

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Chapter 13

HS Adenwalla, PV Narayanan

Introduction

The unilateral cleft lip in its many varying manifestations of shape, size and asymmetry is a complex deformity. To obtain consistent results one requires basic training in soft tissue handling, an understanding of the bony foundations of the face followed by experience and a fair amount of craftsmanship.

In the late 1950s the senior author was introduced by his mentor Charles Pinto to the straight repair of Rose [23] and Thompson[27] as modified by Eric Peet,[21] who called it the "Oxford modification of the straight repair". In the hands of the artistic Peet it gave good results **(Figure 13-1).**

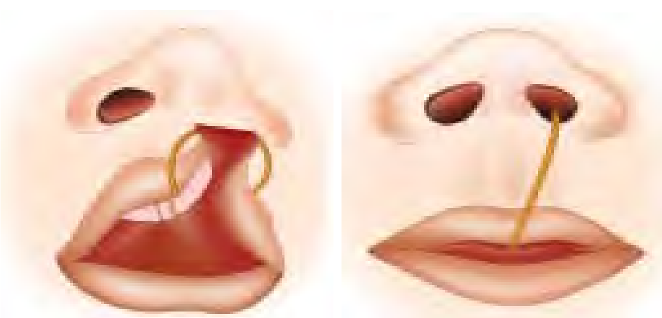

Figure 13-1: Straight repair.

Looking for something better Charles Pinto brought back from St Louis, Missouri, then Barrett Brown's unit, a form of the triangular flap of Mirault **(Figure 13-2)**[17] modified by Vilray Papin Blair, Brown and Mc Dowell[3,4] into a smaller triangular flap. The Blair-Brown-Mc Dowell plan held centre stage for a good 10 years. The stature of these three great men and their artistry was probably one of the reasons why this procedure flourished. In our hands the results were no better than with the straight repair. There was not the slightest semblance of a Cupid's bow in these patients, instead there was an unnatural central peak and in most cases a tight lip resulted. Secondary corrections of these lips were always difficult.

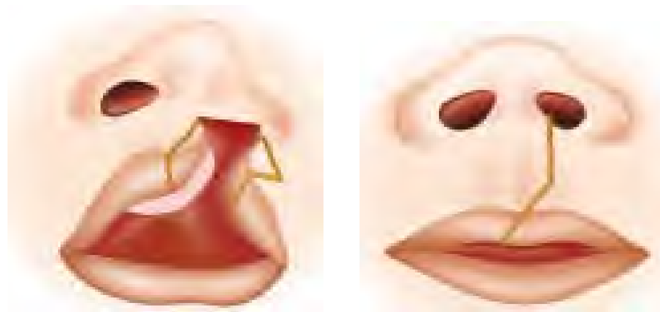

Figure 13-2: Mirault repair.

A major breakthrough in cleft surgery took place when an orthopedic surgeon working at the Hospital for sick children at Toronto, Le Mesurier[14] modified the Werner Hagedorn's quadrilateral flap[9,10] and for the first time created a Cupid's bow **(Figure 13-3)**.

Figure 13-3: Le Mesurier technique.

No surgeon at the time could ignore the positive advantages of having a nice Cupid's bow. As time went on and the long-term results of the Le Mesurier were shown at conferences it became obvious that the lip on the cleft side became long and over-hanging and the scar like the triangular flap was unnatural and did cut across the normal philtral line.

As the Le Mesurier began to fade out, Tennison's modification[26] of the Mirault triangular flap with a Z plasty began to be accepted **(Figure 13-4).**

Figure 13-4: Tennison's triangular repair.

Peter Randall[22] did to the Tennison what Blair and Brown had done to the Mirault - he made his triangle smaller and marked his points with greater precision. Sawhney[24] of Chandigarh improved on the Tennison-Randall's operation making the cutting of the triangular flap almost geometrical in its precision. With Sawhney's contribution, the triangular flap became easy to teach and easy to execute and is still popular with surgeons in north India. When well executed, the Tennison-Randall-Sawhney procedure gives reasonably good results. The scar however is unacceptable and, when not properly executed, secondary repairs are difficult.

Somehow we at the Charles Pinto Centre missed out on the Tennison-Randall-Sawhney improvements and went straight on to the Rotational advancement technique of Millard. In 1958, on his last visit to India, Sir Harold Gillies demonstrated the Rotational Advancement technique to a group of Indian surgeons in Pune. He turned round to the fascinated audience and said "Gentlemen, try this one - I think it has merit, but I must warn you that it has not yet been published". The Millard procedure[15, 16] broke like dawn on the Indian horizon and caught the imagination of surgeons the world over by its clear logical thought process **(Figure 13-5)**.

Millard said that:-

1. All the previous flap procedures based their operations on the false premise that the actual defect in the cleft is in the lower third of the lip, this is not so. The discard of tissue in the Tennison's approach where there was already poverty is against all plastic surgical principles.

Figure 13-5: Millard's rotation advancement technique.

2. Three quarters of the Cupid's bow is there in the non-cleft side but is riding high - what better way of bringing it down in a horizontal line with its fellow than by a rotational flap. No rotational flap is complete without a back cut and this further drops this point to compensate for the contracture of the straight line of the Millard procedure.
3. This main rotational flap is taken from the rich non-cleft side and not from the poverty stricken cleft side as in the triangular and quadrilateral flap procedures (It is unwise to borrow from Peter to pay Paul when Peter can ill afford it).[6]
4. The defect thus created is in the upper part of the lip and can be hidden under the over-hanging nostril.
5. What better way of filling this defect than by advancing a flap from the cleft side.
6. The advancement flap gives the additional bonus of correcting the nostril flare and so the Millard does not need a separate action for the nasal correction like in the other methods.
7. The "C" flap helps to lengthen the short columella.
8. The scar imitates the philtral line, creates a philtral column, a philtral dimple and a slight pout which adds charm to the finished result. The scars of both the triangular and quadrilateral flaps crisscross a normal Langer's line and again goes against the basic laws of plastic surgery.

This to our mind is the eight-fold path to the cleft Nirvana that the reconstructive surgeon wants to achieve.

The authors would not like to give the impression that a surgeon can just read these eight points and achieve a good result. The Millard procedure needs to be taught on the table, needs a considerable amount of virtuosity on the part of the surgeon and it needs a fair amount of experience. Unlike the Tennison-Sawhney there are very few mathematically precise points to mark and you can "cut as you go" depending upon the needs of the case, keeping your eye on shape and symmetry. "All art depends on freedom for its vitality for no two lips are identical—they may be similar but never identical".[16] The straight line part of the Millard incision often contracts and pulls the Cupid's bow up in the first few months, but in a year's time it descends without any further intervention.

Critics of the Millard operation have often said in publications that the rotational advancement procedure is only suitable for partial clefts and not for the complete ones.[16] This statement is far from the truth. To the original Millard theorem, in this article, we have added our own original method of correcting the nostril deformity and our method of avoiding a notch or whistle deformity on the vermillion.

Classification

Unilateral cleft lips are classified according to the extent of the deformity into microform, partial or complete clefts.

A microform cleft lip is also referred to as Forme Fruste,[13] occult cleft,[28] minimal cleft[13] or Nature's Union.[5] In these there is always a notch on the vermillion. In addition, there may be a discontinuity in the white roll, a scar or a furrow on the body of the lip, a cleft nostril deformity and even an abnormal lateral or central incisor tooth.

A partial cleft lip, in addition, extends into the body of the lip, but the nasal sill and the nasal floor are intact. The alveolus is not cleft. The alar deformity seen in a typical complete cleft lip may also be present.

In a complete cleft lip, the cleft extends across the alveolus, and the oral and nasal cavities communicate directly.

Treatment Protocol

The "rule of tens"[29] is followed worldwide for cleft lip repair. This involves treating the lip at 10 weeks of age with the child weighing 10 lbs, and having a Hemoglobin of 10%. However, this is not applicable in a country like India, because, as a rule, we are of a smaller build, and our children attain a weight of 10 lbs only around 5 months of age. We operate on our unilateral cleft lip patients at 5-6 months of age.

In those children with a residual nasal deformity, we perform a limited anterior rhinoplasty prior to school-going age, usually 5-6 years.

In those who have a cleft alveolus, an alveolar bone graft, using cancellous bone from the iliac crest, is performed at 7 years.

In those with severe maxillary regression, a Le Forte I Osteotomy is done at 16 years.

In the case of patients with a bony nasal deformity (dorsal hump, septal deviation involving the ethmoid, etc.), we perform a definitive secondary rhinoplasty at 16 years.

Presurgical Orthodontics

We do not routinely use any presurgical orthodontics for our unilateral cleft lip patients. Latham used his orthodontic appliance to align the alveolar segments in all of Ralph Millard's patients.[16] This is an invasive procedure but can align the shelves in a fairly short period of time. The deleterious effects of this technique have been discussed in detail by Berkowitz.[2] He believes that affects the growth of the maxilla.

Nasoalveolar moulding (NAM) is a noninvasive, but more protracted method to approximate and align the alveolus. Treatment must be initiated in the first few weeks of life for optimal moulding. This technique has been pioneered by Grayson.[8] A modification of this technique has been used extensively by Liou.[19] NAM requires frequent patient visits and readjustment. Lack of patient compliance becomes a limiting factor in many instances. The advantages over Latham's method is that the nasal deformity is also corrected to a great extent.

Anesthesia

The baby is placed supine with a good degree of neck extension. Surgery is done under general anesthesia and a PORTEX endotracheal tube is used. Local infiltration of a solution containing 1 in 200,000 adrenaline with 1% lignocaine is infiltrated in the vestibular sulcus on the cleft and non-cleft sides. The septal mucoperichondrium and the medial wall of the maxillary antrum are also infiltrated.

Surgical Procedure

We follow the Millard's Rotation Advancement procedure in all our unilateral cleft lip patients. After preparing the skin with Povidone iodine solution and removing the grease on the skin with solvent ether, skin marking is done using Bonney's Blue.[20]

The apex of the Cupid's bow and the high point on the non-cleft side are marked carefully at the mucocutaneous junction **(Figure 13-5)**. A point equidistant to the distance between these two points is marked lateral to the apical point. From this lateral point, the rotation incision is marked with a gentle convexity upto the base of the columella. At this level the incision turns medially, hugging the base of the columella, for about two-third of its distance. A back-cut is marked perpendicularly at the end of this rotation incision. This back-cut should not transgress the philtral line on the non-cleft side. If this happens, it also lengthens the non-cleft side of the lip. A paring incision is marked along the edge of the cleft.

As a result of the rotation and the paring incision, a flap generally known as the "C flap" is obtained. This is used to lengthen the cleft side hemi-columella.[16] The part of the "C flap" that remains after it is used for the columella is de-epithelialized and used as a filler for the nasal sill area.[7]

A lateral point, i.e. the base of the cleft side philtral column, is marked on the white roll on the cleft side. This is an ambiguous point. There are different ways of marking it. One is by measuring the length of the philtral column on the non-cleft side and measuring the same distance on the cleft side edge. Another method is to measure the distance from the alar base to the corresponding lateral point on the non-cleft side and marking the same distance on the mucocutaneous border on the cleft side. This is also marked as the distance from the oral commissure to the lateral point on the non-cleft side. The lip is stretched medially and the corresponding distance is marked on the cleft side. The height from the normal side lateral point to the redline of Noordhoff (line at the junction of the dry and wet mucosa) is measured and should be equal to the distance on the cleft side from the marked lateral point and the red line. Despite all these measurements the point remains ambiguous and one learns to mark it well only by experience.

A perialar incision is marked from the cleft edge along the groove beneath the alar base. If it deviates inferior to the alar base, the resulting scar will be noticeable. We believe that this is the reason why many authors today have abandoned this extension of the incision. We find it useful and also believe that the scar remains out of sight if the incision is accurately placed. A paring incision is marked along the cleft edge, with a slight concavity to match the convexity of the rotation incision.

Advancement Flap

As a routine, we commence the dissection on our left hand side. The paring is done initially using a No.67 Beaver blade to etch the skin and then a No.65 Beaver blade to complete the incision through the full thickness of the lip. The skin and mucosa are undermined **(Figure 13-6)**.

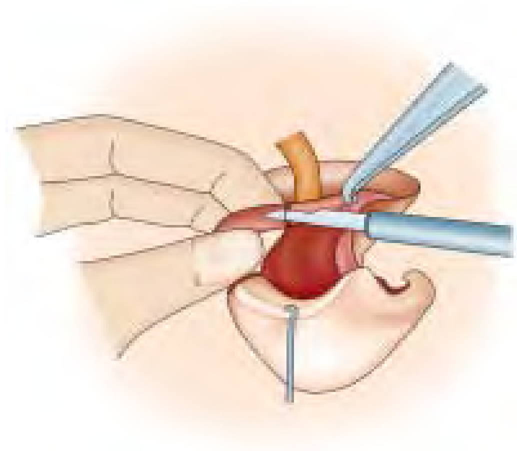

Figure 13-6: Undermining the vermillion on the cleft side.[1] The non-cleft side vermillion is also similarly undermined.

The perialar incision is also made in a similar manner and the paranasal muscles are dissected. The advancement flap is thus created and its tip is truncated so that the flap will fit into the apex of the back cut of the rotation incision.

We then proceed to pare the cleft side vermillion. The skin and mucosa are then undermined. We retain an excess of orbicularis oris marginalis muscle at the vermillion free border **(Figure 13-7)**.

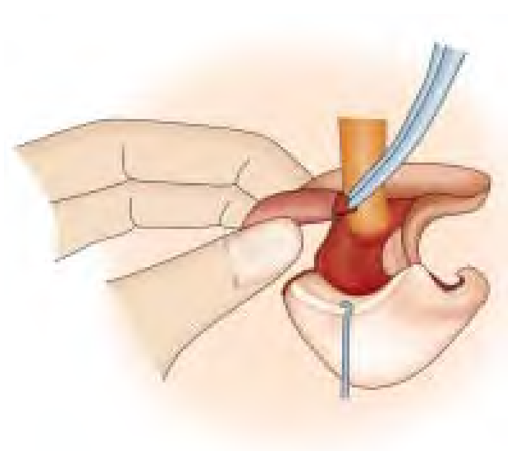

Figure 13-7: Shows the excess of orbicularis oris left behind while paring the vermillion.[1]

Rotation Flap

The paring incision on the non-cleft side is made similarly. Next, we divide the frenum of the lip by diathermy. This is to free the lip from the tethering effect of the frenular attachment. Only then will one be able to gauge the exact extent of rotation required.

Next, the rotation incisions and the back-cut are made through the full thickness of the lip **(Figure 13-8).**

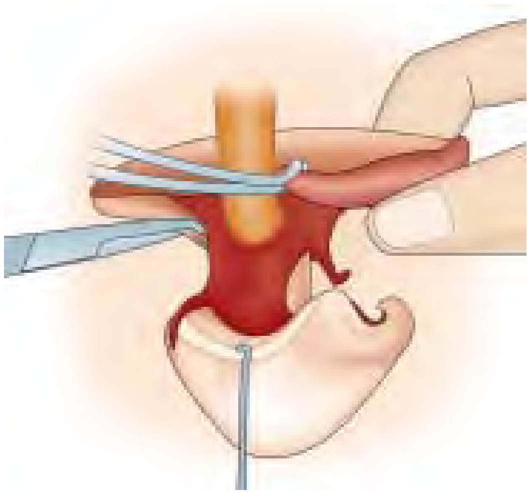

Figure 13-8: Back-cut completed. Cupid's bow peak points are at same horizontal level.

Skin and mucosa are undermined. The non-cleft side vermillion is pared, leaving behind excess of orbicularis muscle as a filler similar to the maneuver on the cleft side.

Subperiosteal Mobilization

We make an incision on the alveolar margin down to the bone, and dissect upwards in a subperiosteal plane upto the infraorbital foramen superiorly and the zygomatic eminence laterally. Medially, once we reach the medial border of the nasal process of the maxilla, we strip the mucoperiosteum off the medial wall of the maxillary antrum. This forms the lateral half of the nasal floor. A similar but limited mobilization is done on the non-cleft side. Posteriorly the subperiosteal dissection extends well beyond the over-hanging alveolar margin on the anterior palate. This enables closure of the nasal layer well posteriorly to avoid an anterior palatal communication between the oral and nasal cavities. Should such a communication occur, closure is done at the time of Alveolar Bone Grafting. The mucosa is undermined extensively so that it is free of its muscular attachment.

Septal Repositioning

We then approach the septum. An incision is placed at the base of the septal cartilage. This is usually marked by a groove. Anteriorly the incision extends to the Anterior Nasal Spine. The septospinal ligament is divided and the anterior border of the septal cartilage is delineated and freed of its attachments. We incise the septum where it joins the maxillary crest and the vomer. Then we strip the cartilage off mucoperichondrium on both sides. The dissection is carried on in the same plane posteriorly to separate the cartilage off the vomer and the perpendicular plate of the ethmoid **(Figure 13-9).**

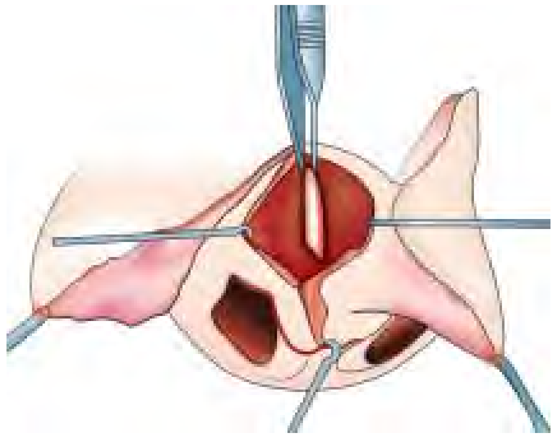

Figure 13-9: Septal cartilage dissected off mucoperichondrium on both sides and from vomer and perpendicular plate of ethmoid[1].

The cartilage thus freed will buckle when it is replaced in the midline. To correct this, a sliver of cartilage is excised inferiorly. These noses do require shortening.[12] With this in mind, we excise a wedge of about 5 mm of the septal cartilage anteriorly. The cartilage is then scored on its concave non-cleft side to make it flail **(Figure 13-10).**

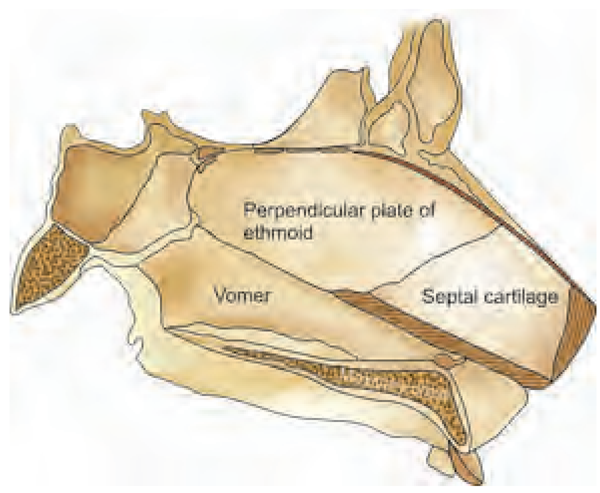

Figure 13-10: Septal cartilage showing the excised portion (shaded) and the scoring on the concave non-cleft side.[1]

A closed extensive and thorough alar cartilage dissection is then carried out using a pair of Kilner's scissors from medially through the columella base incision and from laterally through the perialar incision **(Figure 13-11).**

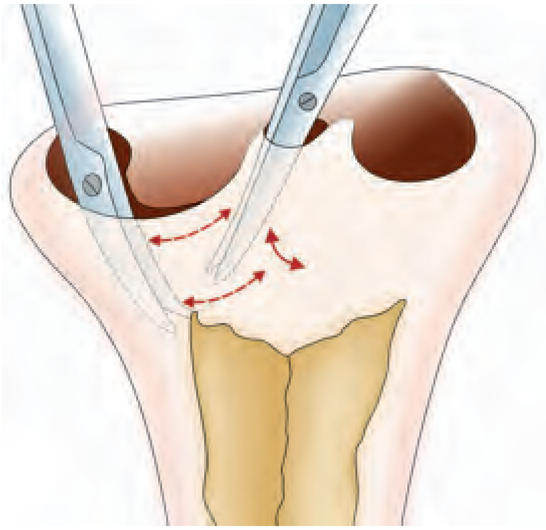

Figure 13-11: Closed alar dissection on the cleft side.[1]

The dissection is carried out in the plane between the lower and upper lateral cartilages and the overlying skin, thus freeing all the attachments of the cartilage to the skin. A more limited dissection is carried out on the non-cleft side too, upto the dome. A sliver of the excised septal cartilage is used as a vertical strut to augment the columella. The C flap is used to lengthen the hemi-columella. Excess of the flap is de-epithelialized and used as a filler in the region of the nasal sill.

Suturing commences with the reconstruction of the nasal floor by suturing together septal mucoperichondrium with the mucoperiosteum lining the maxillary antrum with 3-0 chromic catgut using mattress sutures with knots on the nasal side.

In patients with gross disparity between the medial and lateral alveolar segments, the alar base tends to drag superiorly resulting in what we call a high riding nostril **(Figure 13-12).**

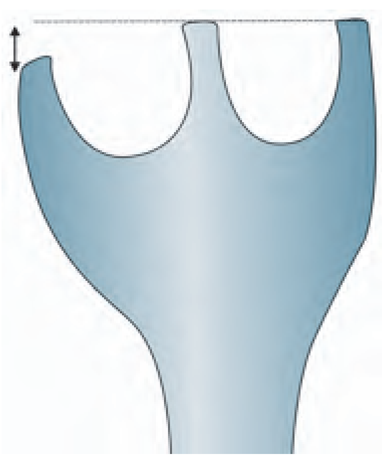

Figure 13-12: High riding nostril.[1]

To eliminate this effect, we perform an unequal Z plasty on the nasal layer as advocated by IT Jackson **(Figure 13-13)**.[7]

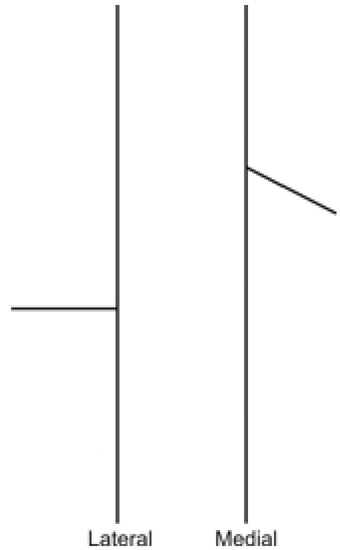

Figure 13-13: Jackson's Z plasty.[1]

In those with severe alveolar disparity, we use two such Zs. With the incorporation of this refinement, we have now been able to avoid the occurrence of a high riding nostril.

The septal cartilage is sutured to the newly reconstructed nasal floor using 5-0 prolene sutures **(Figure 13-14)**.

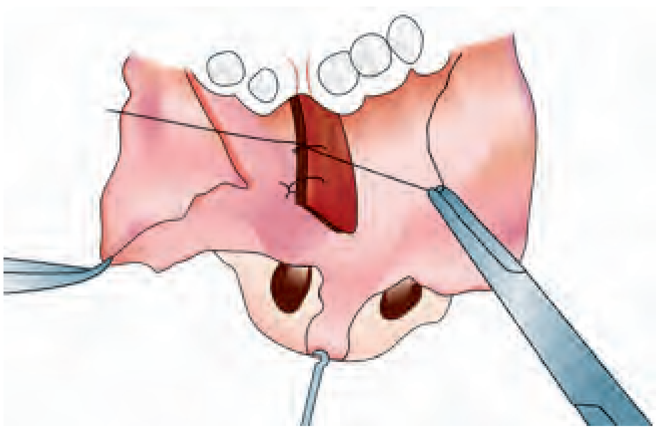

Figure 13-14: The septal cartilage is fixed to the nasal floor.[1]

Many cleft surgeons have shied away from primary septal correction following apprehensions regarding the effect of this on subsequent nasal and maxillary development. However, the senior author has been following this radical septal correction for the past 40 years and we have not found any detrimental effect on any of our patients on long-term follow-up. In fact, we strongly believe that this has helped the overall functional outcome of the nose in our unilateral cleft lip patients. This has also been the view of other exponents[25] who have objectively studied long-term effect using cephalograms. Other authors[11] have confirmed that there is no additional deleterious effect in the long-term to maxillary or nasal growth from septal cartilage repositioning.

The Millard Cinch suture is then placed with 5-0 Prolene passing from the non-cleft side nostril through the membraneous septum, and after taking a bite on the paranasal muscles at the base of the ala, returns through the membraneous septum to the normal nostril. When this is tightened, it draws the alar base medially, thus correcting the alar flare. Care must be taken not to over-tighten it, as this can lead to a narrow nostril. We believe that accurate placement of this suture is enabled by the use of the perialar incision for this allows direct visualization while placing the suture.

In addition to the above suture, the senior author has added another Cinch suture 5-0 Prolene at the nasal sill. This goes through the subcutaneous tissue medially and the dermis laterally. When this is tightened, one obtains a good nostril shape. The operator has more control over this stitch than he has over Millard's Cinch suture.

We then suture the vestibular sulcus and the mucosa with 3-0 chromic catgut. As the lip is still open, the access for the mucosal suturing is better. Hence, this precedes the suturing of the muscle and the skin. A Z plasty is mounted on the mucosa to break the straight line scar and if possible to get Noordhoff's red line in alignment **(Figure 13-15).**

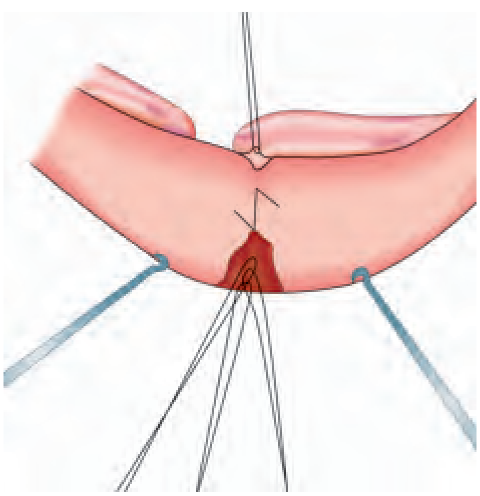

Figure 13-15: Z Plasty on the mucosa.[1]

The next step is to put the key suture of Millard, bringing the truncated apex of the advancement flap to the apex of the back-cut of the rotation incision with 5-0 Prolene passing through the subcutis and abutting the dermis. This is an important stitch and as Millard says "upon this stitch depends the law of the prophets".[16]

The orbicularis oris muscle on the two sides on the body of the lip is approximated, again with 5-0 prolene. These non-absorbable sutures provide sustained support for the muscles and are also non-reactive. The excess of the orbicularis muscle that has been left behind at the free vermillion border is next sutured with at least three 6-0 ethilon sutures, providing a roll of muscle in the vermillion **(Figure 13-16).**

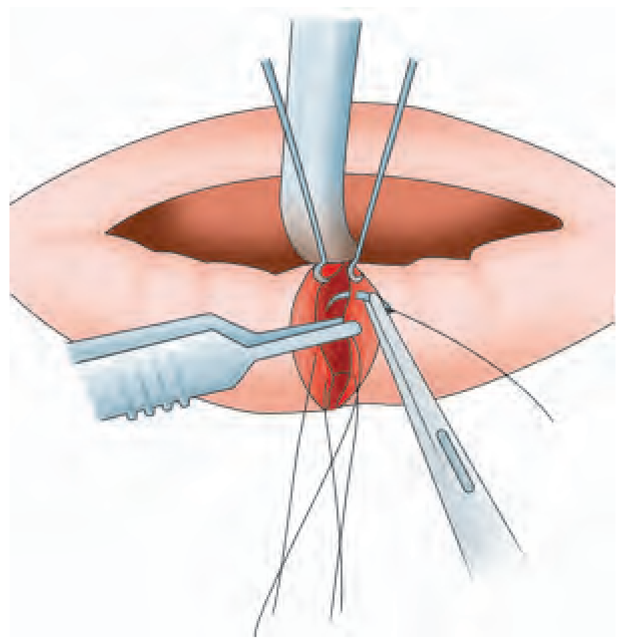

Figure 13-16: The muscle retained on both the sides being sutured with 6-0 ethilon. A minimum of 3 stitches.[1]

Skin is sutured with 6-0 Ethilon. Some patients have a prominent webbing of the vestibule of the nose. In these, a Z plasty, demonstrated to the senior author by his mentor, Charles Pinto, is a useful tool in one's armamentarium to tackle the web **(Figures 13-17A and B)**.

The long axis of the Z is along the web, and the medial and lateral limbs are marked as shown in the figure. When this Z plasty is completed, it not only obliterates the web, but also improves the nostril axis. However, care should be exercised to avoid damage to the underlying alar cartilage.

With such an extensive mobilization and with all the added technical refinements to the Millard procedure, one is able to consistently obtain good results, and the width of the cleft ceases to be a daunting factor **(Figures 13-18A to 13-20B)**.

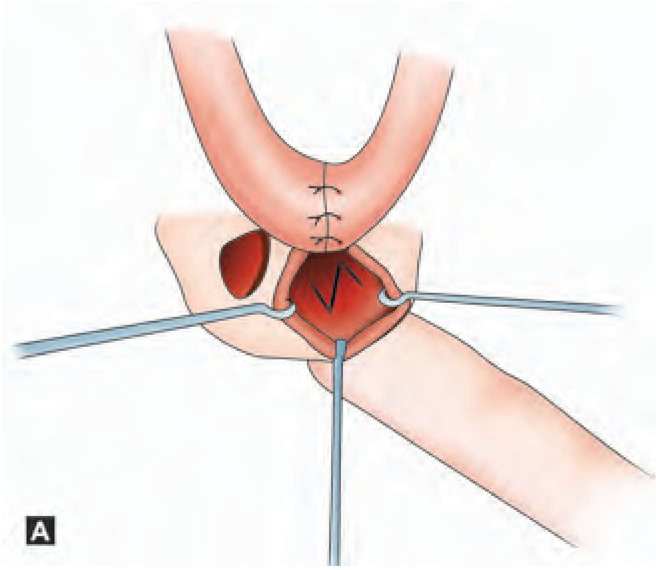

Figure 13-17A: Pinto's Z plasty for the vestibular web incision marked.[1]

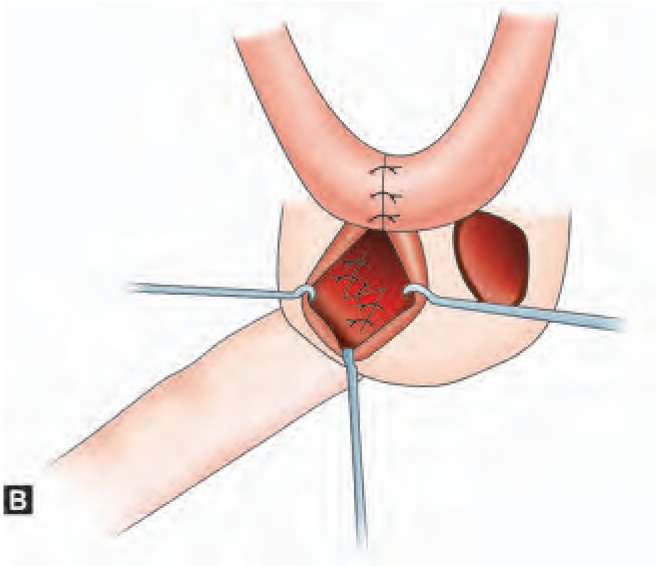

Figure 13-17B: Completed Z plasty.[1]

Figures 13-18A and B: Pre- and 7 years postoperative result after unilateral cleft uprepair

Figures 13-19A and B: Pre- and 12 years postoperative result after unilateral cleft up repair

Figures 13-20A and B: Pre- and postoperative result after unilateral cleft lip repair at 6 months and open structure anterior rhinoplasty at 5 years.

Complications

A vermillion notch is one of the most common complications following unilateral cleft lip repair. The senior author analyzed the factors responsible for such notching. These are: (1) Inadequate rotation causing the Cupid's bow to be pulled up and resulting in a notch on the vermillion. (2) In drawing of the cleft edges round the vermillion. (3) Deficiency of muscle at the free vermillion border. (4) Straight line scar contracture on the mucosal aspect of the vermillion.

These have been addressed individually:[18]

1. An adequate rotation with an ample back-cut is done in all these patients **(Figure 13-8)**.
2. Undermining of the skin and the mucosa around the vermillion on both sides of the cleft **(Figure 13-6)**.
3. An excess of muscle is left as a filler on both sides while paring. These are sutured together with three 6-0 ethilon sutures **(Figure 13-16)**.

4. A Z plasty on the mucosa breaks the straight line scar. The Z is so mounted so that Noordhoff's red line is brought into alignment (not always possible) **(Figure 13-15)**.

All these maneuvers are performed in all our unilateral cleft lips to eliminate vermillion notching.

Other Problems

There are certain problems which are almost unavoidable despite all the refinements mentioned. One of these is a droop of the soft triangle of the nose. In most patients this is minimal, and does not need any further attention. In those that are more noticeable, we perform a limited open structure anterior rhinoplasty at the age of 5-6 years and build up the skeletal framework by suturing the cleft side lower lateral cartilage to the upper lateral on the cleft side, and also hitching the alar domes and the medial crura together.

Another such problem is deficiency in height of the vermillion on the cleft side. This, we believe, is part of the cleft deformity. As yet, no technique has been described to avoid the occurrence of this problem. If it is significant, then a secondary correction is possible using the Gillies' hemicupid's bow procedure[16] or a V-Y advancement of the mucosa on the cleft side.

No cleft surgeon should ever forget the pathos of this deformity and the severe psychological trauma that it inflicts on parent and child.[1]

A plastic or reconstructive surgeon is really a general surgeon with a hobby and that hobby lies in the aesthetic realm of a refined reverence for tissue and the true appreciation of the dignity and beauty of the normal human form. His art would be quite meaningless if he reconstructed a face but failed to put a smile on it. The true plastic surgeon must always hope that the skill of his surgery will help towards the healing of all the internal scars that external wounds do cause.

Acknowledgement

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Chapter

14

HS Adenwalla, PV Narayanan

History

It is not surprising that cleft lips were repaired way before anyone tried to repair a cleft palate. Credit for the first successful repair of a congenital cleft palate goes to Le Monnier a French dentist from Rouen. Le Monnier in 1766 cauterized and sutured the cleft edges successfully.[13] Cleft palate surgery then passed through a stormy period of uncertainty in the hands of giants like Ferdinand von Graefe[29] Roux, Dupuytren[25] Dieffenbach[9]andWarren.[32] Mucosal flaps and even lateral osteotomies were tried to move the hard palate medially.

In 1859 Von Langenbeck[30] emphasized the need to move mucoperiosteal flaps in a bipedicled fashion to repair the cleft palate **(Figure 14-1)**. And for this he must be given credit.

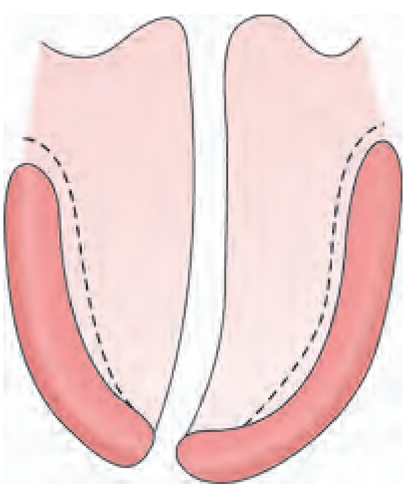


Figure 14-1: Langenbeck procedure.

This was a fundamental breakthrough, and with this the incidence of major breakdowns of the palate were reduced. Refinements then followed, Veau in 1931[28] parted from the bipedicled flaps of Langenbeck to single pedicled flaps based on the greater palatine vessels **(Figure 14-2).**

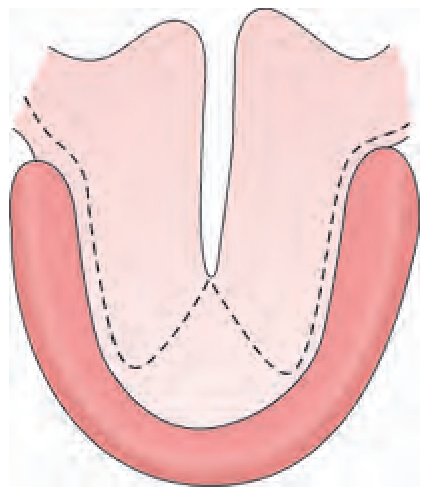


Figure 14-2: Veau Wardill V-Y retroposition procedure.

Veau talked about the importance of repairing the nasal lining of the palate and the need to lengthen the palate. In 1937 Wardill[31] and Kilner[15] working independently used a four flap procedure for the complete cleft palate. The weakness of the operation was a high fistula rate at the junction of the four flaps **(Figure 14-3)**.

In the 1940 Dorrance,[10] Cronin[7] and others used various flaps to lengthen the palate. In 1966 Millard[18] introduced his island flap based on the greater palatine vessel to lengthen the nasal lining. This was soon given up because it caused a collapse of the alveolus. Ravin Thatte[26] took two island flaps, one for lining and one for cover and used a tongue flap on the denuded hard palate. All these procedures were short lived in their popularity. However, special mention must be made of the buccal myomucosal flap originally called the cheek flap by

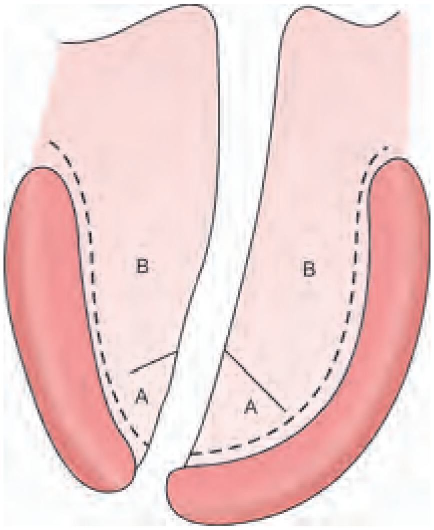


Figure 14-3: Wardill's four flap palate repair. (A represents the anterior flaps and B the posterior flaps).

Padget.[20] This flap was revived 30 years later by Murari Mukherjee[19] of Calcutta. He changed the direction of the cheek flap. Recently Ian Jackson[14] has been using it in all his cleft palates. It lengthens the nasal lining by 1 to 1.5 cm and he strongly believes that as a result he achieves better speech.

General Consideration

The cleft surgeon today is no longer a virtuoso. To get optimum results he must work in close conjunction with a team of specialists and they are the pedodontists, the orthodontists the maxillofacial surgeon, the ENT surgeon, the speech pathologist and the psychiatrist. The science and art of cleft surgery has become multi-disciplinary in nature. The surgeon must have a sound fundamental knowledge of the child's dentition and the bony foundations of the face.

The cleft lip and palate is a complex deformity and affects every function of the face except sight and even the sight is affected in an oro-ocular cleft. It affects speech, alimentation, hearing, taste and smell. It affects nasal breathing and facial expression, not to mention the child's psyche. A child with unintelligible speech is out of the main stream of life forever.

The speech problem has two main components, velo–pharyngeal incompetence and defects in articulation. To overcome velo-pharyngeal incompetence, it is imperative that the surgeon reconstructs a good functional palate. To overcome articulation defects malocclusion must be corrected by the orthodontist. Alveolar bone grafting pioneered by Abyholm, Bergland and Semb[1] in 1981 is an essential step before good orthodontics can be instituted. The proper time for bone grafting is during the period of mixed dentition when the canines and lateral incisors are erupting. The bone graft is like the soil through which the tooth erupts like a tree, and like the tree that holds the soil by its roots, so the tooth holds the bone graft in place. It's a symbiotic existence and so the operation should be properly timed usually between the age of 7 and 9 years. Recently, David Precious[24] has recommended alveolar bone grafting as early as 6 years of age.

Anatomy

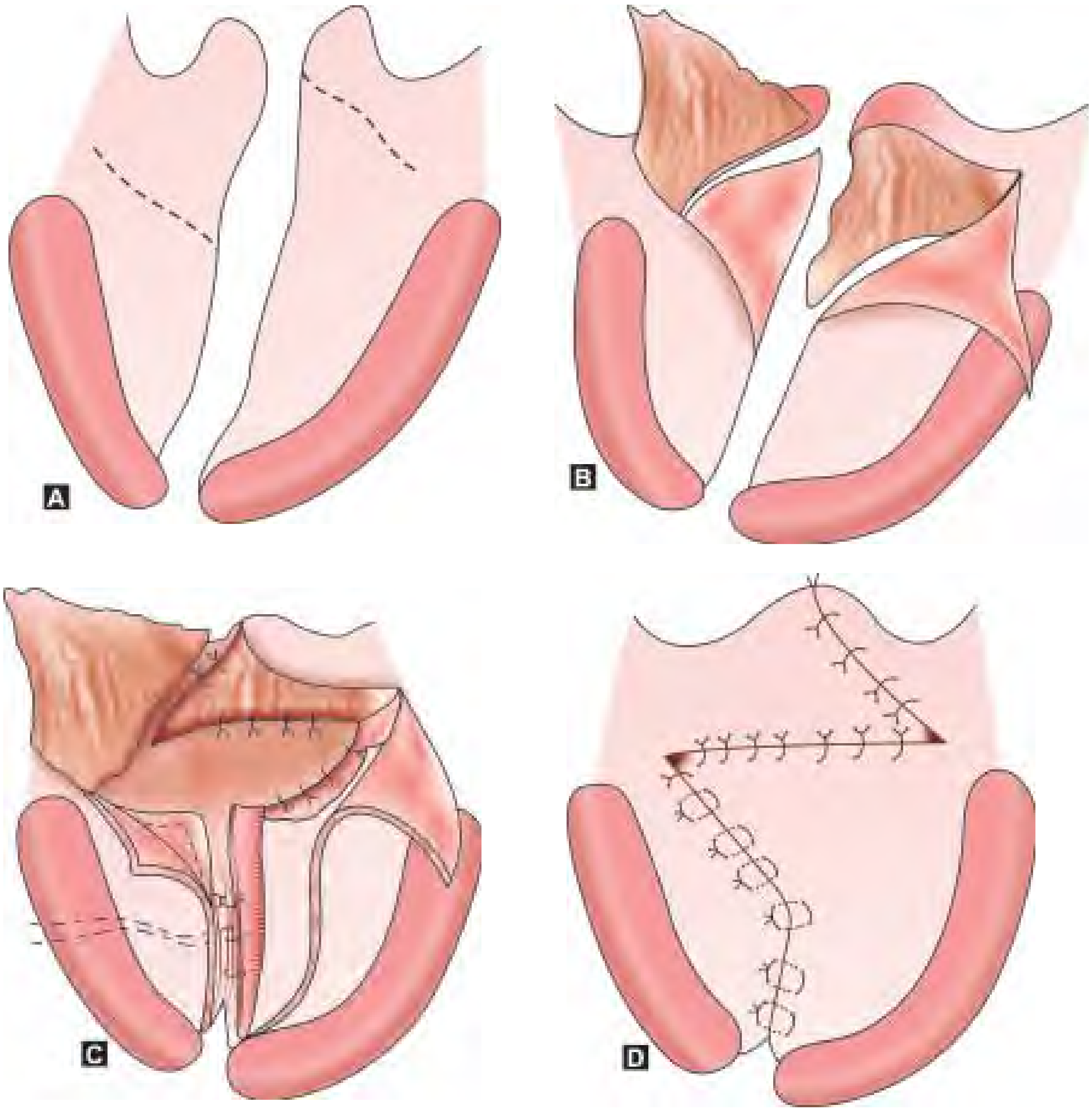
Kriens[16] and Braithwaite[3] focused the attention of cleft surgeons on the anatomy of the muscles of the palate. They postulated that the muscles must be moved into their normal position if they are to function efficiently and produce a good quality of intelligible speech.

All the muscles of the palate are paired. However their functions overlap—there are the muscles used primarily for speech, and there are those used primarily for deglutition.

The velopharyngeal sphincter is formed mainly by the levator palati aided by the muscularis uvulae anteriorly, the palatopharyngeus laterally and the superior constrictor posteriorly. It is this sphincter that controls nasality and it must be remembered that it takes just 1/10th of a second for this sphincter to open and shut, and this may happen about 20 times in a long sentence; one can imagine the fine neural coordination that must be in place for speech to be intelligible.

For all practical purposes the levator, the muscularis uvulae and the palato-pharyngeus raise the palate while the tensor and the palatoglossus depress the palate. In the cleft child it is mainly the levator palati which is in the wrong position; instead of lying transversely at the junction of the middle and posterior third of the soft palate, the levator runs longitudinally along the edge of the cleft and gets inserted into the posterior border of the hard palate. This was mentioned by Veau in 1931[28] Fara and Dvorak in 1970[11] and Kriens in 1975.[16] This repositioning of the levator in its proper position by an intravelar dissection is of prime importance in obtaining a good sphincter mechanism. Furlow[12] described a double reversing Z plasty that lengthens the soft palate and also moves the levator palati muscle posteriorly **(Figures 14-4A to D).**

Cleft palate deformities of various types and magnitudes can easily be recognized but the surgeon must be aware of the occurrence of rarer clefts like the submucus



Figures 14-4A to D: Furlow's double reversing Z plasty

cleft and the submucus occult cleft palate. Calnan[5] described the three criteria of a submucus cleft palate and these are a bifid uvula, a notch on the hard palate and the zona pallucida (blue line) running in the midline of the soft palate, suggesting that the levator palati are not crossing transversely to fuse with its fellow in the midline.

The submucus occult cleft looks like a normal palate from the oral aspect but on naso-endoscopy one sees a trough-like depression on the nasal aspect of the soft palate, suggesting again lack of or poor muscle union in the midline.[6]

The interesting features of these subtle deformities is that they can easily be missed by the casual observer, and that not all these children have a speech defect and therefore not all of them require surgery. The problem then arises as whether to operate or not to operate. And also, when to operate. There are two main schools of thought—the conservative school operates late when the child manifests velopharyngeal incompetence. The more radical school led by David David[8] believes that this might be too late for good speech results and therefore they operate on every case of submucus cleft deformity, perhaps subjecting many children to the trauma and the deleterious growth effects of unnecessary surgery. Vadodaria of Oxford[27] in a recent paper has suggested a high resolution CT scan or MRI to see if there is good levator muscle bridging across. If there is not, he advocates early surgery.

Nerve Supply of the Muscles of the Palate

With the exception of the tensor palati all the muscles of the palate are innervated by the vagus through the pharyngeal plexus. The tensor is innervated by a branch of the mandibular nerve. It is believed by Broomhead[4] that the muscularis uvulae is supplied by the lesser palatine nerve. The levator palati and the muscularis uvulae have a double nerve supply. They are also innervated by the facial nerve. Pigott[22] calls the facial nerve "the nerve of facial and vocal expression".

Classification of Cleft Palates

Victor Veau in his classic book,[28] Division Palatine (Paris, Masson et al 1931) describes four main types of palates:

i. A cleft of the soft palate only; this usually has a notch on the hard palate.
ii. A complete palatal cleft extending up to the incisive foramen. This cleft may be narrow but is usually wide and horse shoe shaped as in a Pierre Marie Robin sequence.
iii. A unilateral complete palatal cleft, involving the alveolus. The vomer in these cases is attached to the non-cleft side of the maxilla.
iv. A complete bilateral cleft of the palate and alveolus with a premaxilla jutting out and a midline vomer.

Timing for Surgery

The consensus of opinion today is that a cleft palate should be repaired nearer one year of age but not later than one year and four months.

The senior author has repaired palates at 9, 8 and 7 months but has found no obvious advantage except that the tissues move easier.

There are exponents who recommend repair at 6 months. Delaire[17] and his school repair the lip and soft palate at 6 months. They believed that the closed lip and the soft palate acts like an orthodontic strut and narrows the hard palate defect to a mere chink. This defect they close at 2½ years by a turn-in flap for lining and two small tramline Langenbeck flaps for cover **(Figures 14-5A and B)**.

Delaire believes that there are three zones in the palate; the gingival, the maxillary and the palatine. The growth centers lie in the two outer zones, and since in the Delaire operation only the palatine zone is vitiated, there will be minimal maxillary growth disturbance.

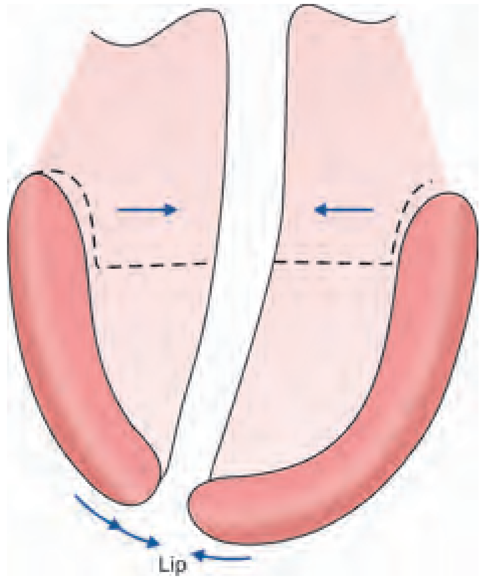


Figure 14-5A: Delaire stage I soft palate and lip repair.

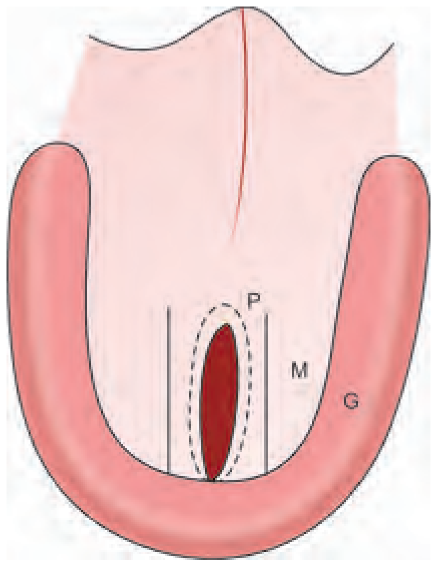


Figure 14-5B: Delaire stage II hard palate closure.

Feeding

A specially trained nurse for counselling the mother on feeding is a great asset specially at the first consultation. If not properly instructed, the mother will present an exhausted and malnourished child for surgery.

A few partial cleft palate children can generate enough negative pressure in the mouth to breast feed without exhaustion.

Most cleft palate children cannot breast feed and they must be fed either with a bottle with a cross cut nipple or with an indigenous feeding cup called a "Palada" or a "gokarna"**(Figure 14-6)**.

Figure 14-6: Palada—Traditional feeding device

There are however now special feeding bottles called the Habermann's bottle made by Medela and available in India. The child should be fed cradled in the mother's arm at an angle of 45º so that milk does not escape into the nasopharynx. A cleft child tends to swallow more air while feeding than a normal child and therefore must be burped more often during feeding than a normal child.

Expressed breast milk must be given as long as possible for reasons of transferring maternal immunity to the child. Undiluted cow's milk is a good second alternative or the mother can give one of the formulas available in the market but this must be properly reconstituted according to instructions on the box (usually it is one measure of powder to one ounce of water) **(Table 14-1)**. In this respect bad mistakes can be made by an ignorant mother. An indication of adequate feeding is appropriate weight gain. A feeding plate or an obturator is not recommended.

All children must be completely immunized and given a supplement of vitamins and iron drops so that the children come up for surgery with a Hb of 11 to 12 gm, blood transfusion as far as possible should be avoided.

Table 14-1: Feeding chart for cleft lip and palate children

Do not heap infant feed formula spoon, fill level, Add 30 ml, (1 oz) of warm water for every infant feed formula spoon of powder, reduced feed, if necessary when baby starts on solid food

Age	*Weight*		*Infant feed formula spoons per FAD*	*Feed OZ*	*Feeds per day*
	Lb	*kg*			
Birth	7	3.5	2	2	6
1 week	7	3.5	2	2	6
2 weeks	7	3.5	3	2	6
3 weeks	7	3.5	4	4	6
1 month	8	4	4	4	6
2 months	9	4.5	5	5	5
3 months	11	5.5	6	6	5
4 months	13	6.5	7	7	5
5 months	14	7	7	7	5
6 months	15	7.5	8	8	5
7-12 months	16-20	8-10	8-9	8-9	5

After first month give baby fruit juice, preferably Orange juice one teaspoon full a day, increasing a teaspoon full every month. A cleft baby swallows a lot of air so burp baby twice during feeds and once after feeds

All children to be fully immunized by your pediatrician. Keep children away from those who have respiratory infections specially before surgery.

If you are giving cow's milk **DO NOT ADD WATER**. Upto 5 months use infant feed formula I. After 5 months use infant feed formula II.

Anesthesia

Cleft surgery is elective surgery and mortality is unacceptable. All cases must be properly evaluated by the surgeon and a pediatrician. A cardiology clearance may be necessary if the baby has a congenital cardiac defect. A plain X-ray of the chest is mandatory. Blood examination for Hb, WBC, Urine, Bleeding and Clotting time and platelet count must be done. If there is a cardiomegaly or a cardiac murmur, an echocardiogram is a must. Pulmonary hypertension and a right to left shunt are ominous findings. Regarding fitness for surgery, after all the above, the anesthetist must have the last word as he/she bears the full responsibility for the child's safety on the table.

An experienced, vigilant pediatric anesthetist is a must on every cleft team. Proper instrumental and hands-on monitoring of the baby is imperative. We have often said that anesthesia in children is like flying an aeroplane; most accidents take place at take-off and landing; therefore the surgeon should be in the theater for the induction and extubation of the child. All extubation should be done when the baby is wide awake—this avoids breath holding spasms. Red rubber tubes are to be avoided as they cause laryngeal edema. In case laryngeal edema develops parenteral steroids and nebulization with racemic epinephrine must be started immediately. When in doubt intubate, when in doubt do a tracheostomy. Hesitation can lead to disaster. Be conscious of the possibility of esophageal intubation, disconnection of the airway on table and inadvertent pulling out of the endotracheal tube during surgery. A metallic Magill's connection is kept on the teeth so that the tube is not compressed on opening the mouth gag. Obstructive breathing on table can lead to distressing pulmonary edema in the immediate postoperative period. All children after surgery must be in a dedicated intensive care unit overnight. We recommend small feeds on day one to avoid postoperative vomiting during those silent though often tragic hours between midnight and dawn.

Anesthesia and Positioning

The procedure is performed under GA with endotracheal intubation using RAE tubes. The child is then placed with a good extension of the neck aided by a pillow under the shoulder. The operator sits at the head of the table. Kilner used to operate with the child's extended head on his lap![15] The mouth is cleaned well with povidine iodine solution.

Infiltration

A solution of 1:200,000 adrenaline with 1% lignocaine is infiltrated using a dental syringe under the mucoperiosteum on both sides and at the site of the lateral incisions posteriorly.

Procedure

We use the 2 long flap procedure popularized in India by Charles Pinto[23] and described by Bardach.[2] Incisions are as shown in the **Figure 14-7.**

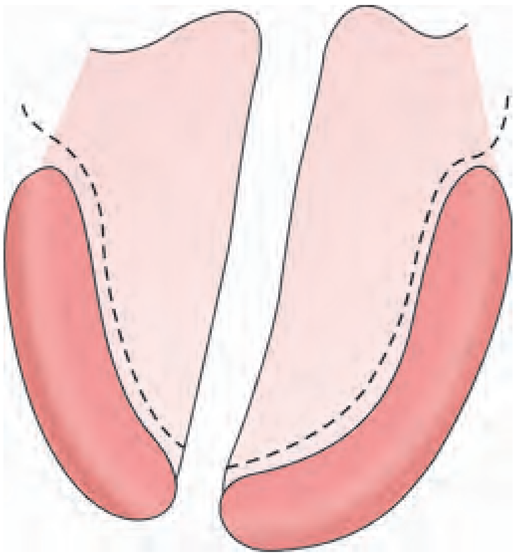


Figure 14-7: Pinto Wardill (Bardach) 2 long flap procedure.

The cleft edges are pared using a No.15 scalpel **(Figure 14-8)**. The lateral incisions are then made on both sides starting from the maxillary tuberosities and extending posteriorly till the retromolar area.

The medial pterygoid muscle on the lateral aspect and the tensor and levator veli palati on the medial aspect are identified. The Pterygoid hamulus is also identified and fractured medially and detached completely from its attachment to the medial pterygoid plate **(Figure 14-9)**. An attempt is then made to bare the medial pterygoid plate.

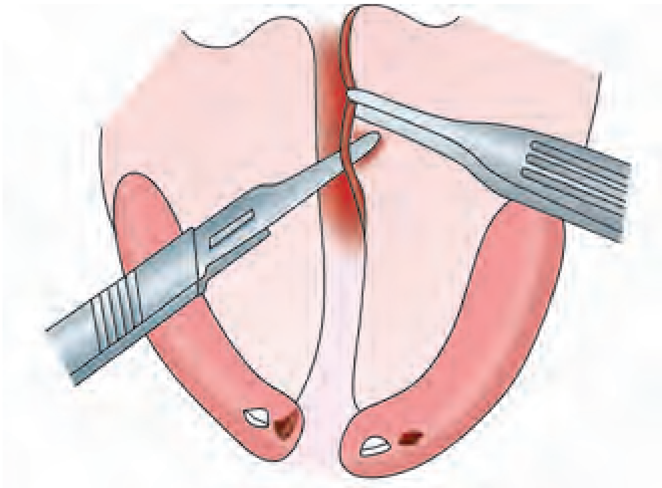


Figure 14-8: Paring of edges.

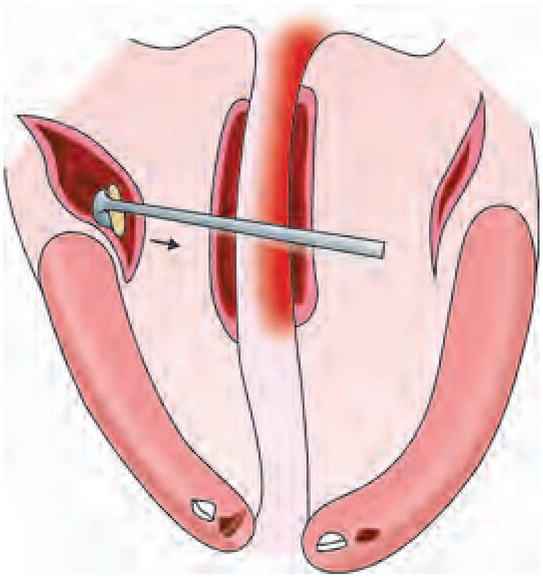


Figure 14-9: Fracture of the pterygoid hamulus.

The lateral incision is then extended anteriorly to the whole length of the palate. The mucoperiosteal flap is raised off the underlying hard palate using a Kilner's palate elevator **(Figure 14-10)**.

The medial paring incision is extended throughout the whole length of the palate and the medial and lateral incisions are connected anteriorly, thus creating the long mucoperiosteal flap. This is elevated off the palatine bone until the posterior edge of the hard palate is reached **(Figure 14-11)**.

Then, an instrument called "The Plastic", which is a part of the dentist's armamentarium is used to define the plane between the medial surface of the medial pterygoid palate and its muscular attachments **(Figure 14-12)**.

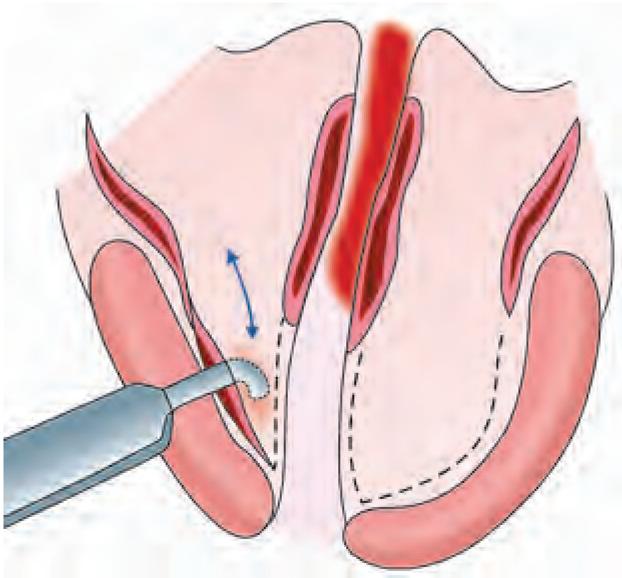


Figure 14-10: Elevation of the oral flap with Kilner's elevator.

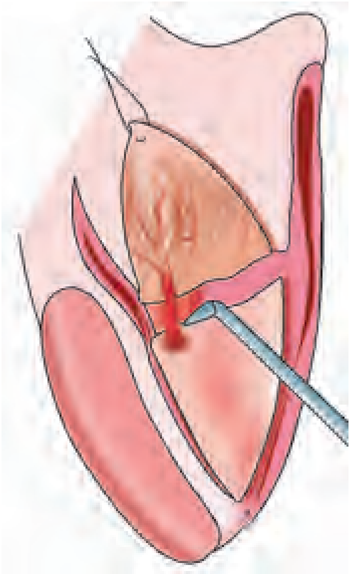


Figure 14-12: Medial pterygoid plate dissection.

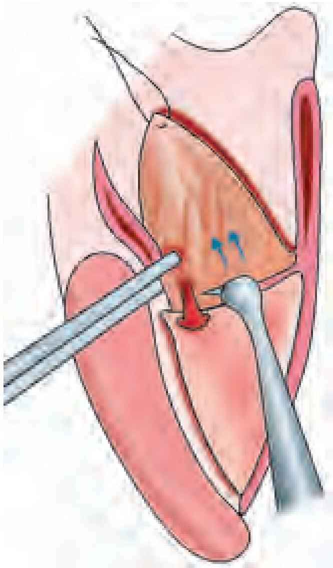


Figure 14-11: Completion of elevation of oral layer.

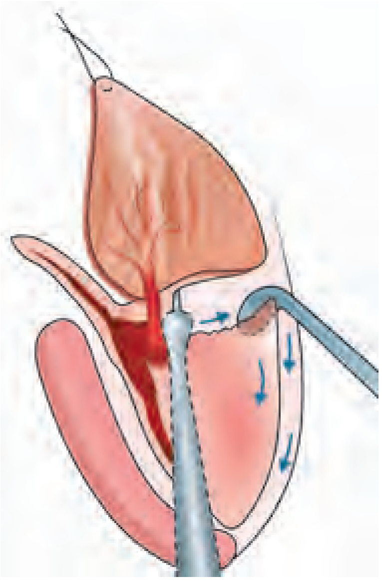


Figure 14-13: Dissection of nasal layer.

This plane is then developed further by dissection with a Mitchell's trimmer or "Cumine scaler" up to the opening of the Eustachian tube. Once the medial pterygoid plate is bared, the instrument is turned anteriorly, stripping the mucosa, i.e. the nasal layer, off the medial edge of the palatine shelf in one clean sweep **(Figure 14-13)**.

This dissection is then completed by using a Wallace Finisher in the same plane **(Figure 14-14)**.

This was the technique used by Kilner [15] and then by his trainees including Eric Peet.[21] However, at some point in time, this has been discontinued. Instead, most surgeons nowadays, try and dissect the nasal layer of the palatine shelf directly and in the process, often cause tears in the nasal layer. However, if one were to follow the original Kilner- Peet technique, then the nasal layer dissection is easy and tears can be avoided consistently. We then proceed with the dissection of the Greater Palatine vessels. The cone of periosteum around the vessel is incised behind and away from the vessel and the vessel is skeletonized **(Figure 14-15).**

The Lesser Palatine vessel is also identified and divided to enable complete mobilization of the flap. The greater palatine artery is then pulled out of the greater palatine foramen as Kilner used to say "like a bird pulls a worm out of a hole"**(Figure 14-16)**.

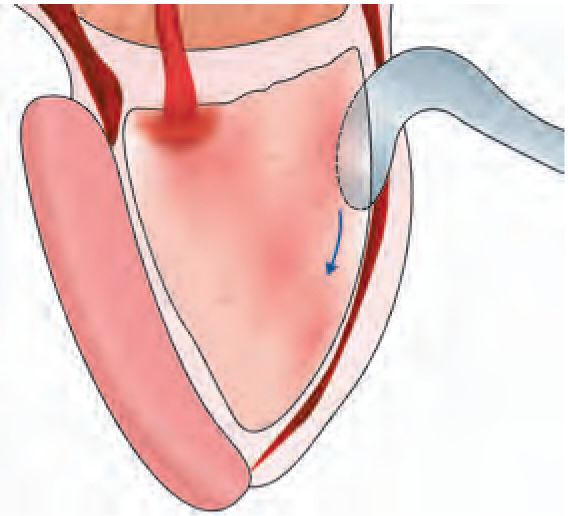


Figure 14-14: Completion of nasal layer dissection with Wallace's finisher.

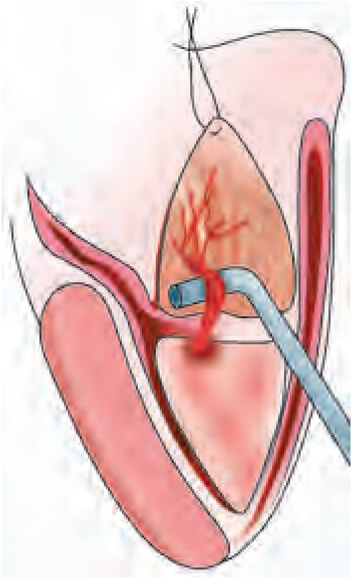


Figure 14-16: Hooking out the greater palatine vessels.

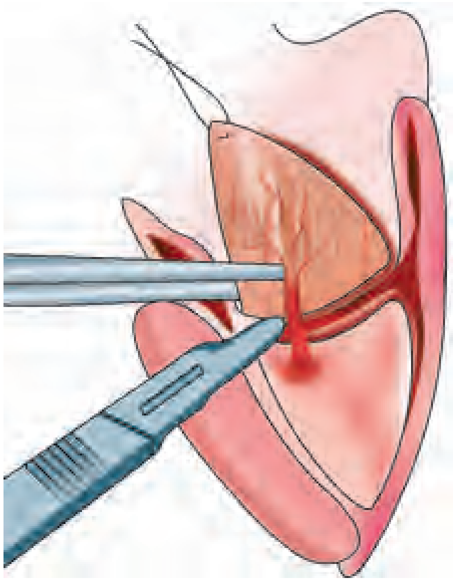


Figure 14-15: Incising the periosteal cone to free the greater palatine artery.

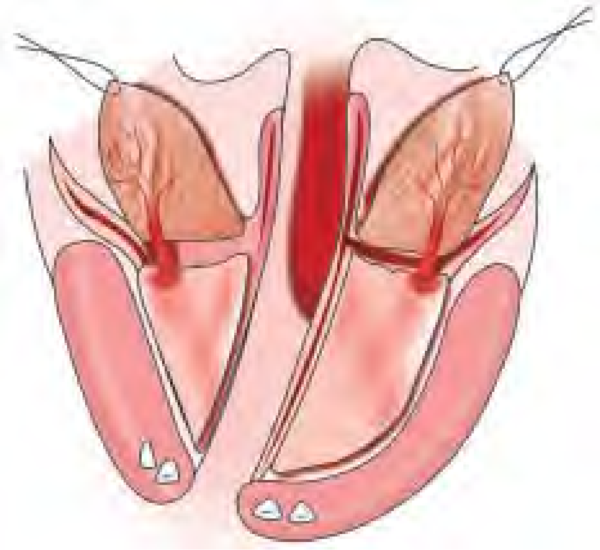


Figure 14-17: Complete dissection of the oral and nasal layers.

A similar procedure is then carried on the other side, mobilizing the long mucoperiosteal flap based on the greater palatine vessel **(Figure 14-17)**.

The Use of the Vomerine Flap

In all complete cleft palates, the vomerine flap is used. After the mucoperiosteal flap is raised on the non-cleft side, the Kilner's palate elevator is carefully introduced beneath the vomerine mucosa as well to raise the vomerine flap. Only then is the paring incision made on the medial edge of the hard palate. The vomerine incision is then carried posteriorly **(Figure 14-18)** to enable the

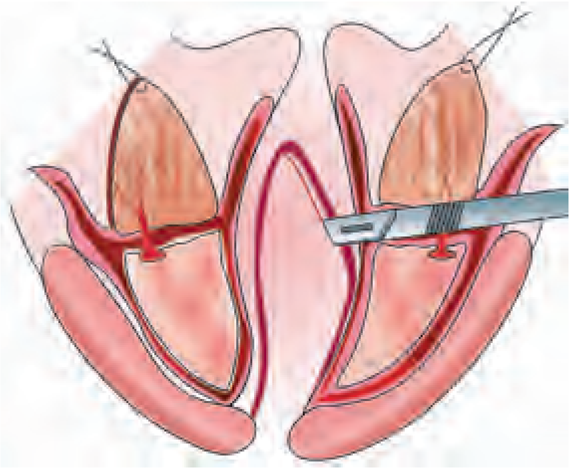


Figure 14-18: Posterior incision on the vomer.

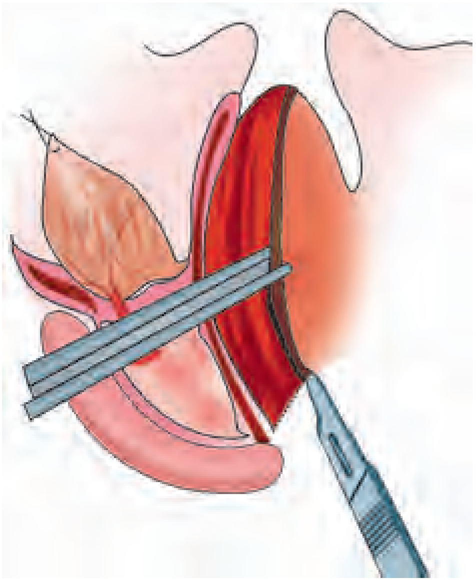


Figure 14-19: Anterior back-cut on the vomer.

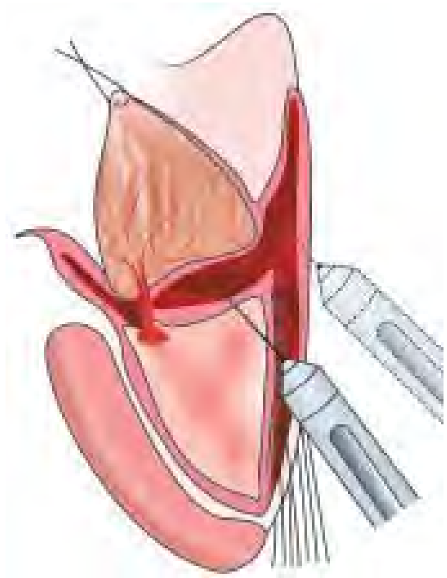


Figure 14-20: Infiltration of adrenaline beneath the palatine aponeurosis.

vomerine flap to be turned over to reach the nasal layer on the cleft side without tension. Sometimes a back-cut is also necessary anteriorly **(Figure 14-19)**.

In a cleft palate with a central vomer, the latter is used based on the need and its availability. In narrow clefts, it is not necessary even if it is easily accessible. In a wide cleft, it should be used if it is within easy reach – in that case, a midline incision is carefully made on the vomer and two vomerine flaps are raised to suture to the corresponding nasal layer (on either side). However, in some cases, the vomer is receding and one is unable to use it.

In clefts of intermediate width, there is often a dilemma on whether to use the vomerine flap or not. We believe that one should use the vomerine flap when in doubt, bearing in mind of course that the use of the vomer enhances maxillary regression.

Suturing

The suturing of the nasal layer is then commenced using 3-0 chromic catgut. The ends are left long and fixed to the suture carrier and tied with the knots on the nasal side. Once the suture just proximal to the hard and soft palate junction is placed, the levator muscle dissection is performed.

Radical Levator Palati Dissection and Retroposition

Using a dental syringe a solution of 1:200,000 adrenaline is infiltrated just above the mucosa on the soft palate under the palatine aponeurosis on both sides **(Figure 14-20)**.

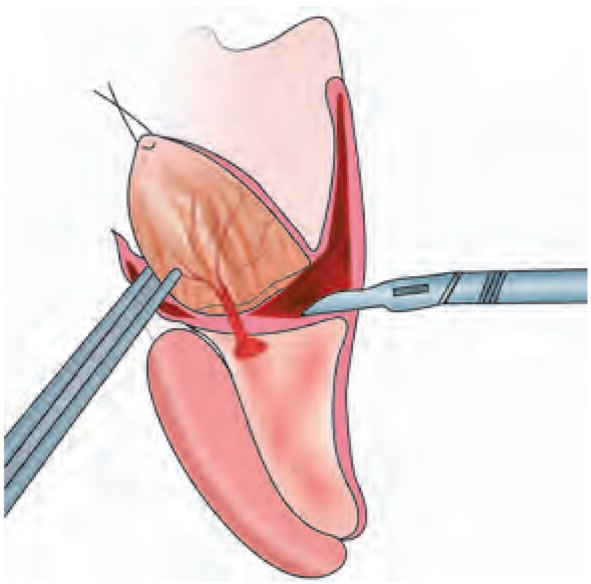


Figure 14-21: Incision of the palatine aponeurosis.

Next a transverse incision is made on the palatine aponeurosis just beyond the hard palate **(Figure 14-21)**.

This incision is deepened until just short of the mucosa, which appears blue. Then the bulk of the muscle, which is the levator palati, is dissected off till it reaches the junction of the middle and posterior third of the soft palate. This procedure is repeated on the other side, thus providing a good muscle bulk bilaterally to produce a good levator sling **(Figure 14-22)**.

The extent of this levator dissection varies according to different surgeons. Some separate the muscle off both

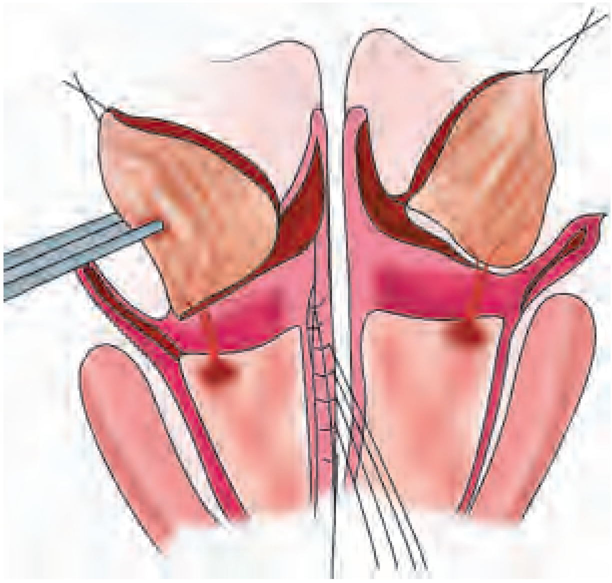


Figure 14-22: Complete dissection and retroposition of the levator palati muscle.

the nasal and oral layers, while others, like us, only separate it off the nasal layer. Sutures are placed until just short of the uvulae; that has so far not been pared. The last nasal layer suture that has been held on the suture carrier steadies the uvula at one end. With the operator and the assistant holding the edges of the uvula, the uvula is pared. This is repeated on the other side. Not a millimeter of tissue is excised.

Next, a mattress suture is placed at the base of the uvula on the nasal layer with 4-0 vicryl **(Figure 14-23)**.

The apices of the uvular halves are then sutured together using a mattress suture of 4-0 Chromic catgut.

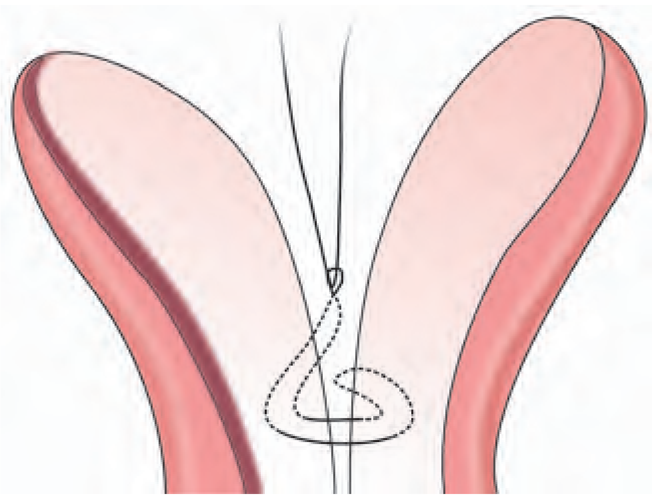


Figure 14-23: Mattress suture at the base of uvula.

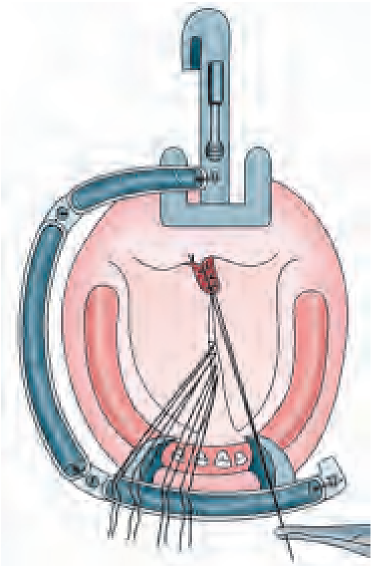


Figure 14-24: Apical suture on uvula turned over and posterior sutures placed.

One end of this suture is kept long and the uvula is turned over. The nasal aspect of the uvula is now exposed and two or three simple sutures are placed with 4-0 chromic catgut **(Figure 14-24)**.

Then the apical suture is trimmed. Two mattress sutures of 4-0 chromic catgut are placed on the anterior surface of the uvula completing the uvular reconstruction **(Figure 14-25)**.

This elaborate technique is necessary for the uvular repair as the uvula is a flimsy and a floppy structure with the repair tending to breakdown quite easily unless a

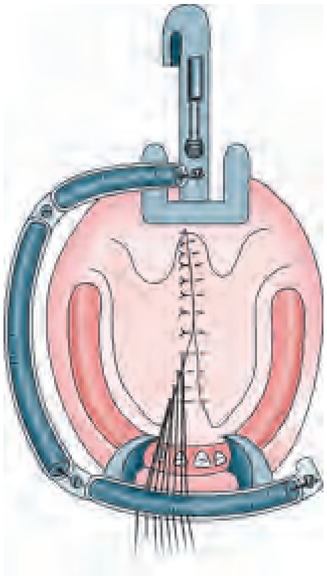


Figure 14-25: Completion of uvular reconstruction.

meticulous technique is used. The uvula has both a cosmetic and functional value. This method of repair has been used by the senior author for many years now and ensures a good uvular reconstruction.

Further Suturing

The nasal layer sutures that have been held on the suture carrier are then tied from behind forwards, taking care that the knot is on the nasal aspect.

The exception to this is the so-called "A Stitch" at the junction of the hard and soft palate.[21] This is not tied at this stage. Instead, the ends are crisscrossed and brought through the oral layer and then tied, thus firmly anchoring the oral to the nasal layer.

The suturing of the oral layer commences posteriorly just proximal to the uvula upto the "A suture". Each suture takes a tiny bite on the nasal layer to eliminate dead space and is mattressed. The long nasal layer sutures anterior to the A suture are brought out through the oral layer and sutured as mattress sutures. This anchors the flap to the underlying nasal layer, thus preventing the anterior flap from being sucked into the mouth creating the complication of what is called a "fallen palate".

Lateral Raw Areas

After all the sutures have been tied, the lateral raw areas are sutured with slight tension for hemostasis. No attempt is made to completely close the raw areas in wide clefts, as this would cause tension at the suture line **(Figure 14-26).**

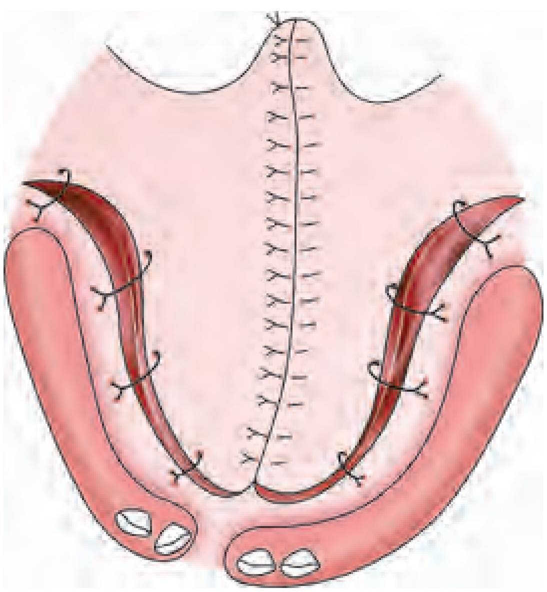


Figure 14-26: Completed suturing of the palate and the lateral raw areas.

A deep tongue stitch is always placed far back at the end of the procedure.

This is a safety protocol, enabling the tongue to be pulled out in case of respiratory obstruction in the post-operative period.

Early Postoperative Complications

1. Postoperative bleeding.
2. Respiratory obstruction leading to anoxia and cardiac arrest.
3. Vomiting followed by aspiration pneumonia or anoxia and death.

Prevention of Complications

1. Postoperative bleeding: Every attempt must be made on the table to arrest all oozing, judicious and careful use of cautery is permissible and Surgicel® or Gelfoam® can be used if necessary. The use of styptics like Uniheal® is recommended.
2. Obstructed respiration leading to anoxia and cardiac arrest. This is the commonest cause of postoperative death in cleft-related surgery. A tongue stitch placed deep and way back on the tongue in all oral surgery in children is a real life-saver. Frequent rounds by the operating team can detect early signs of obstructive breathing. Adequate steps to relieve the child should be taken without delay.
3. Vomiting followed by aspiration, leading to pneumonia and even anoxic death. We have made it a rule to give small feeds (half the usual quantity) on day one after surgery. The staff nurse in the intensive care is drilled to cope with this emergency. A big child is turned on his side, head lowered and the mouth aspirated. A small baby is picked up by its feet, turned upside down and thumped on the back. These are life-saving measures. In the ICU there must be a trained person who can intubate a baby. To send for an anesthetist to intubate a child who has stopped breathing is an exercise in futility and can only be a face-saving measure.

Speech

Perfect speech is the ultimate aim of the cleft surgeon, and this is often unattainable in all cases. The surgeon could compromise with acceptance of good intelligible speech with minor nasality

There are two aspects that contribute to bad speech, velopharyngeal incompetence and faulty articulation. The former is due to the inability of the surgeon to reconstruct a good sphincter either due to poor surgery or a very capacious pharynx. Articulation defects are due to poor alignment of teeth and must be corrected by orthodontics or in extreme cases by orthognathic surgery. A good speech therapist is an integral member of a cleft team. The authors believe that too much must not be expected from the speech therapist—they have their limits. Speech therapy is still a fluid science, nothing is carved in stone. Gross velopharyngeal incompetence is a surgical problem and as Ian Jackson says "It is like cancer - it never gets better"[14] so there is no point in persisting with speech therapy, one has either to go in for a redo palate or perform one of the pharyngoplasties guided though not ruled by naso-endoscopy findings.

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Chapter

15

R Gunaseelan, P Anantanarayanan

Introduction

Bone grafting of the alveolus has become an essential part of the contemporary surgical management of cleft deformities. While the concept of grafting of the cleft maxilla was introduced in the early 1900s, it was not widely recognized until a half century later. Beginning in 1955, successful cortical grafting of maxillary clefts in both infancy and later childhood was reported in Europe. Since then, alveolar cleft grafting has continued to grow in both popularity and success and is now generally acknowledged to be integral to the management of the cleft patient. The benefits and goals of this procedure are well understood and include the stabilization of the maxillary arch, elimination of oronasal fistulae, creation of bony support for subsequent tooth eruption, and reconstruction of the hypoplastic pyriform aperture and the soft tissue nasal base support. There are different techniques and philosophies involved in alveolar bone grafting, but secondary grafting with iliac marrow is the current gold standard. It requires good orthodontic work-up, meticulous planning and preoperative arch alignment. Its high success rate currently makes it the most practised method. The scope of this chapter is to discuss the management of the alveolar cleft in general and the technique of secondary alveolar bone grafting, advances and complications associated with it.

Incidence and Etiology

Among the many congenital birth defects, there have been more than 250 different types of facial clefting disorders described in literature. The most frequently reported defect is clefting of the palatine bone and the alveolar process of the maxilla. The overall incidence of cleft lip and palate is reported at 1:800 live births in India. The location of the clefting is usually on the left side of the maxilla (left:right:bilateral = 6:3:1). Out of the various combinations of isolated cleft lip, isolated cleft palate, and cleft lip and palate, the cleft lip and palate is the most common in occurrence. In 75% of cleft lip and palate occurrences, the cleft involves the alveolus.

Table 15-1: Historical perspective

Year	*Author*	*Contribution*
1908	Lexer	Free bone grafts
1914	Drachter	Bone grafts to alveolar cleft
1931	Veau	Classification and attempt at tibial graft to cleft palate
1955	Nordin et al	Early alveolar cleft repair with autogenous bone
1968	Jolley	Detrimental effects of early bone grafts on maxillary growth
1972	Boyne and Sands	Protocol for secondary bone graft
1983	Wolfe et al	Favorable results with calvarial bone
1987	Nique, Fonseca	Alveolar graft with allogenic bone

Incidence of Cleft Lip and Palate

Cleft lip	0.29 per 1000
Cleft palate	0.31 per 1000
Cleft lip and palate	0.48 per 1000

It is currently believed that less than 40% of clefts of the lip and palate are of genetic origin. Environmental factors play a clear role in gene expression, which affects the phenotype. The various environmental factors identified are:

1. Maternal smoking
2. Maternal malnutrition

3. Drugs taken during the course of pregnancy. Example: Antiepileptic drugs
4. Maternal alcohol consumption
5. Infections (rubella and toxoplasmosis) during pregnancy and
6. Growth factor deficiency.

Clinical Features of an Alveolar Cleft

The cleft alveolus can never exist alone and usually co-exists with an isolated cleft lip or as a composite cleft lip, palate and alveolar deformity. The various clinical features associated with a cleft alveolus are:

1. Persistent palatal or nasolabial fistula with nasal discharge and regurgitation
2. Inability to produce positive pressure in the mouth like blowing balloons or suck a straw
3. Poor speech and articulation problems
4. Deformed teeth, missing or supernumerary teeth in the area of the cleft
5. Dental malocclusion with cross-bites and collapse of the dental arch
6. Deformed, missing teeth and poor oral hygiene with periodontal problems
7. Mobility and overgrowth of the premaxilla in the bilateral case
8. Lack of support for the alar base of the nose and lip in the unilateral case
9. Lack of support for the alar base, columella, and lip in the bilateral case.

Rationale for Grafting

- Grafting achieves stability of the arch and prevents collapse of the alveolar segments. This provides improved orthodontic stability.
- Grafting preserves the health of the dentition. It provides room for the canine and lateral incisors to erupt into the arch into stable alveolar bone and maintains bony support of teeth adjacent to the cleft.
- Grafting restores continuity not only of the alveolus, but also of the maxilla at the pyriform rim. This lifts the alar base and provides support for the nose. This may have a direct esthetic benefit and may also provide a stable platform for a formal rhinoplasty procedure later.
- To facilitate the reconstruction of the nasolabial musculature and establish a functional nasal airway.
- Palatal and nasolabial fistulas are often present even following palatoplasty. Grafting of the alveolar defect provides an opportunity for the surgeon to address the residual oronasal fistula. This may have potential benefit for both hygiene and speech. Many cleft patients present with chronic upper respiratory and sinus disease, which may be related to reflux into the nasal cavity. There is some evidence that the residual fistula, whether labial or palatal can have an effect on speech, articulation and nasality. There is also evidence that closure of the fistula and grafting the cleft defect can improve nasal emission and nasality.

Philosophies in Alveolar Bone Grafting

Bone grafting of the alveolus is very essential in reconstruction of the orofacial cleft. The two major schools of thought in alveolar bone grafting in terms of the timing of bone graft placement are primary and secondary bone grafting. The terms primary (younger than 2 years of age), early secondary (between 2 and 5 years of age), and secondary (greater than 5 years of age) are typically used. These terms are based on patient age and ultimately represent the interaction of bone grafting surgery on maxillary growth and dental development. Primary grafting with rib results in a unified maxilla, eliminates the oronasal fistula, and does not adversely affect midfacial growth. It assists in preventing maxillary segmental collapse, particularly in the bilateral cleft patient. Secondary grafting with iliac marrow consistently produces trabecular bone to unify the maxilla and provide odontogenic support. It requires preoperative maxillary alignment, well designed mucoperiosteal flaps, and good oral hygiene to be optimally successful. It however is considered to be the gold standard in contemporary alveolar cleft management.

< 2 Years of Age: Primary Grafting
After lip repair
Before palate repair

Above 2 Years of Age: Secondary Grafting
Age in years
2–5: Early secondary
6-12: Secondary
>12: Late secondary grafting.

Surgical Procedures

Currently, the surgeries of primary and secondary alveolar cleft grafting represent two methods with similar objectives but vastly different surgical techniques. While secondary grafting remains by far the most common approach, primary grafting has less advocates but is increasingly becoming popular.

Primary Bone Grafting

The principal aim in primary alveolar grafting is to prevent significant transverse maxillary collapse and occlusal distortions between the upper and lower arches. Ideally this early stabilization decreases the time period of orthodontic treatment in the transitional and adult dentition periods as well as the eventual need for orthognathic surgery. In addition, the early obliteration of the alveolar oronasal fistula eliminates nasal liquid escape and improves oral hygiene in the preschool and early school periods. With this technique, all complete clefts are fitted with a maxillary obturator appliance. The obturator's dynamic purpose is to orthopedically align the maxillary segments before surgery. Typically, good segmental alignment occurs between 9 and 12 months of age dependent upon the original cleft width. The surgical technique for primary bone grafting is relatively simple and is a procedure of limited dissection that steers clear of the important midfacial growth region of the premaxillary-vomerine suture with buccal placement of an onlay rib graft.

Secondary Bone Grafting

The principal aim in secondary bone grafting is to unify the maxilla and create an osseous environment that will support tooth eruption into the arch. Typically, this procedure is undertaken at the stage of the transitional dentition (when the canine root is still incompletely formed) and in conjunction with orthodontic therapy. While small amounts of maxillary segmental alignment can be done postoperatively, it is best to attempt to optimize maxillary arch alignment before graft placement. This will usually involve varying degrees of transverse maxillary expansion, which occasionally may need to be assisted surgically through lateral maxillary corticotomies. One of the most crucial surgical issues in secondary grafting, albeit often overlooked, is the flap design. It is important to use gingival mucoperiosteal flaps for the success of this procedure. Unlike labial-based flaps, it can support tooth eruption and provide the proper periodontal qualities to sustain their longevity once in proper position in the arch. Grafting of the cleft is accomplished with cancellous bone from the ilium or tibia or corticocancellous particulate bone from the calvarium or mandibular symphysis.

Alveolar reconstruction with grafting during the eruption of the permanent dentition may be best for various reasons. The reasons for grafting and the choice for timing of grafting during this time period include the following:

1. There is minimal maxillary growth after age 6 to 7 years, and the effect of grafting at this time will result in minimal to no alteration of facial growth.
2. Cooperation with orthodontic and perioperative care is predictable.
3. The donor site for graft harvest is of acceptable volume for predictable grafting with autogenous bone.
4. Bone volume may be improved by eruption of the tooth into the newly grafted bone.
5. Grafting during this phase allows placement of the graft before eruption of permanent teeth into the cleft site, which achieves one of the primary goals of grafting— to enhance the health of teeth in and adjacent to the alveolar cleft.

Grafting Material and Donor Sites

Numerous variables affect the decision-making process in choosing an appropriate donor site for alveolar cleft bone grafting, including factors such as the size of the cleft, the volume of bone needed, whether teeth will erupt through the graft material, the health of the donor site, and the healing potential of the patient. The various donor sites and grafting materials along with their advantages and disadvantages are enumerated in **Table 15-2**.

Presurgical Orthodontic Care

Two major orthodontic considerations intimately integrate with the timing of the alveolar cleft grafting:

1. The correction of cross-bites, and
2. Alignment of the anterior teeth.

If posterior cross-bites exist secondary to narrowed transverse dimension of the maxilla, maxillary expansion may be performed before grafting. If the graft is performed before the expansion of the maxilla, a 3-month period must elapse before this expansion. If a bilateral cleft exists with a premaxilla, the maxilla must be expanded first before distalization of the premaxilla to ensure proper space. The Quadhelix and Hyrax appliances that are usually used for maxillary expansion should be left in place for at least 3 months postoperatively to help prevent relapse. It is critical that the orthodontic alignment of the anterior teeth be attempted with great care to avoid root exposure through the thin alveolar bone in the cleft region.

Table 15-2: Advantages and disadvantages of various graft material

Donor site/grafting material	*Advantages*	*Disadvantages*
Autogenous: greatest number of viable osteoprogenitor cells, which allow for early revascularization (osteogenic, osteoconductive, osteoinductive)		
Iliac crest	Adequate quantity (uni- and bi-) Easily condensed and placed Proven successful results Little donor site morbidity Two-team approach	Questionable effects on growth Possible gait disturbance Postoperative hematoma Donor site morbidity
Tibia	Adequate volume (uni- and bi-) Quality similar to iliac crest Predictable results Two-team approach	Concern with ambulation and epiphyseal injury
Rib	For infants Two-team approach	Donor site morbidity Unpredictable results
Cranial bone (corticocancellous block graft)	Adequate quantity (uni- and bi-) Less resorption (membranous bone) Rapid vascularization Two-team approach	Donor site aesthetics/defect Stigma and fear for patient Less cellular component
Mandibular symphysis	Quantity adequate for uni- Less resorption (membranous bone) No external scars	Limited amount of bone
Allogenic: derived from a genetically unrelated member of same species (osteoconductive, osteoinductive)		
	Comparable to autogenous Allows for eruption of teeth Avoids donor site morbidity	No osteogenic potential Delayed incorporation
Alloplastic: inert foreign body material (osteoconductive, osteoinductive)		
	Avoids donor site morbidity	Delayed healing Inability of teeth to erupt

Surgical Technique (Figures 15-1 to 15-5)

The surgical procedure of alveolar bone grafting should satisfy three main requisites for the successful treatment of the alveolar cleft:

1. Closure of residual oronasal fistula,
2. Optimal reconstruction of the alveolar ridge dimension aiding the proper eruption of the permanent canine or lateral as involved, and
3. Water tight and tension-free closure ensuring maximum take of the grafted bone.

The preoperative evaluation and planning by the surgeon should consider the type of cleft involved unilateral or bilateral, the amount of mucosa available for closure, the best flap design to maintain adequate blood supply and tension-free closure, the extent of the oronasal communication, the bony support needed for the lateral pyriform rim and the alar base, and the donor site selection. The various donor sites have been elaborated earlier; however, the particulate cancellous marrow bone from the ilium is the gold standard.

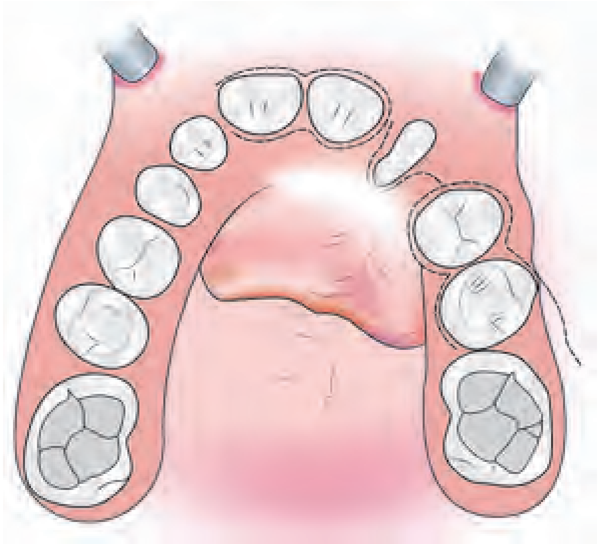


Figure 15-1: Outline of incision for alveolar bone grafting encircling the residual oronasal communication.

The procedure is performed under general anesthesia. Orotracheal intubation either with a pre-formed RAE tube or regular orotracheal tube tucked to the opposite side commissure is preferred. A throat pack can be used to

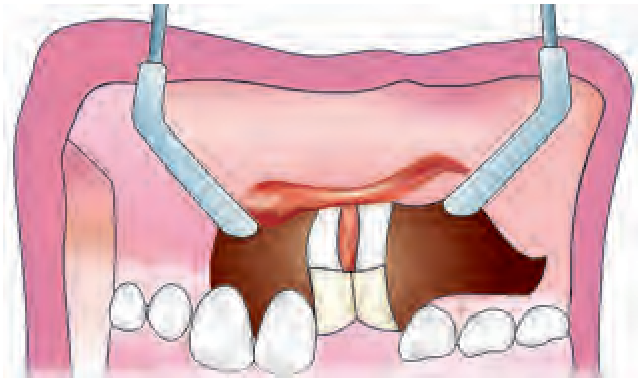


Figure 15-2: Reconstruction of palatal layer with closure of oronasal communication forming recipient bed for the bone graft.

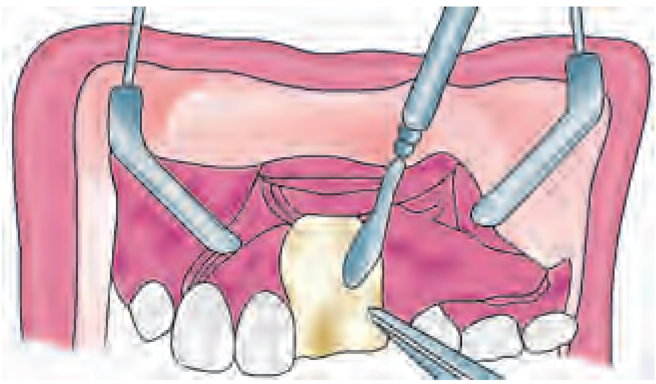


Figure 15-3: Packing of bone graft in the prepared site and condensing with manual pressure.

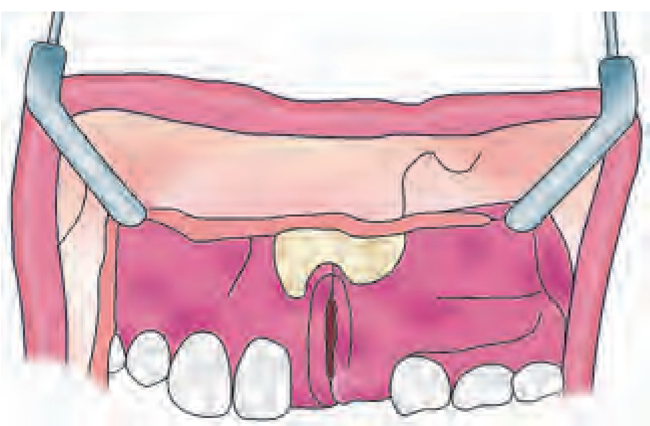


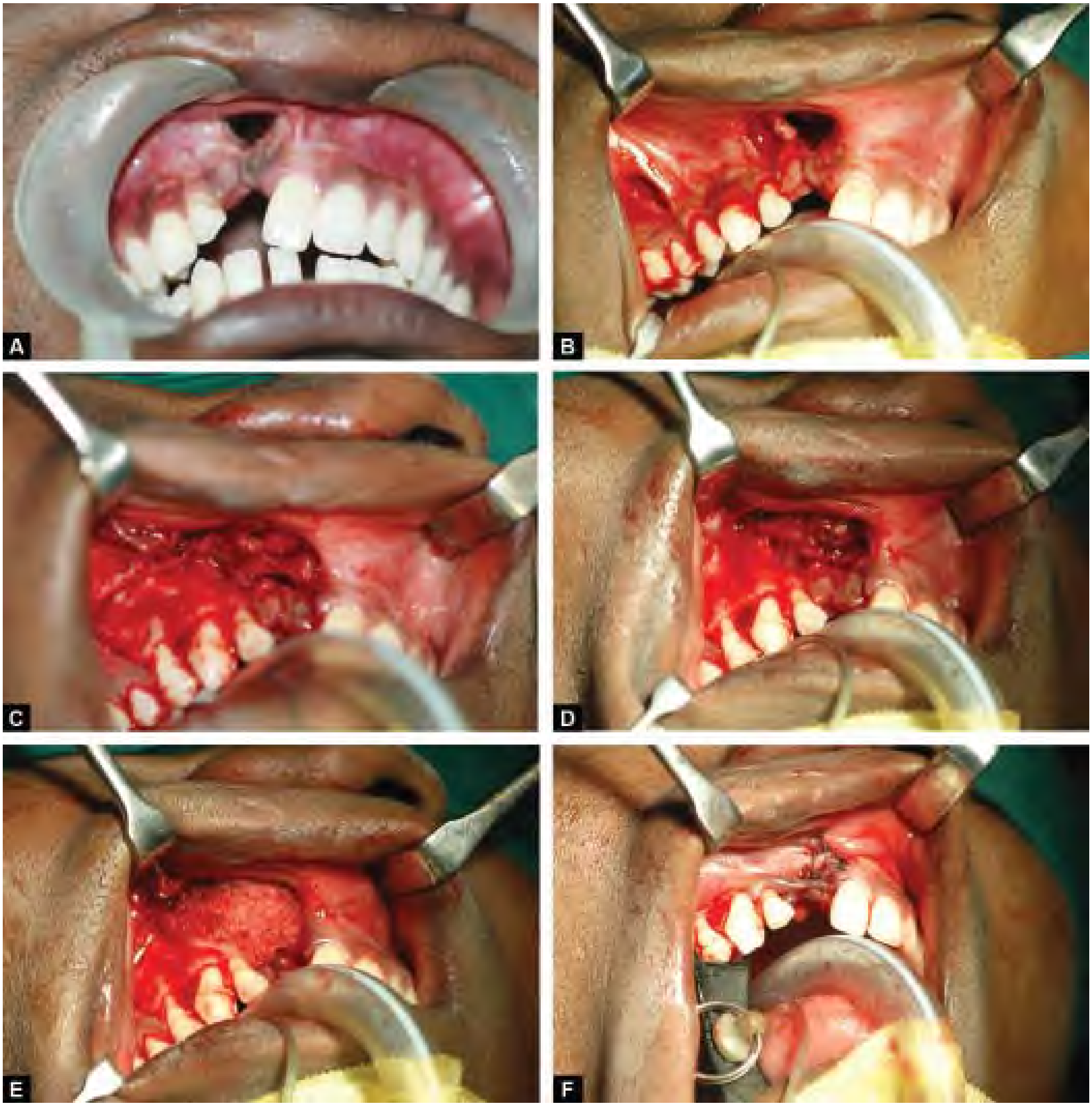
Figure 15-4: Closure of labial layer by a buccal advancement flap.

prevent passage of excess blood into the stomach, minimizing chances for postoperative vomiting and possible aspiration. Irrigation of the oral cavity with antiseptic solution is advised to decrease the chance of immediate postoperative infection. Injection with local anesthetic solution with adrenaline not only aids postoperative pain control and intraoperative hemostasis but also allows the tissues to be hydrodissected to identify the margins of the bony cleft and the residual oronasal communication. If available two independent surgical teams can be involved in the procedure making the duration of the surgery shorter, at the same time reducing the chances of cross contamination between the oral site and the donor site.

Once the local anesthesia has been applied, an incision is made through the mucosa overlying the cleft down to the bony margins to allow the vertical portion of the cleft lining mucosa to be used for the closure of the nasal floor. There is usually adequate amount of tissue present within the oronasal fistula, which leaves one with enough tissue to achieve an oral closure. The area of the pyriform aperture is tricky as there are no bony margins. In this area, the soft tissue is divided into two layers to create adequate tissue for the closure of the most superior and anterior aspect of the oronasal fistula. A periosteal elevator is used to elevate the mucosa within the cleft, which allows for the closure of the oronasal fistula and full exposure of the bony walls of the cleft. All excess soft tissue should be trimmed from this area to allow for maximum contact of native bone with the bone graft.

The ideal position for the inverted suture line and the knots of the oronasal fistula closure is toward the nasal side. Once the soft tissue flap design is carried out and the tissue is elevated, the bone graft material can be placed in the area of the alveolar cleft, condensed well and the final closure started with a mucosal flap. There are three main soft tissue flap designs described in the literature. Two important factors that must be considered in choosing a flap design are: (1) preserving the vestibular architecture, and (2) providing the maximum attached mucosa in the area of the alveolar cleft to allow for development of a normal periodontal sulcus and attachment of erupting canine.

The buccal finger flap has an excellent blood supply and provides adequate soft tissue for the closure over the bone graft. It does not satisfy the two factors mentioned previously, however. It shortens the buccal vestibule and provides nonkeratinized tissue in the area of eruption of the canine. The lateral sliding flap is raised on the lesser segment with a broad base and has an excellent blood supply. It brings adjacent attached gingiva to the area of the alveolar cleft. It leads to shortening of the buccal vestibule, however. Another negative factor associated with this type of flap is the reliance on secondary healing of the mucosa in the denuded area adjacent to the alveolar cleft. This flap design provides for an excellent tension-free closure and decreases the chance of dehiscence. The



Figures 15-5A to F: (A) Intraoral photo showing right sided cleft alveolus + residual oronasal fistula. (B) Incision outlining the fistula and crevicular component with distal release. (C) Mucoperiosteal flaps reflected exposing the cleft alveolus. (D) Reconstruction of the oronasal communication. (E) Bone graft packed and condensed to fill the alveolar defect. (F) Mucosal closure with 4-0 vicryl.

oblique sliding flap is a modification of the Moczair flap. The adjacent attached mucosa from the lesser and the greater segments are brought to the alveolar cleft site, thus covering the newly formed ridge. It provides more than adequate attached gingiva for tension-free closure of wide alveolar clefts. There is a minor decrease in the vestibular depth. This same approach may carried out with the palatal tissue, and there may be reliance on healing by secondary intention at the distal release sites. The four corners of the flap are closed with a horizontal mattress suture. The authors prefer the unilateral oblique sliding flap in most cases and use the bilateral flap design only in extremely wide alveolar clefts. The palatal flaps have two modifications. The excessive mucosa lining the alveolar cleft can be turned over to the palatal side if the cleft is narrow requiring very minimal mucosal cover or a palatal advancement flap can be used with posterior release incisions. The obvious danger of damage to the greater palatine neurovascular bundle detracts from such flap design, however. Literature describes use of a palatal splint (fabricated preoperatively) to provide maximum immobilization of the bone graft and support the palatal tissue. The splint also may play a role in minimizing the formation of a hematoma.

In the case of a bilateral alveolar cleft, the technique is essentially the same, but should be executed with caution bearing in mind that the premaxilla cannot provide significant tissue for advancement. The adjacent sites must provide the soft tissue coverage. The greatest challenge in the closure of such cases occurs in the area directly posterior to the premaxilla. The patient is placed on antibiotics and nasal decongestants after the operation and for at least 1 week postoperatively. Meticulous oral hygiene with antiseptic mouth wash rinses is essential in minimizing the chance of infection.

Complications in Alveolar Bone Grafting

Complications in alveolar bone grafting are relatively minor and can be managed by instituting simple remedial measures. They can be divided into two categories which are enumerated as follows.

Recipient site complications:
1. Infection
2. Wound dehiscence
3. Loss/resorption of bone graft
4. Residual oronasal communication.

Donor site complications (Anterior ileum):
1. Infection
2. Wound dehiscence
3. Pain
4. Postural/gait disturbances
5. Hematoma/Seroma
6. Loss of sensation in the anterolateral thigh
7. Herniation of abdominal contents due to perforation of the peritoneum.

Outcomes in Secondary Grafting and Assessment

Delayed grafting and repair of the cleft alveolus with cancellous tissue has widespread acceptance because of the predictable presence of viable bone with adequate cross-sectional width for tooth eruption, orthodontic tooth movement, or endosteal implant placement. Secondary graft failures are uncommon and are manifested as loss of the graft, the reopening of the oronasal fistula, or both. Poor tissue quality is the most common reason for compromised results and failures. The choice of donor site for graft material is overwhelmingly the ilium from which ample amounts of cancellous tissue can be easily obtained. Particulate bone grafts are superior to block cortical or corticocancellous grafts because they are more readily incorporated into the alveolus with the capacity for postoperative remodeling. The restoration of alveolar bone height is one of the best benefits of the secondarily grafted alveolus. This procedure typically provides greater than 80% root coverage of incisors and cuspids adjacent to the cleft. With such bony coverage, the incidence of periodontal defects and fistulae are decreased and long-term tooth retention is markedly improved. The amount of retained alveolar bone height, however, appears to be related to whether teeth erupt through the graft site. When teeth are present and erupt into the grafted alveolus, usually with the aid of surgical exposure and orthodontic assistance, alveolar bone height is retained. When teeth are not present to erupt through the graft, partial resorption of the graft occurs, even when intraoperatively overfilled.

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Chapter

16

Varghese Mani

Introduction

Occurrences of dental and skeletal deformities are much more common in those who have cleft lip, cleft palate or both, than in the general population. The primary lip and palate repair carried out during infancy and early childhood provides the foundation for normal speech, occlusion and facial appearance. One long-term negative effect of cleft palate surgery is a significant retardation of maxillary growth resulting in secondary deformities of the jaws and malocclusion. These deformities are variable, and are related to various factors. These include the severity of the original defect, the surgical procedures performed, the development of complications and the subsequent orthodontic treatment. Extensive operative intervention in the maxilla and cartilaginous nasal skeleton in early childhood increases the probability of malformation of the midface.[17] There is no intrinsic growth deficiency in patients with clefts, and among the myriad of factors that combine to yield poor maxillary growth, the most influential is surgery **(Figure 16-1).**

Figure 16-1: A patient who had cleft lip and palate. He had undergone lip surgery but not the surgery of the palate. There is only minimal deficiency of the maxillary growth. The occlusal relationship is Cl I.

Secondary defects often include lip deformity, alveolar cleft, oronasal fistula, midfacial hypoplasia, dental defects (like crowding, collapsed arch), palatal scar, velopharyngeal incompetance, and septal and other deformities of the nose. The physiological functions affected are speech, respiration, hearing, mastication, deglutition, etc.

Maxillary hypoplasia resulting in a class III malocclusion, a collapsed alveolar arch, and vertical shortening of the maxilla can all be part of the late skeletal deformity in the cleft lip and palate patient. Orthognathic surgery for these patients, as for any patients with a dentofacial deformity, should be designed to achieve good facial aesthetics and a stable functional occlusion. In addition it should be the aim in every cleft lip and palate patient to achieve a complete arch form without the need for bridges or removable prosthesis. Unfortunately due to reasons like bony asymmetry, nasal deformity, fistulae, missing teeth, velopharyngeal closure, the presence of a pharyngeal flap, soft tissue scarring, etc. ideal rehabilitation is difficult to achieve.

Lip Deformities

Primary surgical correction is important to achieve reasonable lip morphology. Proper orientation of orbicularis oris muscle and proper placement of levator labii superioris and its nasal slip during primary surgery is important in achieving proper symmetry. The secondary defects of the lip often require reopening and reconstruction of the entire lip (**Figure 16-2).**

Nasal Deformities

Cleft lip and palate often affect the septum, the bony frame work and the ala. Alar cartilages may be hypoplastic on the affected side. Because of the alveolar cleft the bony base

Figure 16-2: Improper positioning of the muscles of the lip during primary repair is the major reason for lip deformities.

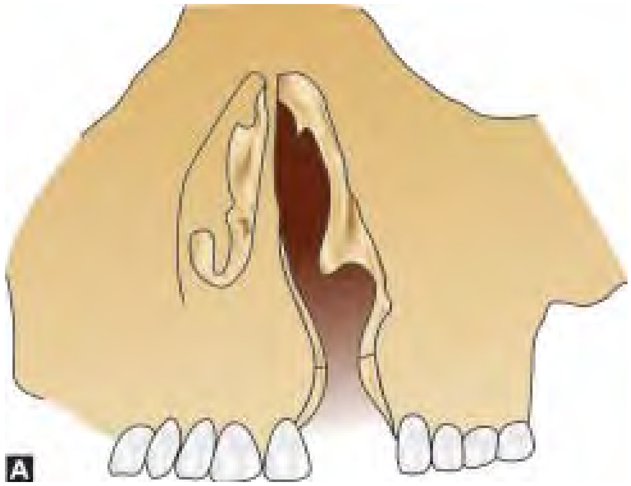
Figure 16-3: The cleft side ala is often collapsed and requires correction.

is distorted and causes nasal asymmetry causing the affected side of the ala to collapse. This is more pronounced in unilateral clefts. Even in incomplete septum the nasal sill is affected **(Figure 16-3)**.

Distortion of the nasal septum and vomer is more pronounced in unilateral clefts.[5,9] Nasal septum deviates to the non-cleft side. But the vomer is deviated to the cleft side. Airway obstruction depends on the degree of deviation. In bilateral clefts the deformity is symmetrical and the alar base is retropositioned. In bilateral clefts columella is short and nasal tip is broad.

Alveolar Cleft

Extent of the alveolar cleft is variable. Often the defect will be extending to the nasal sill. There may be hypertrophic mucoperiosteum filling the gap and extending to the inferior turbinate. Repair of the alveolar cleft and the oronasal fistula if any may be taken up before the eruption of the permanent dentition. Important aims of the surgery



A

B

Figures 16-4A and B: Alveolar cleft causes oronasal fistula. Correction of the fistula and bone grafting of the cleft is important to give proper substrate and foundation for canine eruption, maxillary growth and later correction of nasal deformity.

are to give proper bony substrate for the eruption of permanent dentition, to give a bony foundation for the alar base, to achieve union of the two segments, to gain uniform arch and to close the fistula. For correction of the nose and maxilla it is better that bony foundation is well constructed **(Figures 16-4A and B).**

Deformities of Maxilla and the Dentition

The secondary deformities of the maxilla and the dental arch exists in all the three dimensions. The often observed problems are the following: (a) The medial collapse of the lesser segment with cross bite, (b) Decreased height of maxilla on the cleft side, (c) Deficiency of the maxilla in all three dimensions in varying degrees, (d) Midfacial hypoplasia with a Cl III dental relationship.

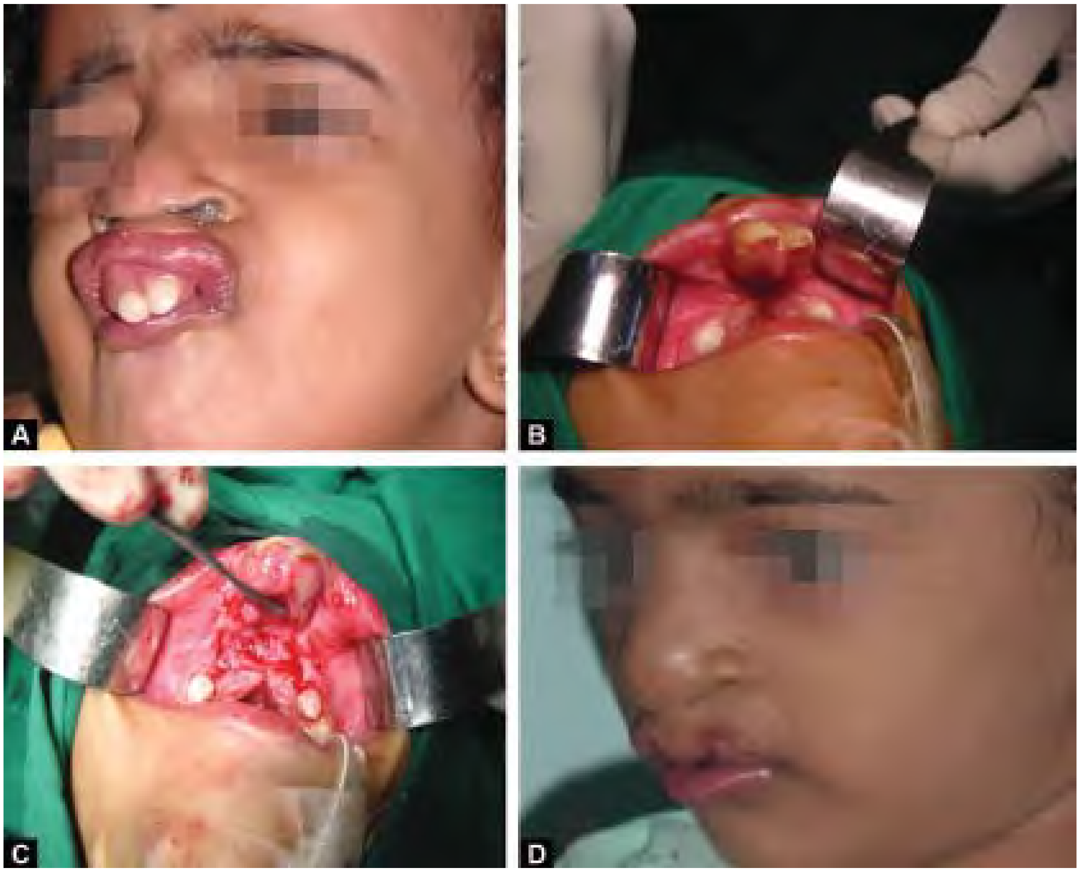
Other dental problems include supernumerary teeth, ectopic dental eruptions, malformation of anterior teeth, etc. **(Figure 16-5).**

In bilateral cleft lip patients the premaxillary segment is often very prominent and jutting out. This poses a challenge to the surgeons in repairing the lip. Naso-alveolar moulding helps to reduce the prominence of the premaxilla. However in some cases the problem may be severe and there may not be enough space for the premaxilla to be accommodated due to forward and mesial positioning of the maxillary segments. Space can be created using the Letham appliance. Premaxillary osteotomy may be done to push the premaxilla backward (**Figures 16-6A to 16-7C**).

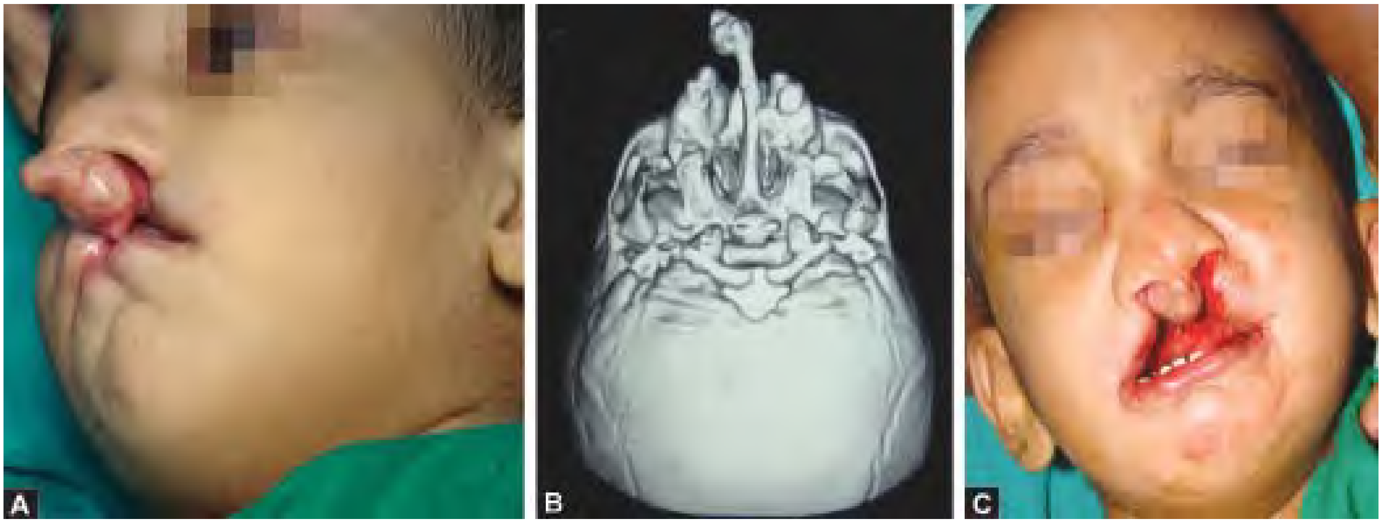
Figure 16-5: Cleft deformities often result in crowding and malpositioning of the upper dentition and deficient growth of the maxilla.

Velopharyngeal Function

The velopharyngeal valving mechanism which prevents the escape of air through the nose during speech, is defective due to scarring and shortening of the soft palate tissues. Surgical advancement of maxilla could sometimes worsen the speech.[29, 33, 36, 43, 56, 57] Anterior distraction osteogenesis is a technique by which this problem can be



Figures 16-6A to D: The pre-maxilla which is prominent (in bilateral cleft lip) can be corrected by pre-maxillary osteotomy done through palatal approach. The osteotomy should be done well behind the permanent tooth buds. This osteotomy may compromise the growth potential of the maxilla. However, the positive psychological impact on the growing child well overshadows the late adverse effects, which can be corrected by adulthood.



Figures 16-7A to C: This 16 months old child is having a bilateral cleft lip with severely protruded premaxilla obviating primary lip repair. To push the premaxilla backward a vomerian osteotomy was done and fixed by intraosseous wiring. Premaxillary osteotomy in children can cause deficient growth of the maxilla. However in such severe cases of maxillary protrusion, pre-maxillary osteotomy is mandatory for repairing the cleft. (A) Preoperative picture. (B) 3-D CT of the pre-maxillary protrusion. (C) Postoperative picture.

averted. Prosthetic obturators with or without teeth can be used for closing the fistula, to recontour the lips and replace the missing teeth.[10, 25] But these prosthetic appliances could be risky for the periodontal structures.

Orthognathic Surgery

Preoperative Planning

Careful preoperative planning is important for the successful outcome of an orthognathic procedure, especially in cleft patients. This should include thorough clinical examination, photographs, cephalometric radiographs and dental models.

Clinical examination should include an analysis of the lip, lip scar and nose, and their relation to normal facial proportions. Evaluation of oronasal fistulae, alveolar residual clefts, cleft dental gaps, amount of overjet and overbite, collapse of maxillary segment on the cleft side are also important. Speech evaluation should be performed on all cleft patients prior to any maxillary surgery. Decision must be made on the management of a pharyngeal flap if present, at the time of surgery.

Cephalometric analysis, besides documenting the skeletal deformity, allows one to monitor facial growth.

Soft tissue analysis permits a presurgical evaluation of the final facial esthetics based on the skeletal movement. Final posture of the lip can be critical in cleft patient.

Dental models can help for presurgical orthodontic treatment, fabrication of an occlusal splint and for positioning the teeth into the desired intraoperative occlusion.

Presurgical Orthodontics

Presurgical orthodontia is a pre-requisite in almost all osteotomies. Full orthodontic treatment is usually necessary in patients with clefts to align the dental arches, to eliminate crowding, and for dental compensations. The purpose is to achieve two independent arches that are compatible in the postsurgical position. Orthodontic treatment is often prolonged because the crowding is often severe. Arch expansion is often hard due to scarring.

Osteotomies

Maxillary Procedures

Axhausen in 1934 published the first report of a horizontal sectioning of the maxilla to correct midfacial deformities associated with cleft lip and cleft palate syndrome.[4]

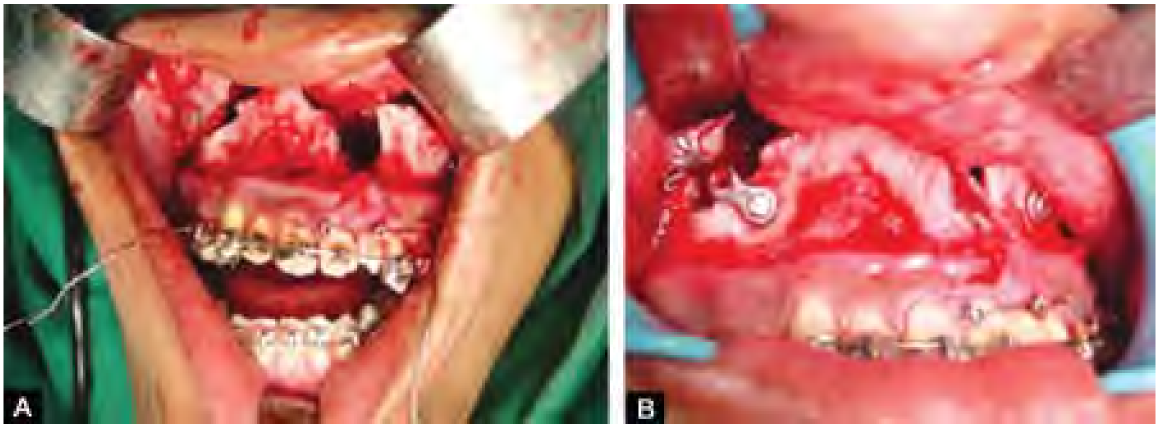
Le Fort I osteotomy is the cornerstone of the treatment of maxillary deformities and it is employed often in the cleft patients to restore esthetic and occlusal harmony. Cicatrization of tissues often accompanied by the presence of a pharyngeal flap can impede horizontal growth and restrict advancement of the maxilla during Le Fort I procedure. These forces along with normal masticatory movements have led to a marked tendency for skeletal and dental relapse after maxillary advancement. Many authors have recommended overcorrection of up to 100% to compensate for this problem. Most of the reports indicated the importance of applying orthodontic elastics to counteract the immediate occlusal relapse. LK Chung and HD Chua have conducted a meta-analysis of cleft maxillary osteotomy and distraction osteogenesis and have documented these findings and come to certain conclusions. The most common complaint was temporary healing disturbances (41.67%). Other important findings are that, the horizontal relapse was 16 to 20% and the vertical relapse was 21 to 25 % by the end of one year. There was diminished velopharyngeal contact in 75%. However in 76.54% cases there was no change in velopharyngeal function, improvement in 5% cases and deterioration in 6.17% cases. Common nasal changes were: increased nasal prominence, increased alar width, thinning of subnasal area (the superior labial sulcus and the upper lip) and changes in the length of the upper lip and the lower face.[14]

Most researchers focus their attention on the horizontal relapse often disregarding vertical and transverse variables. In 1977 Freihofer pointed out that it is wise to wait until the eruption of permanent dentition and skeletal maturity, before attempting maxillary advancement.[21] Palatal scar compromises the blood supply. Moreover the active mobilization can also jeopardize the blood supply.[31] During regular Le Fort I osteotomy the collateral blood supply is lost. Infraorbital and sphenopalatine arteries are lost as they are divided. So Drommer suggested leaving mucous membrane bridges when the maxilla is advanced more than 12 mm **(Figure 16-8)**.[15]

Figure 16-8: Mucosal bridges may be maintained to ensure better blood supply to the maxilla.

As excessive mobilization is risky, slow movements are advocated by Freihofer.[24] Distraction osteogenesis is at present the widely accepted technique for maxillary advancement. For cleft defects the preferred osteotomy is at the Le Fort I level.[8, 9,46,55] The basic Le Fort I osteotomy has to be modified slightly in the cleft patients. Soft tissue incisions should be placed, that allow direct exposure for dissection, osteotomies, disimpaction, fistula closure, bone grafting and application of rigid fixation and that do not risk blood circulation to the dento-osseous and musculomucosal flaps. In bilateral clefts the blood supply to the premaxilla is compromised. Hence, it is better to avoid circumvestibular incision. Ideal method is to give vertical incision and tunnelling to perform osteotomies. In unilateral cleft cases the risk is lesser. The terminal anterior teeth in the greater segment are at greater risk of avascular necrosis. Hence, preservation of an anterior mucoperiosteal bridge is advisable. The horizontal osteotomy cut frequently needs to be at a higher level in cleft patients **(Figures 16-9A and B).**

Surgical closure of cleft-dental gaps through differential maxillary segment repositioning also can be incorporated. For patients with cleft lip and palate, approximation of the maxillary segments for closure of the cleft dental gaps



Figures 16-9A and B: High Le Fort I osteotomy for cleft maxilla can take the nasomaxillary area forward. Rigid fixation helps to reduce tendency for relapse.

also closes the dead space of the cleft alveolus. This method approximates the labial and palatal flaps and allows for closure of the oronasal fistula without tension.

It is possible to correct maxillary hypoplasia, alveolar cleft and oronasal fistula by a single instance surgical procedure.[11] Schendel SA and Delaire J advocate lip-nose correction along with Le Fort I osteotomy in secondary cleft deformities.[3,42]

Simultaneous autogenous corticocancellous bone grafting can be accomplished in selected patients. For patients with cleft lip and palate, bone grafting can be used to fill the residual palatal, alveolar and floor of the nose defects. Onlay grafting for contouring the maxilla helps to improve the profile in some patients. In patients with unilateral cleft lip and palate, an additional micro-plate is frequently applied in the horizontal direction across the cleft site to further secure the maxillary segments.

During Le Fort I procedure, elevation of the nasal mucosa from the nasal floor may be difficult because of scarring from previous palate repair and also due to the deviation of the septum. On such occasions the inferior deviated portion of the septum must be resected. In addition hypertrophic inferior turbinates may require reduction to facilitate the surgery.

Depending on the esthetic considerations Le Fort II or III osteotomies are performed **(Figure 16-10**). The added advantage is that, perfusion is not compromised in these osteotomies.[3, 15, 24] Some reports have concluded that maxillary advancement has no real adverse effect on the speech of CLP patients.[7, 33] Some other reports describe deterioration in both velopharyngeal closure and speech after maxillary advancement.[29,47] When distraction osteogenesis is successfully applied to correct maxillary hypoplasia, the surrounding mucosal and muscular tissues may have a better chance to adapt to the skeletal changes through slow movement than with the sudden changes produced by conventional Le Fort I osteotomy.

Le Fort II osteotomy is indicated in patients with severe paranasal hypoplasia. Many have noted a significant tendency for horizontal relapse when Le Fort II procedure was used in adult cleft patients. But situations warranting the use of Le Fort II procedure are rather rare. LK Chung and HDP Chua have conducted a meta-analysis of cleft maxillary osteotomy and distraction osteogenesis and had documented the following findings.

They have evaluated 72 articles and evaluated 1418 CLP patients who underwent maxillary osteotomy. Le Fort I was the preferred technique. Le Fort II were 15 and Le Fort III were only 3 cases. Mandibular surgery during maxillary osteotomy was done in 346 cases (24.4%).[14]

Mandibular Procedures

Mandibular procedure is indicated in two situations in the cleft patient. It is necessary for the cleft patient with true mandibular prognathism and in patients in whom the maxillary retrognathism exceeds 10-12 mm when the proposed maxillary advancement would not be stable. In this situation, a two jaw procedure is indicated **(Figures 16-11A to 16-12D)**. In 1939 Axhausen during a meeting of the Berlin Surgical Society challenged the concept of treating cleft patients in the mandible.[16] He was against doing surgery in a normal jaw (the mandible), to correct the maxillary defect secondary to cleft.

Wassmund advocated surgery on the mandible, since the maxillary advancement compromises the speech. He also felt that the cosmetic and functional results were superior with retropositioning of the mandible.[52]

Figure 16-10: Le Fort II osteotomy may be used if the midfacial deficiency involves the nasoethmoidal complex. This osteotomy has got the added advantage that the blood supply is not compromised.

Figures 16-11A and B: This patient had undergone a two jaw procedure- Le Fort I advancement and mandibular set back by bilateral sagittal split osteotomy.

Figures 16-12A to D: Pre- and postoperative pictures of a patient who has undergone a two jaw surgery (Le Fort I advancement and BSSO for mandible set back).

Figures 16-13A and B: This patient who had a cleft deformity has undergone mandibular setback only instead of Le Fort advancement, as he had a prognathic mandible.

Schuchardt, based upon his experience, also opined against maxillary advancement surgeries.[44] Obwegeser was able to establish the role of maxillary surgery in cleft deformities. He insisted on adequate mobilization of bony segments. He also demonstrated the advantages of combining Le Fort I and III osteotomies.[39,40]

The workhorse osteotomy for the mandible is the sagittal split osteotomy **(Figures 16-13A and B)**. Sometimes a genioplasty or an anterior subapical osteotomy of the mandible may be done to enhance facial esthetics.

Mori Y, et al have advocated a two stage surgical procedure to correct severe maxillary hypoplasia. In the first stage, by an intraoral device, the maxilla is advanced, and, after appropriate advancement is achieved, the maxilla is fixed with miniplates; and simultaneously mandibular set back is done.[38]

Nasal Procedures

Rhinoplasty is often performed on a cleft lip-palate patient to correct the nasal defect as a secondary procedure. Nasal tip surgery could be performed at the time of an osteotomy, and a dorsal bone graft to the nose and a columellar strut can be done at the time of a Le Fort II or a Le Fort I osteotomy. In unilateral cleft cases cartilaginous septum is deviated to non-cleft side and vomer is deviated to cleft side. Often septorhinoplasty is required. Open rhinoplasty is the approach of choice as it affords better visibility and access **(Figures 16-14A to C)** (Chapter 23 is exclusively devoted for rhinoplasty in this book).

Figures 16-14A to C: Cleft side ala is often collapsed and requires correction. (A) Collapsed ala of the nose. (B) Open rhinoplasty. (C) Postoperative photograph.

Rigid Fixation

Many authors who have recorded vertical relapse have shown that it is significantly higher than horizontal relapse and tends to occur predominantly during the period of intermaxillary fixation. The reasons proposed are the forces exerted by muscles of mastication, the influence of lower jaw position, the effects of intermaxillary fixation and the pull exerted by suspension wires if they are used. Hence, rigid fixation by plates and screws is favored. Since the fixation is rigid, the relapse tendency will be much less and there is no need for an intemaxillary fixation. Rigid fixation improves food intake and enhances healing and function. Rigid fixation also reduces the risk of graft resorption, and early jaw motion is beneficial to function. In spite of the advantages of rigid fixation, intermaxillary fixation is advised by some authors, to achieve predictable occlusion.[22, 28] The plates must be bent to conform to the surface contours of the maxilla. If the plates do not lie flush with the underlying bone as the screw is tightened, the position of maxilla will change **(Figures 16-15A to D)**.

Figures 16-15A to D: (A) Preoperative photograph of a patient who had cleft lip and palate.(B) Postoperative photograph after she had undergone Le Fort I osteotomy augmentation. Nasal contour has improved. (C, D) Pre- and postoperative cephalograms.

Postoperative Orthodontics

Despite rigid fixation, relapse tendency (lesser than in IMF) is observed in the majority of cases. Orthodontic treatment during the postoperative period for a minimum of 6 months is often required. A face mask which exerts an anterior pull on the maxilla and push back on the mandible is an ideal adjunct. Postsurgical orthodontics also provides finer adjustments of teeth to achieve better postoperative stability.

Distraction Osteogenesis for CLP Deformities

Regeneration of the bone takes place at the gap when the cut ends of the bone are slowly distracted. This helps to lengthen the bone. Cleft lip and palate deformities are traditionally corrected by orthognathic surgery since 1970s.[7,19,23,30,41,51] Advancement of maxilla by osteotomy especially in secondary deformities of cleft lip and palate often entails many complications like compromised blood supply, difficulty in mobilization due to scar tissue and relapse tendency. Most of these problems can be overcome by distraction osteogenesis. Since 1997 distraction osteogenesis has become an alternative treatment option for maxillary hypoplasia.[4,12] The first team to report gradual distraction of human mandible was Snyder, et al[45] and later popularized by Mc Carthy, et al[34] Some authors have preferred distraction even without disjuncting the pterygomaxillary junction.

Out of 1418 cases evaluated by Chung L Kand and Chua HDP, only 276 cleft patients were reported to have undergone distraction osteogenesis of the maxilla. 65% patients were between 6 and 10 years of age. Maxillary expansion attained was in the range of 5 to 9 mm, without the formation of palatal fistula. The device used in 68.64% of cases was Rigid External Distractor (RED). In 25.72% cases Face Masks were used. Internally placed maxillary distractors were used in 2.17% of cases.[14] The ideal rate of distraction is about 1mm per day. The latency period recommended before starting the distraction is 4 to 7 days, and the period for consolidation is usually 2 to 4 weeks. Latency period before distraction allows healing of the soft tissue. Other factors like age, stability of fixation and type of operative procedures, that affect the formative process at the initial stage in distraction osteogenesis are to be taken into consideration before deciding on the latency period.[1] But certain other studies do not show any difference in the bone formation, between no latency and 4-7 days latency period.[2,49,50]

It is better to do distraction after the growth is completed. Early distraction may require osteotomy later.

Figures 16-16A to H: This patient aged 17 years had unilateral cleft lip and palate repaired at a very young age. She was treated with orthodontia to expand the palate and align the teeth. She underwent anterior maxillary distraction and rhinoplasty in a single go. The distraction created mild open bite which was corrected by orthodontic elastics. (A) Preoperative X-ray. (B) Postoperative X-ray. (C) Preoperative occlusion. (D) Occlusion after creating space for anterior maxillary osteotomy. (E) Occlusion after distraction. Mild anterior open bite is present. (F) Occlusion after the open bite is corrected by heavy interarch elastics. (G) Preoperative profile photograph. (H) Postoperative profile photograph.

Surgical difficulty of using conventional osteotomy to transpose the maxillary segments at the time of surgery, in CLP patients is related to the severity of scarring from cleft palate repair, the less predictable vascular supply, the extent of advancement, the fixation of transposed segments and the possibility of postsurgical relapse.[53] It has been demonstrated that an incompletely cut Le Fort I osteotomy can be distracted by externally placed distractors.[1,26,37] However, this could cause tension, pain and loosening of the screws; hence it is advisable to go in for a full osteotomy prior to distraction.

Since distraction of the maxilla as a single segment is better, prior grafting of the alveolar cleft is advised. One definitive advantage of distraction over conventional osteotomy advancement is that the volume of the bone and the range of advancement are much more. It is possible, to achieve more than 20 mm of distraction. Hence, concurrent mandibular set back osteotomy can be avoided.[54]

It has also been noted that the relapse is much less than with conventional osteotomy.[13] In conventional osteotomy transverse expansion is not possible. By distraction, expansion is effective without fistula formation. In conventional osteotomy bone graft has to be done while in distraction the same is not required as the gap is filled with new regenerated bone. It is necessary to ensure bone-to-bone contact before starting distraction. Insufficient distraction and defective distraction vectors can compromise the final result. These complications can be managed to a great extent by manipulating the regenerated bone by the application of orthodontic traction.[18, 27, 35, 48] Of the very few disadvantages of distraction osteogenesis the primary one is that it requires a second surgery. Use of external fixator for a long period of time is required, i.e. till the consolidation is over.

Figure 16-17: Break down of the primary palate repair causes oro-nasal fistula formation.

Distraction of the Anterior Maxilla

Le Fort I distraction osteogensis too has got a few risks like compromised blood supply, exaggeration of velopharyngeal incompetence, etc. Use of extra oral rigid fixation is an inconvenience for the patient. Distraction of the anterior maxilla is a promising technique used for advancing the maxilla. Hygienic rapid expansion appliance is a rigid tooth borne appliance used for expanding the maxilla transversely. This appliance can be rotated 90° and can be used for pushing the anterior segment forward. After anterior maxillary osteotomy the previously fixed expansion appliance is activated at the rate of 1 mm everyday, till the segment comes forward to the pre-planned position. Advantages of this technique are that the surgery is simpler, there is no increase of VPI, more space is created in the dentoalveolar area to align the teeth, and the discomfort is minimal, as the expansion appliance is intraoral and not cumbersome **(Figure 16-16)**.

Co-existing Conditions: Palatal Fistulae

Cleft palate fistula is an occasional complication of primary palatoplasty. Palatal fistulae in cleft patients occasionally occur because of the failure of proper healing after cleft palate repair. In general it is much safer to close large fistulae as a separate procedure and then proceed with the osteotomy at a later date. Small fistulae which do not require large flap elevation can be closed at the time of the osteotomy **(Figure 16-17).**

Temporal myofacial flap tunnelled under the zygomatic arch and brought to the fistula through the LFI osteotomy space can be used to correct large oronasal fistulae.

Figures 16-18A and B: After Le Fort I osteotomy temporal myofascial flap tunneled underneath the zygomatic arch can be brought to the fistula through the Le Fort I osteotomy cut. The flap is sutured to the edges of the fistula, with the fascia facing the oral side. The tissue should be bulging into the oral cavity to give provision for scar contracture.

In large defects other procedures like Langenbeck technique, rotation flaps or tongue flaps, may not be successful. Moreover they may be having maxillary regression. In such cases maxillary augmentation by Le -Fort I osteotomy is indicated for esthetic and functional correction. Transmaxillary transfer of temporal myofascial flap will be much easier after Le Fort I down fracture **(Figure 16-18)**.[32]

Pharyngeal Flaps

Nasoendoscopy, combined with clinical examination by a speech pathologist and a surgeon familiar with clefts, can reliably predict current and expected velopharyngeal function in a patient scheduled for a Le Fort I procedure. When significant postoperative velopharyngeal deterioration is anticipated, the patient and family should be educated about the sequencing of the treatment. If the revision of a pharyngeal flap is recommended after an endoscopy and clinical examination, it is best carried out 6-12 months after surgery, as a secondary procedure.

Conclusion

In cleft patients, who are considered for orthognathic surgery, the osteotomies should be modified to meet the needs of the individual patient. Two-jaw surgery is indicated for those patients in whom the movement required to achieve a Class I occlusion exceeds 10 to 12 mm. Rigid fixation should be used in all patients. Placement of bone grafts for esthetic augmentation is indicated in majority of patients. Distraction osteogenesis has revolutionised the cleft osteotomies. Gradual

Figures 16-19A to F: Columella was lengthened using the prolabium and the maxilla was advanced. Though this procedure is excellent for lengthening the columella, the cupid bow and the philtrum of the upper lip were lost (A and B). As a second stage Abbe flap and genioplasty were done for reconstructing the philtrum and the cupid's bow, (C and D) Ceramic crowns were given for upper and lower anterior teeth (E and F).

advancement yields better results by regenerating the bone and the surrounding structures.

Case Report

Young lady aged 22 years, had undergone bilateral cleft lip and palate repair at a young age. She came for the correction of her facial deformity **(Figures 16-19A to F)**. The following were the findings.

1. Deficient maxilla with crowding of upper teeth
2. Short columella with drooping nose tip
3. Deformity of the lip

After clinical, cephalometric and model analysis, the following course of treatment was planned and implemented.

Le Fort I osteotomy was done to advance the maxilla, and the columella was lengthened using the prolabium. As the second procedure augmentation genioplasty and Abbe flap were done. Her anterior teeth were not in satisfactory health. So, ceramic crowns were given for both the upper and lower anterior teeth.

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Chapter

17

Varghese Mani

Introduction

It is hard to find a perfectly symmetric face. Minor asymmetries are seldom noted generally and do not need any intervention. But major asymmetries may be a concern for the patient and hence need correction.

For analysis of facial asymmetry, PA cephalogram and other radiographs like submentovertex and both lateral cephalograms are used for three-dimensional understanding of the jaws. Three-dimensional CT reconstruction of the skull gives better understanding of the defect, helps in treatment planning and helps to predict the outcome of treatment **(Figure 17-1)**.

Clinical analysis and history taking are very important in assessing the deficiency and arriving at the etiology and diagnosis. Trauma to the mandibular condyle during childhood is one of the major causes for asymmetric development of facial skeleton and musculature. Deformity noticed from early childhood is often congenital and observation of deformity later during growth could be developmental. Another major cause for asymmetric facial growth is Hemifacial microsomia. In Hemifacial microsomia the surrounding tissue is also affected though in mild deformities it may not be pronounced. In most cases maxillary involvement is secondary to the involvement of the mandible.

Figure 17-1: Three-dimensional CT of facial asymmetry due to ankylosis of the temporomandibular joint (Left side).

Congenital Deformities

Hemifacial Microsomia

Hemifacial microsomia is the term coined by Gorlin and Pindborg after studying various conditions affecting the development of the face. It is otherwise called the first and second arch syndrome. Sometimes the term craniofacial microsomia is used interchangeably.

This syndrome is characterized by under development of unilateral temporomandibular joint, mandibular ramus and associated muscles of mastication. The maxilla and the zygomatic arch are also frequently underdeveloped and the external ear may be affected. Deformities are often hemifacial. The maldevelopment usually affects the first (mandibular) and second (hyoid) arches. Experimental evidences indicate that craniofacial microsomia may be due to the loss of crest cells early in life.[12,13,30]

Common features are the following **(Figure 17-2).**

1. Missing or distorted auricle
2. Chin deviated to the affected side.
3. Underdevelopment of skeletal and soft tissue components.
4. Macrostomia of the affected side.
5. Hypoplasia of the maxilla and zygoma.

Figure 17-2: Hemifacial microsomia.

6. Mandibular retrusion due to unilateral hypoplasia.
7. The occlusal plane may be tilted.
8. Ramus may be broad anteroposteriorly with reduction in vertical dimension.
9. Antegonial notching may be present.
10. Underdevelopment of mastoid process.
11. External auditory meatus may be underdeveloped.
12. Malocclusion due to asymmetric growth.
13. Crowding due to reduced growth of the jaw.

Plagiocephaly

Plagiocephaly is another reason for facial asymmetry. This is due to unilateral synostosis of the coronal suture. The characteristics are: (a) lack of projection of the forehead, (b) elevation and posterolateral displacement of the supra-orbital region, (c) deviation of sagittal suture, radix, posterior cranial fossa, foramen magnum, etc. to the side of synostosis.[17] Plagiocephaly is ideally corrected in infancy itself.[8,15, 32]

Developmental Deformities

Unilateral hyperplasia of the mandible is often a cause of facial asymmetry **(Figure 17-3)**. Condylar hyperplasia is also one of the major causes. Obwegezer termed this as hemimandibular hyperplasia because the enlargement affects entire ramus and body.[24] This problem occurs mainly due to the continued growth of the mandible on one side even after the growth has stopped on the opposite side. The problem becomes more pronounced during late teens.

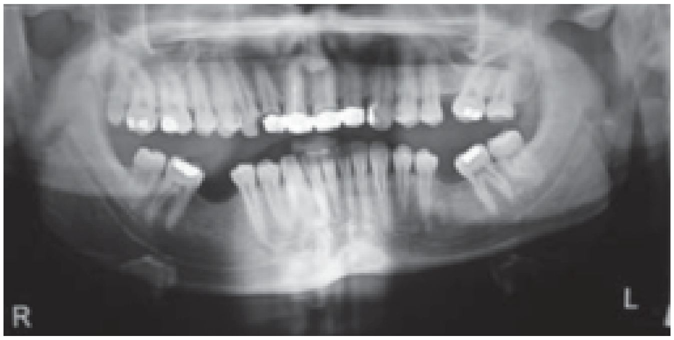


Figure 17-3: Unilateral hyperplasia of the mandible. Vertical dimension of the mandible on the right side is increased and the midline of the lower jaw is deviated to the left.

Muscle activity has a major influence on the bone growth. Loss of muscle tone, deviation or injury to the muscles can cause reduced bone growth and cause facial asymmetry. Hyperactivity or hypertrophy of the muscles can produce facial asymmetry. Unilateral hypertrophy of the masseter is a typical and common example. This is often associated with an outward flaring of the ramus.

Torticolis causes excessive muscular tone and excessive contraction of sternocleidomastoid resulting in deformed growth, facial asymmetry and tilting of the head.[4]

Unilateral Mandibular Hyperplasia

This is usually characterized by unilateral enlargement of the condyle, elongated neck and elongated ramus and body of the mandible. Gonial angle is poorly defined and the antegonial notch is often absent on the affected side. Deformity stops at the mandibular symphysis. Face has got a rotated appearance. Occlusion is often canted with the maxillary teeth inferiorly positioned on the affected side. There is an increased distance from the root tip to the mandibular canal.

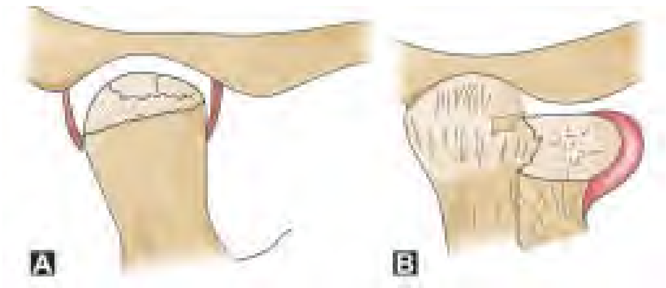
In hemimandibular elongation the inferior border is more or less similarly placed. The mandible is displaced towards the unaffected side. Occlusal cant is not seen usually **(Figures 17-4A and B)**.

Unilateral Mandibular Hypoplasia

Chin is deviated to the affected side, the ramus is short with decreased body height. Antegonial notch is often increased with occlusal cant and lack of downward growth of maxilla on the affected side.

Isolated Condylar Hyperplasia

This is characterized by the enlargement of one of the mandibular condyles. There is an increase of the ramus



Figures 17-4A and B: (A) Injury to the condyle inside the capsule in children can cause hemarthrosis and fibrosis and later ankylosis. (B) Fracture displacement of the condyle can restrict the movement and may result in ankylosis.

height on affected side and the chin is deviated to unaffected side but not as pronounced as in hemi-mandibular hyperplasia. There is a possibility of open bite on the affected side. Neoplasms of the condyle can also produce similar features.

Injury to the Mandible

Another common cause of mandibular asymmetry is condylar injury in childhood.[27] Neck of the condyle is a frequent site of fracture **(Figures 17-5 and 17-6)**.[5] Studies have shown that fractured condyle in children can undergo remodeling and even regeneration.[9, 18] Injury to condyle inside the capsule in children can cause hemarthrosis and fibrosis, and later ankylosis. According to Proffit it is scarring at the region of injury that reduces normal growth and not the loss of growth center.[28] Open reduction of condyle fracture in children should be avoided as far as possible. Scar tissue has got the potential to retard anterior and downward growth of the mandible.

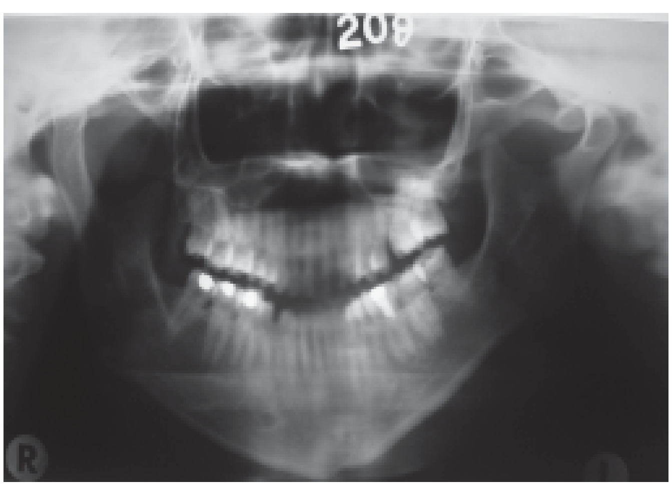


Figure 17-5: Unilateral hyperplasia of the condyle on the right side.

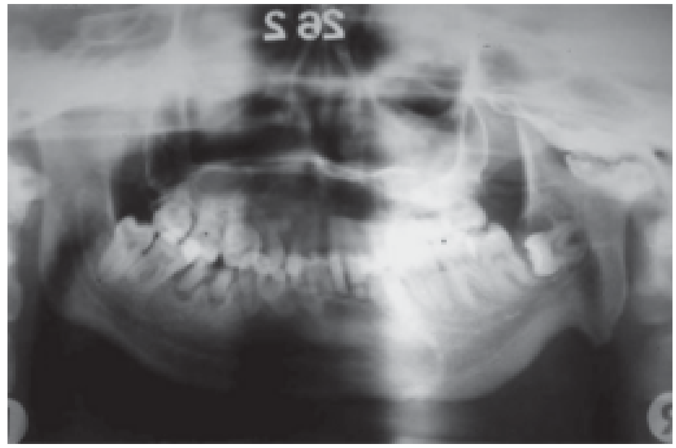


Figure 17-6: Ankylosis of the left TMJ, resulting in facial asymmetry. Coronoid process is elongated and the antegonial notch is pronounced on the affected side

Degeneration of Joint

Degenerative diseases can cause resorption of the condylar head. Usually it is bilateral. However, unilateral resorption can also happen resulting in facial asymmetry by reducing the ramus height. Though etiology of degenerative disease is not clearly known, injury to TMJ and surgery of TMJ are known to cause degeneration. Alloplastic interposing graft in TMJ arthroplasty is another cause for resorption of condyle.[34] Disc removal without interposing can also lead to resorption of the condyle.[7] Various pathologic entities, such as fibrous dysplasia, tumors of the mandibular condyle, etc. are known to cause facial asymmetry.

Clinical Assessment of Facial Asymmetry (Figure 17-7)

a. Visual assessment will generally help in the overall understanding of the facial deformity.
b. Palpation of hard and soft tissue will help to assess the location of the deformity. Deficiency in the soft tissue and/or the hard tissue can be ascertained by palpation.
c. Assessment of the dental and the skeletal midline.
d. Assessment of the occlusal plane.
e. Examination of TMJ.

These examinations have to be combined with radiographic evaluation. The PA cephalogram and orthopantomogram are the ideal radiographs to assess the facial asymmetry. Three-dimensional CT is an excellent tool for assessing facial asymmetry.

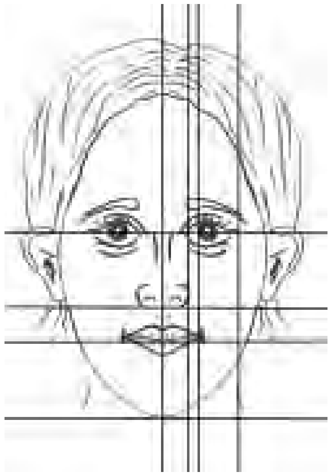


Figure 17-7: Vertical and horizontal lines drawn on the tracing helps to assess the asymmetry

Radiographic Findings

Orthopantomogram, PA cephalogram and three dimensional CT are the often used radiographic aids to assess the facial asymmetry. These pictures are ideal to assess the extent of skeletal and dental deformities, occlusal cant and level of mandible, orbit, malar bones and the external auditory canals. Lateral cepholagrams can also be used to assess the areas of asymmetry as in symmetrical patients, exact overlapping of the structure happen in the radiography.

If the external auditory meatus is in different level, cephalogram is taken without the ear rods but the head in the natural position; lest the asymmetry gets exaggerated. Submentovertex view will help to assess the symmetry of ramus, zygoma and zygomatic arch.

Orthopantomogram is also helpful to assess the symmetry of ramus, body and condyles.

Three dimensional CT scans are excellent in assessing the facial asymmetry and in developing a treatment plan. Three dimensional MRI is an excellent tool in assessing the soft tissue deformities.Technetium-99 is a radioactive isotope which localizes in areas of greatest bone turnover. Technetium-99 bone scans are frequently used to determine the condylar growth activity in progressive asymmetry. After injecting the isotope intravenously the radiation emission is assessed using gamma counter. If the activity is pronounced in one joint, condylar resection or high condylectomy is warranted.

Treatment Modalities

Soft tissue repair is taken up early in the childhood. Auricular and sinus tract repair may require repeated surgeries. Correction of microtia and middle ear deformity are also taken up early as middle ear growth is completed by the age of ten, although the mandible and related structures grow till adulthood.

Opinions vary about the timing of surgery. Proponents of early surgery argue that growth can be guided by this method. Early creation of interocclusal space promotes normal eruption of teeth. It is also pointed out that soft tissue development is stimulated by early surgery. The proponents of delayed surgery point out that early surgery can cause untoward effects on facial growth and that the final outcome is difficult to predict.

Kazangian suggested soft tissue repair in early childhood and hard tissue (bone) surgery after adulthood. He also stressed the importance of orthodontic treatment to correct deviation and to achieve functional occlusion.

Cast Prediction

Face bow is used to position the maxillary cast on a semi-adjustable articulator in hemifacial microsomia. It is difficult to determine the horizontal plane. If the orbit is not affected interpupillary line may be taken as the horizontal plane. The mid-sagittal plane and the deviation of the jaw and chin are marked on the cast after analyzing the PA cephalogram. The next step is to correct the mandibular horizontal plane so that the sagittal line runs through the dental midline of the mandible. This may result in open bite on the affected side and cross bite on the opposite side. An occlusal splint is fabricated on the predicted cast. This splint is used during surgery for positioning the mandible and fixing it in the desired position.

Principles of Treatment in Facial Asymmetry

The first step, like in any other orthognathic surgery, is to understand the patient's concerns. This is followed by assessing the deformity. Treatment planning for facial asymmetry is more intricate than symmetric deformities. The asymmetry can be extending from the head to the chin and even beyond. More stress is given to the asymmetry of the maxillofacial region.

Important concerns are:

a. Symmetry of the orbit
b. Symmetry of the malar bones
c. Symmetry of the nose

d. Symmetry of the maxilla
   1. Occulasal cant
   2. Upper dental midlines.
   3. Visibility of gums
e. Symmetry of the mandible
   1. Vertical dimension of ramus and body
   2. Dental midline
   3. Chin midline
   4. Horizontal dimensions
   5. AP dimensions
f. Symmetry of the soft tissue.

In a growing child functional appliance is the ideal method of treatment. Functional appliances enhance and modulate growth, provided adequate growth potential is remaining. Surgery is indicated if the asymmetry is not controlled by functional appliance.

Le Fort I osteotomy is the procedure advised for correcting maxillary asymmetry. Maxilla can be moved in all the three dimensions. It can be rotated in the horizontal plane to correct midline, and rotated vertically to correct the occlusal cant.

Often segmental osteotomy like anterior maxillary or posterior maxillary osteotomy can be used with Le Fort I to get optimum result.

Different types of osteotomy like ramus osteotomy, inferior border osteotomy, genioplasty, etc. can be used in combination or in isolation to correct facial asymmetries. Proper planning is necessary to decide the type of surgeries to be employed. Often grafting is required to get desired results. Inferior border and lateral margin of the mandible, chin, and zygomatic region are the major areas which require contour adjustments by onlay grafting.[1,14,23,26] Extended lateral sliding genioplasty is a versatile procedure for the correction of vertical, lateral and chin midline asymmetries.[19]

Surgical Approaches

Facial asymmetry can be corrected by satisfying the following conditions:

1. Bringing the mandibular symphysis to the midsagittal plane.
2. Aligning the mandibular and maxillary occlusal planes to the horizontal plane.
3. Aligning the bilateral facial height in order to attain optimum esthetic result.

Osteotomy for Hemifacial Microsomia

Change in the position of the TMJ is to be avoided, so bilateral mandibular osteotomy is advised. Either intraoral or extra oral approach can be used. While using the extra oral approach the incision is made about 2 cm below the lower border of the mandible on the normal side [The important structures encountered during the dissection are the marginal mandibular nerve, submandibular salivary gland, facial vessels and their anterior communicating vessels. On the affected side the hypoplasia of the muscles varies greatly to even absence. Though the articulation of the TMJ is distorted, no attempt should be made to alter the joint position. On the affected side the incision is made about 3 to 4 cm below the border of the mandible.

The usual osteotomy used is an inverted 'L' design on the affected side while routine subsigmoid vertical osteotomy is performed on the normal side. The affected side is dragged forward. If major bony defect is present, grafts from the iliac crest or rib are used to fill up the defect **(Figure 17-8)**.

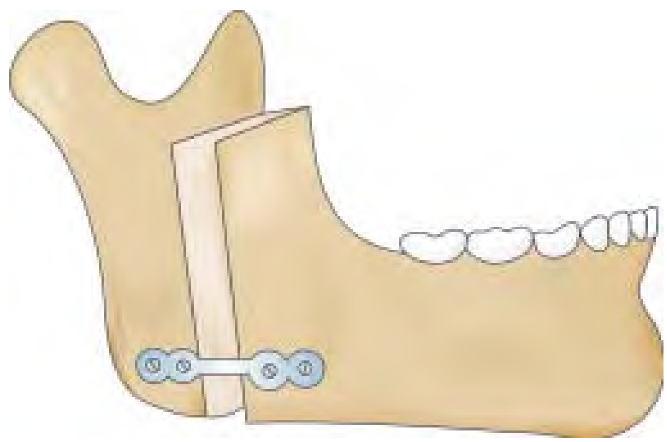


Figure 17-8: Inverted 'L' osteotomy can be used to advance the mandible; but requires bone grafting of the gap created.

For intraoral approach anterior ramus incision is used. Sagittal split osteotomy is performed on both sides of the mandible, if the anatomy of the affected side is not greatly disturbed. It may be necessary to lengthen the affected side by 2 or 3 cm. For this the soft tissue envelope should be freed from the ramus region. The sphenomandibular ligament has to be separated to allow proper rotation and to prevent postoperative relapse.

The advantages of the intraoral approach are the following:

a. Extraoral scar is avoided.
b. Injury to the marginal mandibular nerve is avoided.
c. Bone grafting can be avoided to some extent.

The disadvantages are the following:

a. Chance of injury to the inferior alveolar neurovascular bundle is greater.[25]

b. Technical difficulty is increased especially due to distortion of the anatomy.
c. Bleeding, if occurs, is difficult to control.

Over-correction is advised for two reasons – it counters relapse as well as the differential growth between both sides.

Postoperative Period and Principles of Orthodontic Treatment

Intermaxillary fixation is usually maintained for a period of 10 weeks if wire osteosynthesis is used. Rigid fixation using mini plates is advisable as it can avoid intermaxillary fixation. Active orthodontic treatment is started after the bony healing is completed which takes 3 to 4 months. During this period mildelastic traction is used to maintain the occlusal splint in position. The orthodontic treatment is mainly intended to achieve the following objectives:

1. To close the interocclusal space of the affected side. This is achieved by extruding the posterior teeth using mild elastics.
2. To correct the cross bite created on the normal side while rotating the mandible.
3. Correction of other occlusal problems, crowding and midline changes.

Combination of Maxillary and Mandibular Osteotomies

Combination procedures become necessary in certain cases when the surgical correction of hemifacial microsomia is taken up after the growth is completed and where the defect is moderate to severe. Treatment planning for two-jaw surgery is challenging.[6]

Since the surgical procedures of Le Fort I and ramus osteotomies have been described earlier in the text, the same are not repeated here; only the outline and plan of surgery is detailed.

In adults, usually there is an occlusal cant and the maxillary midline is tilted to the affected side. Le Fort I osteotomy is done. According to the severity of the condition and esthetic consideration, the following methods are used to align the maxilla:

1. Excision of a segment of bone on the unaffected side so that the vertical dimension is reduced on the normal side and maxillary occlusal cant is corrected.
2. Affected side is rotated downwards to increase the vertical dimension. The gap formed on that side while increasing the vertical dimension is grafted, preferably with autogenous bone graft and rigidly fixed.
3. Combination of the above two techniques.

Next step is to do sagittal split ramus osteotomy on both the sides as mentioned in the previous section and rotating the mandible to correct the dental midline. This technique need not necessarily correct the midline of the chin. If such is the case, genioplasty is advised. The various techniques of genioplasty have already been described in the chapter on genioplasty.

Though the maxillary surgery is often the first one performed many surgeons including the author prefers to perform the mandibular surgery (if it is a ramus procedure) initially, for the following reasons. After BSSO mandible can be moved forward or backward. It can also be moved horizontally to correct the midline. But it is hard to roll the mandible in vertical direction. Moving the mandible as the first step may provide improved surgical accuracy by preventing intraoperative maxillary shifting during the placement of intermaxillary fixation. Surgery of the mandible as the first one in two-jaw surgeries provides overall improvement in predictability of the final functional and esthetic outcome.[3] Maxilla has got a better maneuverability in all the three dimensions and so minor adjustments are possible to achieve better occlusion which is inevitable for better function. Fixation of both jaws is preferably done after the pre-planned occlusion is achieved on occlusal splints.

Camouflage

Facial asymmetry can be corrected by camouflage procedures. These procedures are mainly intended for mild defects and also used in association with skeletal surgeries.

Rotational or sliding genioplasty may be used in mild asymmetries of the chin and chin-midline correction.

Another important and effective method of camouflaging is by recontouring the area and building up the deficiencies through grafts. The grafts usually used are of alloplastic or biocompatible materials. Alloplastic materials are biologically inert and do not produce any tissue reaction. Common materials used are silicone rubber, fluorocarbon, acrylic or metals. Biologic materials are mainly autogenous or homologous tissue. Autogenous material is far superior especially if it is transplanted immediately after harvesting, since it contains plenty of viable tissue and has greater biocompatibility. For homologous material the chances of rejection are greater. The tissues commonly used are bone, cartilage and dermal-fat grafts. Since the chances of resorption are greater with biologic material, over-correction is often advised. Another problem associated with autogenous bone grafts is the need for separate surgery to harvest the bone, while alloplastic materials can be easily controlled presurgically. The chance of migration of alloplastic material is a disadvantage. However, this can be prevented by stabilizing the graft to the skeleton using non-absorbable materials like wires. Another method is to make holes of about 3 to 5 mm diameter for the in growth of tissues and the same helps to keep the graft in position **(Figure 17-9).**

Grafting is usually done on the zygoma and the mandibular ramus and body regions. At the zygoma the graft is positioned through a preauricular incision and an infraorbital skin fold incision is used to stabilize the graft. Preauricular and/or submandibular incisions are used to insert the graft on the ramus region. Intraoral buccal sulcus incision is used to plant the grafts on the body of the mandible.

Figure 17-9: Silicone rubber which is a biocompatible alloplastic material is used as an onlay graft on the ramus to augment deficiencies of the ramus.

Dead space around the graft should be avoided as much as possible for the risk of infection. Negative pressure drains for 1 to 2 days and pressure dressings for several days can reduce dead space formation and resultant hematoma.

Maxillary Asymmetry

Minor asymmetries of the maxilla which do not create any functional and esthetic problems for the patient can be left alone without any treatment. Most of the dentoalveolar deformities can be corrected by orthodontic treatment; but when the deformity is skeletal, surgery is resorted to. Maxillary deformities can be vertical, horizontal or sagittal. Evaluation of the maxillary asymmetry is mainly through PA and lateral cephalograms, well poised photographs and study models. Surgery is planned after exactly assessing and quantifying the deformity and doing prediction tracing and model surgeries.

Maxillary deformity secondary to the mandibular deformity has been described and treatment procedures were discussed earlier in this chapter.

Vertical asymmetry of the maxilla is characterized by the vertical dimensional difference between the two sides of the maxilla in relation to the horizontal plane. Occlusion, alar base and stomion may be canted. The

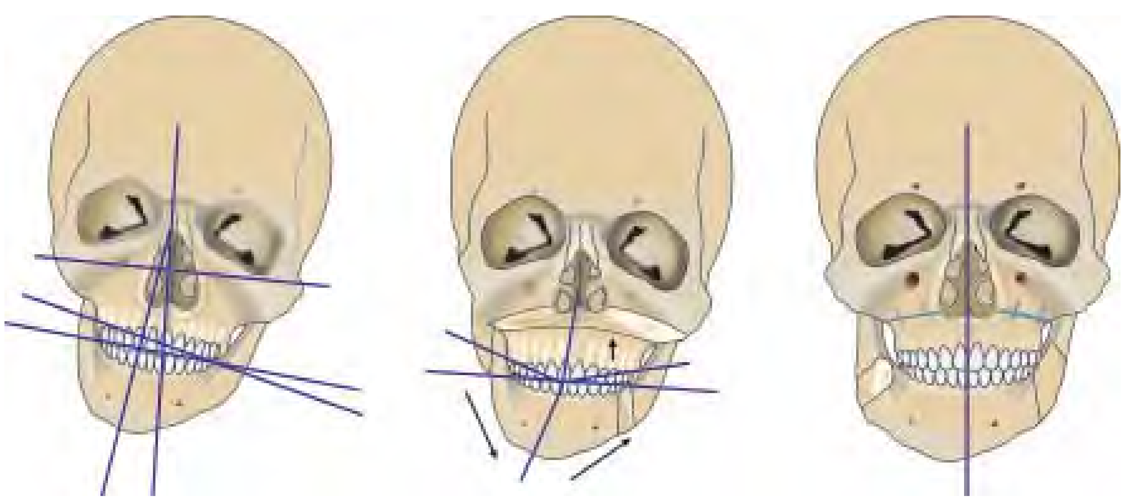
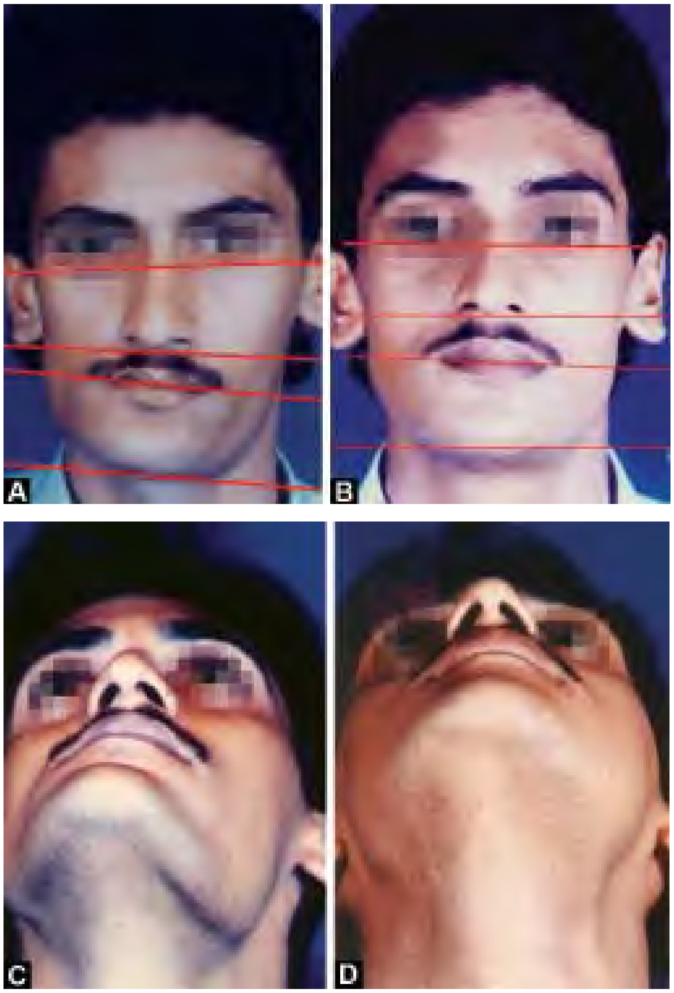


Figure 17-10: Drawing horizontal and vertical lines on the frontal photograph and the PA cephalogram is used to exactly analyze the facial asymmetry and the exact location of asymmetry.



Figures 17-11A to D: This patient having Hemifacial Hypertrophy has got the facial asymmetry extending from the orbit to the chin. This can be clearly understood by drawing transverse lines on the frontal photograph (A and B). He had occlusal cant as well. He has undergone Le Fort I osteotomy with anti-clockwise rotation to correct the occlusal cant. BSSO was done to bring the mandible to the midline. Inferior border ostectomy was done to remove the excess of bone (C and D). (A and C) Preoperative photographs. (C and D) Postoperative photographs.

deformity can be corrected after deciding which side is more pleasing. It is usually necessary to combine both maxillary and mandibular surgeries. The maxilla can be moved in all three dimensions using total or segmental maxillary osteotomies **(Figures 17-10 and 17-11A to D)**.

Horizontal asymmetry is characterized by difference in width of the right and left sides of the maxilla in relation to the sagittal plane. Usually this deformity does not produce marked facial asymmetry unless it is very severe. The primary deformity is often in the posterior maxilla. There may not be any mandibular asymmetry. Posterior cross bite is usually present. The treatment is decided depending on the site and size of the deformity. Posterior maxillary osteotomy is usually sufficient; however, segmental osteotomy may have to be combined with total maxillary osteotomy (Le Fort I). These procedures have been discussed under maxillary surgery **(Figures 17-12A and B)**.

Figures 17-12A and B: A case of hemifacial hypertrophy having occlusal cant, mandibular prognathism with deviation. She has undergone Le Fort I, BSSO and genioplasty (Preoperative and Postoperative photographs).

Sagittal maxillary asymmetry is probably the most pronounced form of all maxillary asymmetries. This deformity is characterized by the deviation from the vertical plane, and one half of the maxilla is more anteriorly placed than the other. These features are usually observed in patients with hemifacial microsomia and certain cases of cleft palate with disturbed growth. In severe forms, both the vertical and horizontal planes are also affected.

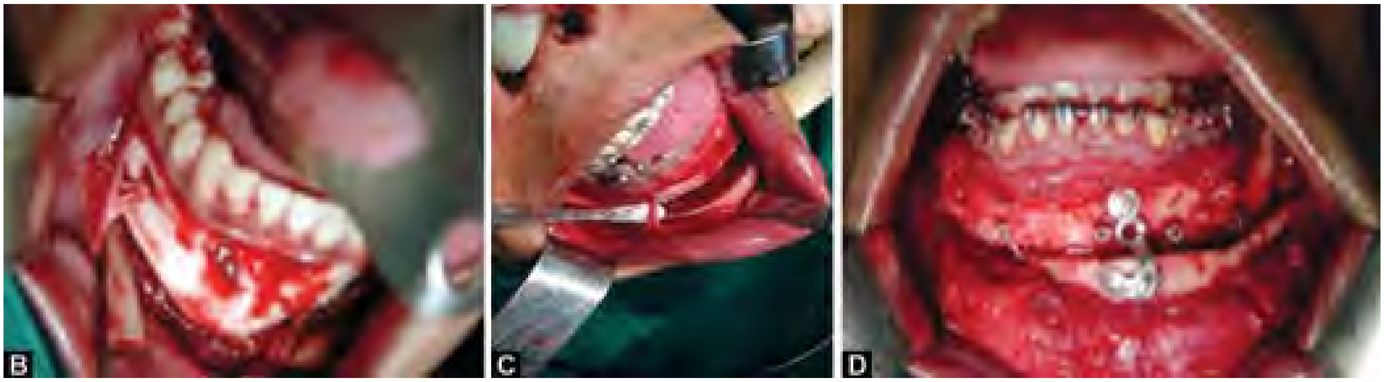
In sagittal asymmetry, segmental maxillary osteotomy is advised to reposition the abnormal side. However, in hemifacial microsomia with involvement of the maxilla, total maxillary osteotomy with segmentation of the maxilla is combined. In hemifacial microsomia, the surgery is primarily done on the mandible, and the interocclusal space is maintained by splints. Maxillary surgery can be done after the healing is complete. With the current techniques, already described, simultaneous correction of maxilla and mandible is also possible.

Extended Lateral Sliding Genioplasty

Introduction

Genioplasty accomplished by the osteotomy of the inferior border of the anterior part of the mandible is a versatile procedure for the rectification of many deformities of chin. The first description of sliding advancement genioplasty is by Hofer[11] in 1942 via an extra oral submental approach

Figure 17-13A: Diagrammatic representation of 'Extended lateral sliding Genioplasty'.



Figures 17-13B to D: Mandible is degloved and the lower border of the mandible is cut and slid laterally to correct the midline and to achieve fullness on the apparently sunken side.

to the chin. However, it was Trauner and Obwegeser who devised an intraoral anterior labial sulcus approach for chin advancement in 1957.[33]

A modification of conventional genioplasty technique termed "Extended Lateral Sliding Genioplasty" has been practiced from 1992 and described by the author in 1995.[22] An inferior border osteotomy extending from one gonial region to the other was performed, following which the osteotomized segment was advanced, translated and/or rotated laterally, for correction of facial asymmetry due to unilateral mandibular deficiency **(Figure 17-13)**.[20-22]

Surgical Technique

A degloving incision is placed on the lower buccal sulcus extending from one ascending ramus to the opposite ascending ramus. The incision is deepened subperiosteally. Mucoperiosteal flap is reflected downwards to expose the lower border of the mandible, and posteriorly till the gonial angle. Inferior border osteotomy was performed below the mandibular canal taking care not to injure the inferior alveolar neurovascular bundle. The cut should be more than 6 mm below the mental foramen. Wolfe has estimated the position of the inferior alveolar canal to be 6 mm below the mental foramen.[35] Anterior to the mental foramen, the cut is slanted upward above the genial tubercle to include more bulk of the bony chin. The cut extends from one gonial region to the other. It is not always necessary to extend the cut to the gonial angle on the side which is opposite to the side to where the lateral sliding is done. After cutting the buccal and labial cortex, multiple holes are made on the lingual cortex and the bone is split using osteotomes and/or spreader.[20] Osteotomized lower segment is slid forward and laterally, so that the chin and the sunken lateral aspect of mandible are augmented. The deficient side of the mandible is lengthened and the deviation of the chin is corrected. The same technique can be employed in combination with other osteotomies like sagittal split, maxillary osteotomies, etc. for correction of hemifacial dysplasia. A stepping on the lateral border is created during lateral sliding. If more bulk is required, autogenous bone may be grafted to interpose or to obliterate the step defect. However the risk of necrosis of grafted bone is to be borne in mind. When esthetic correction, simultaneous with functional correction of ankylosis is done the resected bone can be used as the graft and there is no need for any separate surgery for bone harvesting.

Care is taken to maintain appropriate soft tissue pedicles to the inferior border and lingual part of the osteotomized segment. The horseshoe shaped cut segment is advanced forward to augment the chin and translated laterally to the side of apparent deficiency of the mandible to correct asymmetry. The inferior segment is stabilized in the preplanned desired position with transosseous wiring and later rigidly fixed using mini plates **(Figures 17-13 to 17-15)**.

Figure 17-14: Facial asymmetry due to hemifacial microsomia, corrected by extended sliding genioplasty.

Surgical correction of facial asymmetry is more challenging than the correction of symmetrical defor-mities.

Often unilateral mandibular deficiencies are associated with slight downward growth of the maxilla on the affected side, altering the position of the midline structures of the middle third of the face, creating an occlusal cant. A line drawn perpendicular to the inter-innercanthal line at the midpoint is taken as the facial midline.

Inferior border osteotomy of mandible performed intraorally can be employed independently or in combination with other procedures to correct the facial asymmetry of the mandible.

In TMJ ankylosis because of the destruction of the growth center and the missing functional stimulus, there is deficient growth, and so mandible on the affected side is short. The opposite side of the mandible is dragged to the affected side. This will result in facial asymmetry, with false fullness of the affected side, and sunken unaffected side with resultant deviation of the mandible.

The conventional technique of esthetic correction of the above described deformity is by ramus osteotomies and bone grafting. This technique often jeopardizes the existing occlusion. In most of the patients, because of the pre-existing trismus, the teeth are unhealthy. Hence orthodontic treatment may not be feasible. Benefits of the 'long' osteotomy cut, extending to the gonial region bilaterally

Figures17-15A to D: This is a case of facial asymmetry due to ankylosis of the TMJ (Rt side), which was treated by functional correction. Esthetic correction was done by extended lateral sliding genioplasty. (A and C) Preoperative photographs. (B and D) Postoperative photographs.

have been put forward by Tessier.[31] These include maintenance of a smooth natural inferior border, non-interference with occlusion and simultaneous increase in the width of the jaw line.

Management of the mental nerve is an important criteria. Hinds and Kent[10] favour dissection and protection of the mental nerve during osteotomy. Posnick et al[22] also advocated dissection and retraction during osteotomy. He has reported persistent sensory deficit in 10% of his cases after one year. Spear and Kassan,[29] and Lindquist and Obeid[16] advised identification and protection of the mental nerve. They have reported permanent mental nerve deficit in 6% and 10% of patients; and are against the idea of dissecting the nerve. Converse and Wood Smith[2] are of the opinion, that the mental nerve may be divided if it obstructs the osteotomy. If divided, anastamosis is advised.

Advantages of Extended Lateral Sliding Genioplasty

1. A simple procedure accomplished through an intraoral degloving incision in the buccal vestibule.

2. Less time consuming than the conventional ramus osteotomies for the correction of unilateral mandibular deficiencies.
3. Existing occlusion is not disturbed.
4. Deficient side of the mandible is lengthened.
5. The chin is brought close to the midline.
6. The apparent deficiency on the unaffected side is corrected by the lateral shift of the inferior border segment and thus fullness is achieved.
7. The procedure can be combined with other orthognathic procedures, including BSSO.
8. The procedure can be done concomitantly with the correction of TMJ ankylosis.
9. Harmony and balance of the face (vertical and horizontal proportion) are improved.
10. Psychological rehabilitation of the patient is rapid.

Facial asymmetry can be due to several etiological factors, of which TMJ ankylosis and hemifacial microsomia are the predominant ones. 'Extended lateral sliding genioplasty' is a very useful intraoral surgical technique for the management of unilateral mandibular deficiency. This surgery can be employed concomitantly with many other surgical procedures like arthroplasty, sagittal split osteotomy and maxillary osteotomies.

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Chapter

18

Radhika Chigurupati, M Anthony Pogrel

Introduction

Condylar hyperplasia and condylar resorption are acquired disorders that affect the temporomandibular joint (TMJ) resulting in skeletal facial deformities and abnormalities in occlusion. The surgical correction of these deformities can be challenging, due to the variable period of abnormal condylar activity. Operative intervention has to be timed appropriately after necessary diagnostic investigations have established that active changes in the condyle have ceased. Skeletal scintigraphy serves as a useful diagnostic tool and treatment planning aid in the management of these skeletal facial deformities, as it detects metabolic bone activity and areas of active bone formation in the condyles. The goal of treatment is to achieve a stable functional occlusion without relapse, normal TMJ function and facial symmetry and balance. We present the etiology, the natural history and progression of these two TMJ disorders; discuss investigations and treatment of the resulting deformities with illustrations of surgical techniques and examples of clinical cases.

Condylar Hyperplasia

Condylar hyperplasia is a postnatal growth abnormality of the TMJ caused by hyperactivity of the growth center of the mandibular condyle, resulting in progressive mandibular asymmetry. Progression of the asymmetry ceases once the hyperactive condyle becomes quiescent.

Etiology and Pathogenesis

The exact cause of abnormal hyperactivity of the condyle is not clear, but several factors contributing to abnormal growth stimulus such as trauma, and vascular and hormonal disturbances have been proposed. Histological studies show that the fibrocartilaginous layer of the condyle is responsible for this hyperactivity. Histologically, the hyperplastic condyle is characterized by the presence of an undifferentiated layer of mesenchymal cells, and islands of chondrocytes in the subchondral trabecular bone.[6, 12, 14, 18, 31]

History and Clinical Presentation

Condylar hyperplasia is almost always a unilateral TMJ disorder. Females are more frequently affected by this condition than males. The most common presenting complaint is jaw asymmetry, often noticed by family members. The majority of the patients present for evaluation in the quiescent phase of condylar hyperplasia. Patients may report a change in their bite, occasionally discomfort during function and limitation in mobility, if the condylar head is too large. Occasionally, they may have symptoms of pain in the contralateral TMJ.[32]

Clinically, jaw asymmetry first becomes apparent usually at the onset of puberty, but it may occur as early as 6-7 years or at any time during the growth period. Asymmetric jaw growth occurs simultaneously with general body growth spurt and often continues for a variable period, beyond completion of overall growth. Depending on the age when condylar hyperactivity begins, and its intensity, compensatory changes are seen in the maxilla, opposite side of the mandible, and the occlusion. The mandibular deformity due to condylar hyperactivity can vary. Obwegesser recognized three different mandibular deformities due to condylar hyperactivity—Hemimandibular hyperplasia, Hemimandibular elongation, and Hybrid forms of hemimandibular hyperplasia and elongation.[32,33] Kaban describes two types of mandibular growth patterns in patients with condylar hyperplasia—Vertical and Rotational.[23]

Vertical

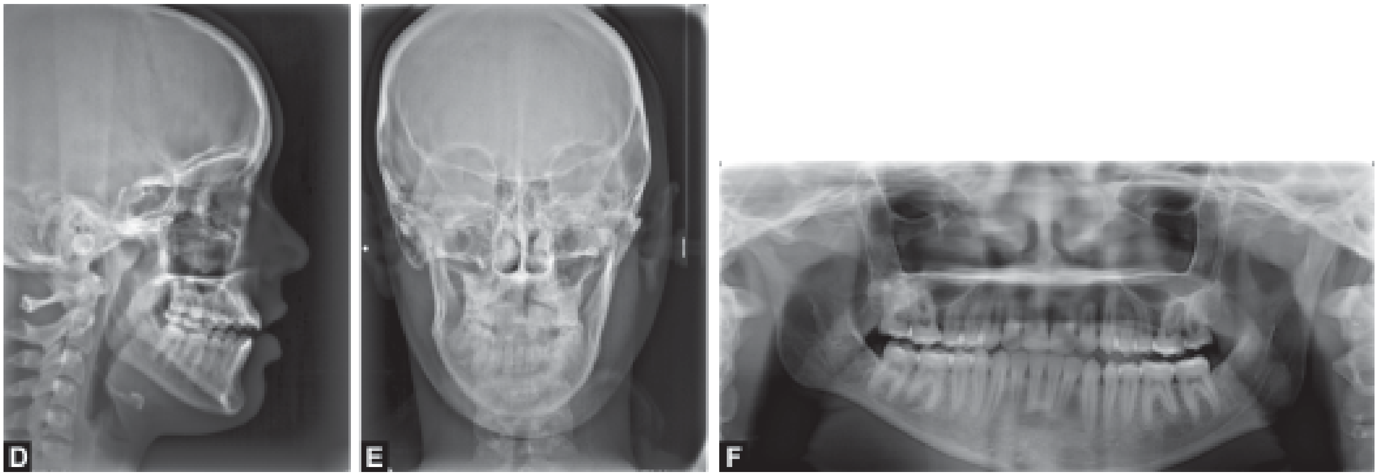
These individuals show a vertical increase in size of the affected hemimandible up to the midline. There is enlargement of the affected condylar head, and increased vertical height of ramus and height of the body of mandible on the affected side. The inferior border of the mandible has an increased convexity and it appears bowed downwards on the affected side. A posterior open bite is seen on the affected side in cases where condylar hyperplasia begins after maturity. If, however, the hyperactivity begins before growth is completed, there will be a cant in the occlusal plane due to compensatory growth of the maxilla and alveolar process on the affected side with no open bite. The mandibular dental midline and chin and lower incisor roots are tipped away from the affected side but there is no deviation of the dental midline and no cross bite on the unaffected side. On lateral and AP cephalometric radiographs there is an obvious asymmetry at the lower border of the mandible and on panoramic view there is increased ramus and body height on the affected side of the mandible.

Case 1 (Figures 18-1A to Q): *21-year-old female with left side condylar hyperactivity showing a vertical growth pattern. Diagnosis and management of a case of condylar hyperplasia with vertical growth pattern*

Rotational

Individuals with a rotational growth pattern reveal an increase in size of the condyle, length of the condylar neck and ascending ramus, as well as horizontal elongation of mandibular body on the affected side. This elongation of the mandibular body results in significant deviation of the chin and dental midline to the unaffected side, as well as a posterior cross bite on the unaffected side. On the

Figures 18-1A to C: Preoperative. (A) Frontal, (B) Profile and (C) Submental facial views showing mandibular inferior border and chin asymmetry.



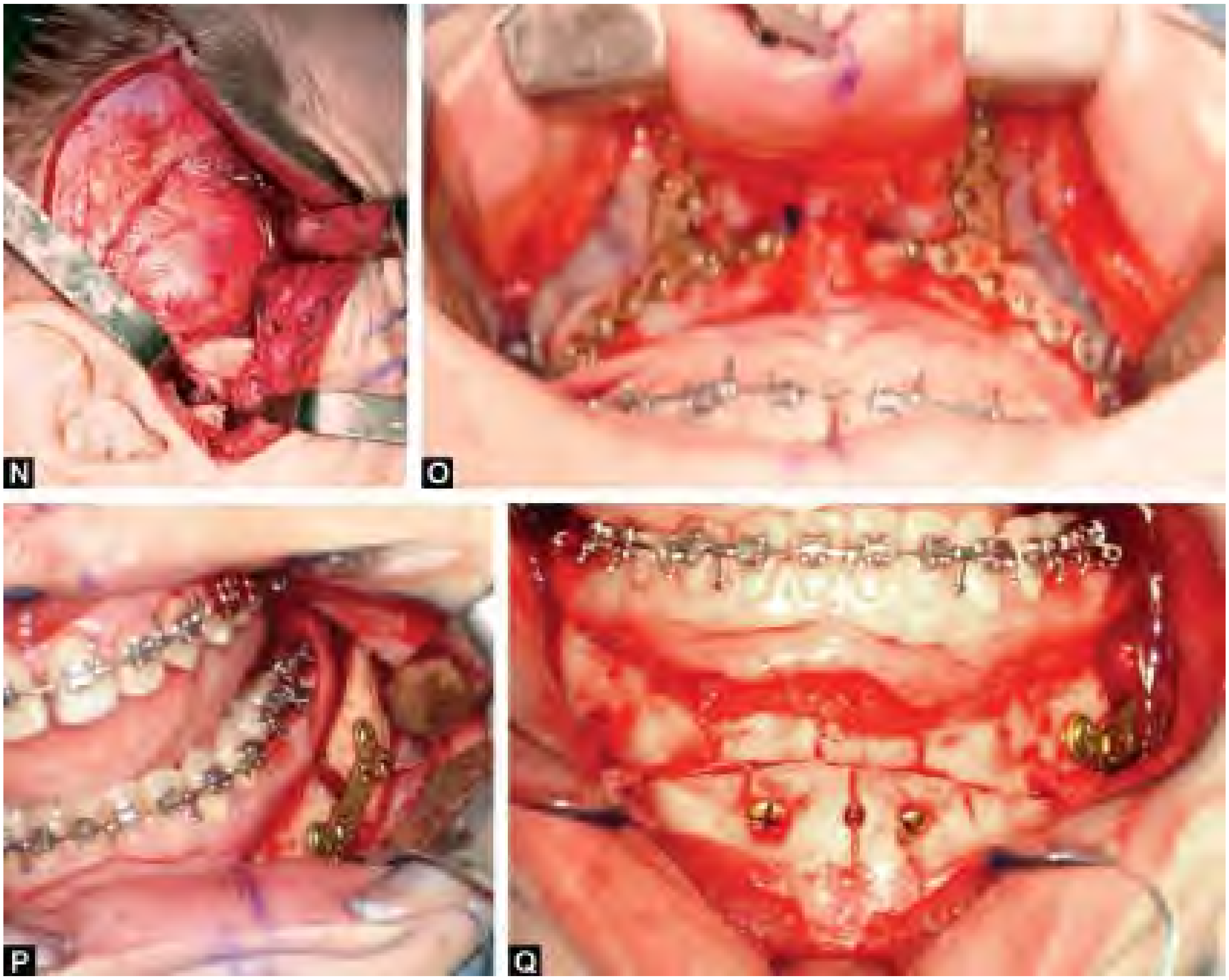
Figures 18-1D to F: (D) Lateral, (E)) Anteroposterior cephalometric views and (F)Panoramic views reveal the obvious asymmetry at the lower border, increased left ramus and body height due to condylar hyperplasia on the affected side.

Figures 18-1G and H: (G) Occlusion showing posterior openbite, more on the affected (left) side compared to the (H) the unaffected (right) side.

Figures 18-1I to K: (I) Frontal rest, (J) Frontal smiling and (K) Profile facial views showing improvement in chin and angle of mandible asymmetry after correction with maxillary Le Fort I and mandibular sagittal split osteotomies and genioplasty.

Figures 18-1L and M: (L) Left side and (M) Right side occlusion intraoral showing good intercuspation and alignment of teeth

affected side the canine and molars are in a class III relationship and on the contralateral side the canines and molars are usually in class I relationship. On lateral cephalometric radiographs the asymmetry at the posterior border is more notable due to the elongation of the body of the mandible and on panoramic views the body and ramus on the affected side are elongated, with deviation of the midline to the opposite side.



Figures 18-1N to Q: Intra and postoperative: (N) Approach for a high condylectomy or condylar shave to arrest the abnormal condylar activity. (O) Fixation of Le Fort I level osteotomy, (P) Sagittal split osteotomy and (Q). Genioplasty (performed 6 months after high condylectomy).

Case **2 (Figures 18-2A to M):** *17-year-old female with condylar hyperactivity of the right side showing horizontal growth pattern. Diagnosis and management of a case of condylar hyperplasia with horizontal growth pattern.*

Diagnosis: The diagnosis of condylar hyperplasia is made by history, clinical assessment, mounted study models of occlusion, radiographic examination using cone beam computed tomography or conventional serial lateral and anteroposterior cephalometric and panoramic images obtained 6-12 months apart and skeletal scintigraphy.

It is important to differentiate condylar hyperplasia from other pathological lesions of the condyle such as osteoma, osteochondroma, chondrosarcoma, fibrous dysplasia and other giant cell lesions, as well as other forms of facial asymmetry such as hemifacial hypertrophy and hemifacial microsomia (HFM).[30]

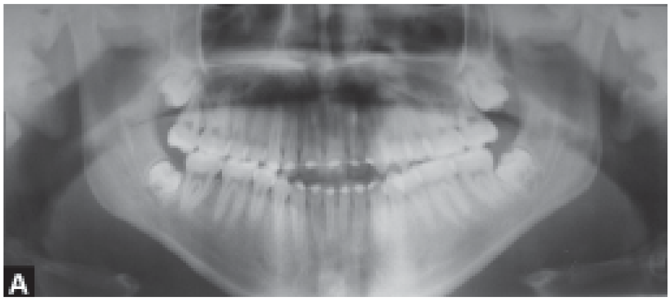
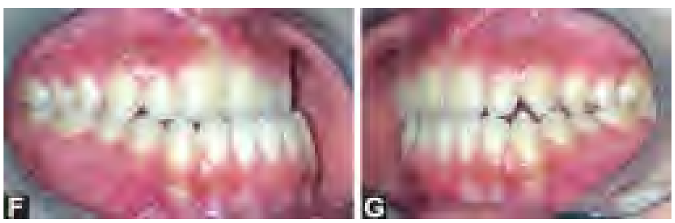


Figure 18-2A: Panoramic view reveals the right mandibular body elongation with chin and dental midline shifted to the left side.

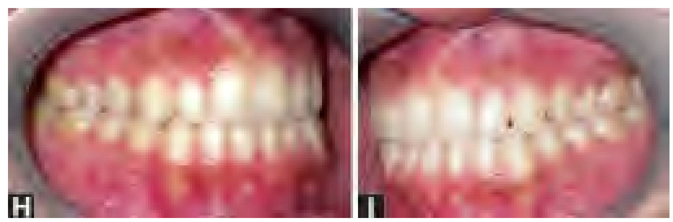
Unlike individuals with hemifacial hypertrophy and hemifacial microsomia, individuals with condylar hyperplasia do not have any jaw asymmetry at birth. In hemifacial hypertrophy the facial asymmetry is due to generalized unilateral hypertrophy of the hard and soft tissues of the face. There may also be an accompanying

Figures 18-2B and C: Preoperative. (B) Frontal facial view and (C) Facial profile view .

Figures 18-2D and E: (D) AP cephalometric view, showing deviation of the chin to the left and mandibular asymmetry and (E) Lateral cephalometric view reveal a prognathic mandible with asymmetry at the posterior border.

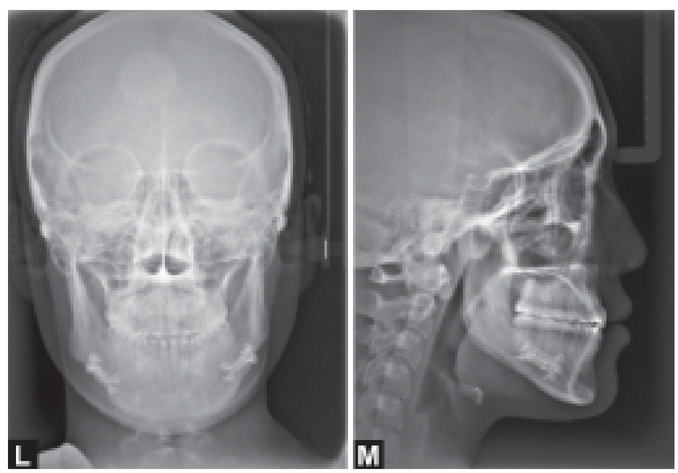


Figures 18-2F and G: (F) Class III relationship of molars and canines on the right side and (G) Class II with posterior cross bite on the unaffected (left) side.



Figures 18-2H and I: (H) Intraoral right side and (I) Left view of the occlusion reveal Class I canine and molar relationship after correction.

Figures 18-2J and K: (J) Frontal rest, and (K) Profile views of the face reveal good symmetry and balance after rotation of the mandible with a bilateral sagittal split osteotomy



Figures 18-2L and M: (L) Antero-posterior and (M) lateral cephalometric radiographic views, six months after correction of asymmetry.

increase in size of other parts of the body on the affected side **(Figures 18-3A to D)**.

In HFM, the mandibular asymmetry has a greater effect on vertical midface growth since this condition is present at birth, unlike condylar hyperplasia. Patients with mild hemifacial microsomia can be differentiated from patients with condylar hyperplasia of the opposite side, by presence of ear anomalies, weakness of the facial nerve, facial soft tissue deficiency and midface deficiency, and retruded chin.[23]

Role of Scintigraphy in Diagnosis

Bone scintigraphy is a useful modality to detect metabolic activity in condyles and facial growth dynamics. The basis

Figures 18-3A and B: (A) Facial view of 48-year-old female with osteochondroma of the left condyle resulting in facial asymmetry and ankylosis. (B) AP cephalometric radiograph.

Figures 18-3 C and D: (C) Frontal facial view of a patient with right hemifacial hypertrophy and (D) Left side hemifacial microsomia (HFM) - note the soft tissue deficiency, ear abnormalities and retruded chin in HFM,

of skeletal scinitgraphy is that blood flow is related to bone formation and bone remodeling, and uptake of the radioisotope is dependent on blood flow. Radioisotope uptake studies are normally carried out with a bone-seeking phosphate isotope such as Technetium 99m pyrophosphate, or methylene diphosphonate (MDP). When these radioisotopes are injected into the bloodstream there is increased uptake in areas of increased bone activity and decreased uptake in devascularized and hypometabolic bone.

Cisneros and Kaban studied the amount of condylar cartilage activity and mandibular growth changes in different age groups of normal growing children and established age adjusted uptake values for ^{99m} TC- MDP in the human mandible.[22] They showed that patients with active condylar hyperplasia exhibit increased uptake in the affected condyle when compared with controls, whereas uptake in condyle of patients with hemifacial microsomia was markedly reduced.[9]

The scan normally involves three phases. The first phase, known as the blood flow phase, shows the degree of uptake of the isotope, which is dependent on blood flow to the region. In the second phase, the isotope is taken up by the actively forming bone matrix, and in the third or excretion phase, the isotope is eliminated and shows mainly in the kidneys, ureter or bladder. The stage of interest in patients with suspected abnormal condylar activity is the uptake phase in the bone matrix, and this normally occurs between two and four hours post-injection of the isotope. A gamma camera equipped with a collimator is used to take images of the region of interest. Condylar activity is then compared to basal bone activity at the clivus or lumbar spine (L-4).

Regions of interest (ROI) are outlined over the images and the ratio of uptake (RU) is calculated as indicated below. An unequal radioisotope uptake indicates ongoing asymmetric growth.

$$RU = \frac{\text{Counts in the ROI in the mandible – background counts}}{\text{Counts in the Clivus – background counts}}$$

Several studies have shown that quantitative assessment with single photon emission computed tomography (SPECT) is more sensitive and accurate than subjective interpretation of planar images without quantification, in order to distinguish normal condylar activity from hyperactivity.[16, 38, 39] Using SPECT, tomographic slices approximately 6.5 mm apart can be taken in any plane. It is easy to image the clivus and the condyles on the same tomographic slice, since it is located at the skull base at the same axial level as the mandibular condyles. When requesting these scans, the surgeon should request a pixel count in numeric and graphic form **(Figure 18-4)**.

Management

Orthognathic Surgery for correction of these facial deformities and malocclusion requires three-dimensional analysis of the anomaly and proper presurgical planning to restore good TMJ function, prevent relapse and achieve facial symmetry, balance and proportions. The preoperative planning requires radiographs and facial photographs, study models mounted on an anatomic articulator with a face bow transfer or software that allows planning of three-dimensional surgical movements.[45]

Hodder, et al recommended a treatment algorithm for patients with facial asymmetry.[16] The timing and type of

Figure 18-4: An SPECT scan is shown in this coronal slice that includes both condyles and the clivus. Note the activity in the condyle on the right is the same as in the clivus whereas the one on the left shows greater activity.

surgical correction is based on the clinical examination and radiographic and scintigraphic studies. Orthognathic surgery to correct the facial asymmetry and malocclusion should be performed after the condylar hyperactivity is arrested.

In patients with radiographic and/ or clinical evidence of abnormal condylar activity, a high condylectomy or high condylar shave should be performed to excise the abnormal condylar growth center in the mandible. The mandibular and maxillary osteotomies can be performed simultaneously at the time of the condylectomy or at a second stage.[47]

In growing individuals early recognition and correction of condylar hyperplasia with a high condylectomy will decrease severity of asymmetric mandibular growth as well as prevent associated compensatory changes in the maxilla and the dentoalveolar process.[30]

A high condylectomy or condylar shave can be performed through a standard preauricular incision as seen in **Figure 18-1N**.

The enlarged condylar head is usually well demarcated from the normal condyle. The condylar head is excised, leaving the rest of the condylar stump and ramus intact. Troulis and Kaban have described an endoscopic technique to perform the condylectomy. The ramus segment with the condylar head is removed after performing a vertical ramus ostectomy via a small submandibular incision to create an optical cavity. The hyperactive condylar head is then excised and the ramus segment is replaced and rigidly fixed. A contralateral sagittal split is performed to complete the mandibular osteotomies.[44] Similarly, Choung and Nam, described a technique that involves removal and reimplantation of the condylar process using the vertical-sagittal ramus osteotomy on the affected side to treat condylar hyperplasia and high condylar process fractures. They used direct intraoral access as opposed to an endoscopic technique. There was no condylar resorption or ischemic necrosis of the head of the condyle after this technique in 23 patients. They found this method useful to improve access and correct vertical discrepancies associated with condylar hyperplasia.[8]

Patients with clinical and radiographic stable deformity without signs of abnormal condylar activity and progressive facial asymmetry can be treated by orthognathic surgery without disturbing the enlarged condylar head to achieve an esthetic and functional result. Orthodontic treatment in the presurgical phase is necessary to decompensate the teeth by aligning them on the skeletal base. The skeletal asymmetry can be corrected by osteotomies of the mandible only, or combining it with maxillary osteotomy in cases where compensatory changes have resulted in maxillary asymmetry and cant of the occlusal plane. The lower border asymmetry can be corrected by an inferior border ostectomy on the affected side as shown in the **Figure 18-5**.

Figure 18-5: Inferior border ostectomy for correction of the lower border and angle asymmetry in individuals with condylar hyperactivity and vertical growth pattern.

A genioplasty is often necessary to correct the position of the chin in vertical and transverse dimensions.[7, 13] Motamedi suggested that in selective cases unilateral mandibular osteotomies can be performed to restore symmetry. In a series of 13 patients with condylar hyperplasia, he used unilateral ramus osteotomies in 6 patients, where the degree and direction of mandibular shift needed was minimal. The basis of this technique is that the condyle can tolerate a rotation of 10-15^{o} as the

Figures 18-6A to D: (A) Typical appearance of a patient with condylar resorption. Note retrognathism, clockwise rotation of the mandible, retruded chin on facial profile. (B) Lateral cephalometric radiographic view. (C) Open bite occlusion with lip incompetence. (D) Panoramic view shows short ramus height and complete resorption of condyles.

mandible is swung to the opposite side after unilateral osteotomy. Cases were assessed intraoperatively to evaluate whether an osteotomy was necessary on the contra lateral side.[29]

Condylar Resorption

Condylar resorption can be defined as a progressive alteration in the shape of the condyle accompanied by a decrease in condyle mass. It is a poorly understood disorder that almost always affects both condyles of the temporomandibular joint. As condylar resorption progresses, there is decrease in posterior facial height, counter-clockwise rotation of the mandible with development of retrognathia, retrogenia and an anterior open bite malocclusion **(Figures 18-6A to D)**.[20]

Etiology and Pathogenesis

The exact etiology is unknown, although it has been associated with medical conditions including autoimmune disorders such as systemic lupus erythematosus, rheumatoid arthritis, and scleroderma.[15,25,34-36,41] Condylar resorption has also been attributed to steroid use, neoplasia, trauma, mechanical forces, and stress generated at the TMJ during orthopedic and orthodontic treatment and orthognathic surgery.[5,37,40,43] In majority of the cases, however, there may be no identifiable precipitating events; hence it is often referred to as idiopathic condylar resorption.

Young women in the second and third decades with high mandibular plane angle, small condyles on long slender condylar necks, and pre-existing temporomandibular joint symptoms seem to be more susceptible to condylar resorption.[24] The predominance of this condition in females between 15-35 years suggests a relationship to hormonal response and estrogen receptors in the TMJ **(Table 18-1)**.[27]

Arnett, et al investigated changes in the bone associated with abnormal joint loading after surgery. They have documented that condyles may be torqued when rigid fixation is used to secure the proximal and distal segments, in particular during sagittal split osteotomy. Excessive pressure on the lateral or medial pole of condyles can lead to condylar resorption and subsequent clinical relapse after orthognathic surgery **(Figure 18-7)**.[2,3,11]

Borstlap, et al reported the long-term effects of miniplate fixation on condylar remodeling and resorption in a multicenter study. They report that a steep mandibular

Table 18-1: Surgical and nonsurgical risk factors for condylar resorption

Surgical Risk Factors
Medial or lateral condylar torquing with rigid fixation during surgery Prolonged period of MMF after bimaxillary surgery in patients with steep mandibular plane angle Anti-clockwise rotation of the distal and proximal segments during mandibular osteotomy Posterior condylar displacement during mandibular osteotomy Large mandibular advancements
Nonsurgical Risk Factors
Female between 15-35 years Preexisting TMJ dysfunction High mandibular plane angle Small condylar head with slender long posteriorly inclined condylar neck Systemic autoimmune disorders—SLE, JRA, Scleroderma

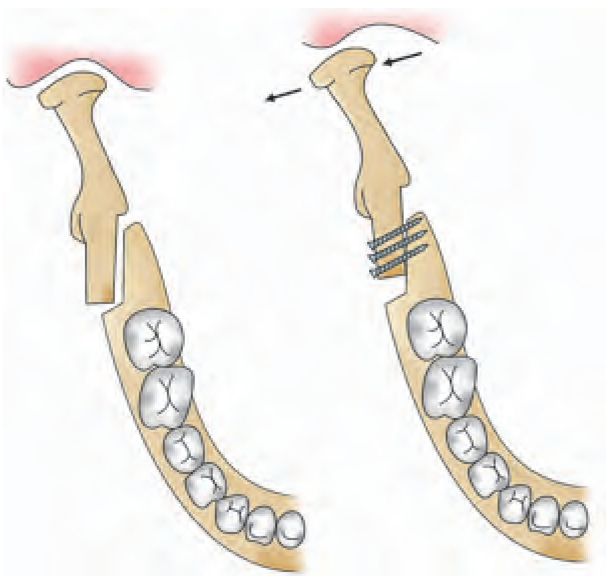


Figure 18-7: Condylar torquing caused by rigid screw fixation following sagittal split osteotomy when the distal fragment is rotated. Use of non-rigid fixation or placing interpositional bone strips between the fragments before screw fixation is appropriate in such cases.

plane angle and the low facial height ratio (post: ant) were significantly related to the occurrence of condylar alteration, but the multiregression analysis showed that these parameters had only limited value. The occurrence of pain and TMJ sounds in the first few months post-operatively are highly suspicious for condylar changes to occur in the next months.[4] Hwang, et al found that surgically induced posterior displacement of the condyle and counter clockwise rotation of the distal and proximal segments in patients undergoing mandibular osteotomies contributed to condylar resorption. Resorption was noted on the superior and anterosuperior aspects of the condylar head.[21] Stoelinga and Scheerlinck, et al reported an incidence of 7.7% condylar resorption following sagittal split osteotomy in 103 patients, and it can be as high as 12.5% when patients fulfil all the at risk criteria.[42] Huang and Ross, et al showed that postoperative condylar resorption may be particularly higher in susceptible patients that undergo large mandibular advancements of 10 mm or greater.[19] Hoppenreijs, et al reported that condylar resorption was greater in the group with intraosseous wire fixation and postoperative intermaxillary fixation (IMF) than in cases with rigid internal fixation without IMF.[17] Wolford, et al evaluated changes in TMJ dysfunction after orthognathic surgery. In patients with documented clinical and radiographic (MR scan) evidence of TMJ dysfunction, i.e. internal derangement, there was significant worsening of the TMJ dysfunction after orthognathic surgery. 24% (6/25) of their patients developed condylar resorption with class II malocclusion and an open bite post-surgically.[48]

Clinical Findings and Diagnosis

Progressive condylar resorption typically affects young women in the second and third decades (15-35 years, mean reported age 20.5 years), unlike degenerative joint disease which frequently occurs later in life in the 5th and 6th decades. Mandibular retrognathia with a retruded chin and decrease in posterior facial height due to clockwise rotation of the mandible are often the initial presenting clinical signs of this condition. Patients develop a Class II malocclusion with an anterior open bite. Sometimes, they present with associated symptoms of TMJ pain and dysfunction.

A thorough history should be obtained to determine factors that may contribute to condylar resorption. A history of prolonged steroid use and the use of orthopedic devices, trauma and surgery that can cause increased loading on the condyles, should be investigated. Patients should be evaluated for systemic illness that can cause bone resorption. Serological tests and a thorough clinical exam should be performed to investigate rheumatoid arthritis and scleroderma. Tests useful in the diagnosis of these autoimmune disorders include rheumatoid factor (positive in 80% patients with rheumatoid arthritis and 33% with scleroderma), C-reactive protein, erythrocyte sedimentation rate, and antinuclear antibodies (present in 40-60% patients with rheumatoid arthritis). Condylar resorption should be suspected when there is skeletal relapse after orthognathic surgery.[28]

Condylysis and the accompanying changes can be evaluated by serial radiographs, panoramic and lateral cephalometric views and tomographic images of the condyle generated by cone-beam computed tomography. Changes in condylar size, condylar morphology, cortical outline of the condylar head, and posterior facial height can be evaluated by these imaging techniques **(Figure 18-8)**.

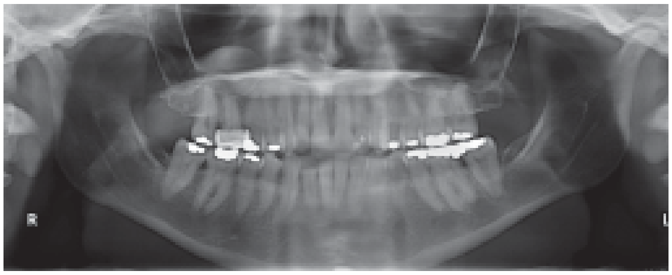


Figure 18-8: This panoramic view reveals changes in the condyles in an "at risk patient". These are small condyles on long, slender condylar necks, inclined posteriorly and there is evidence of loss of cortication on the right side.

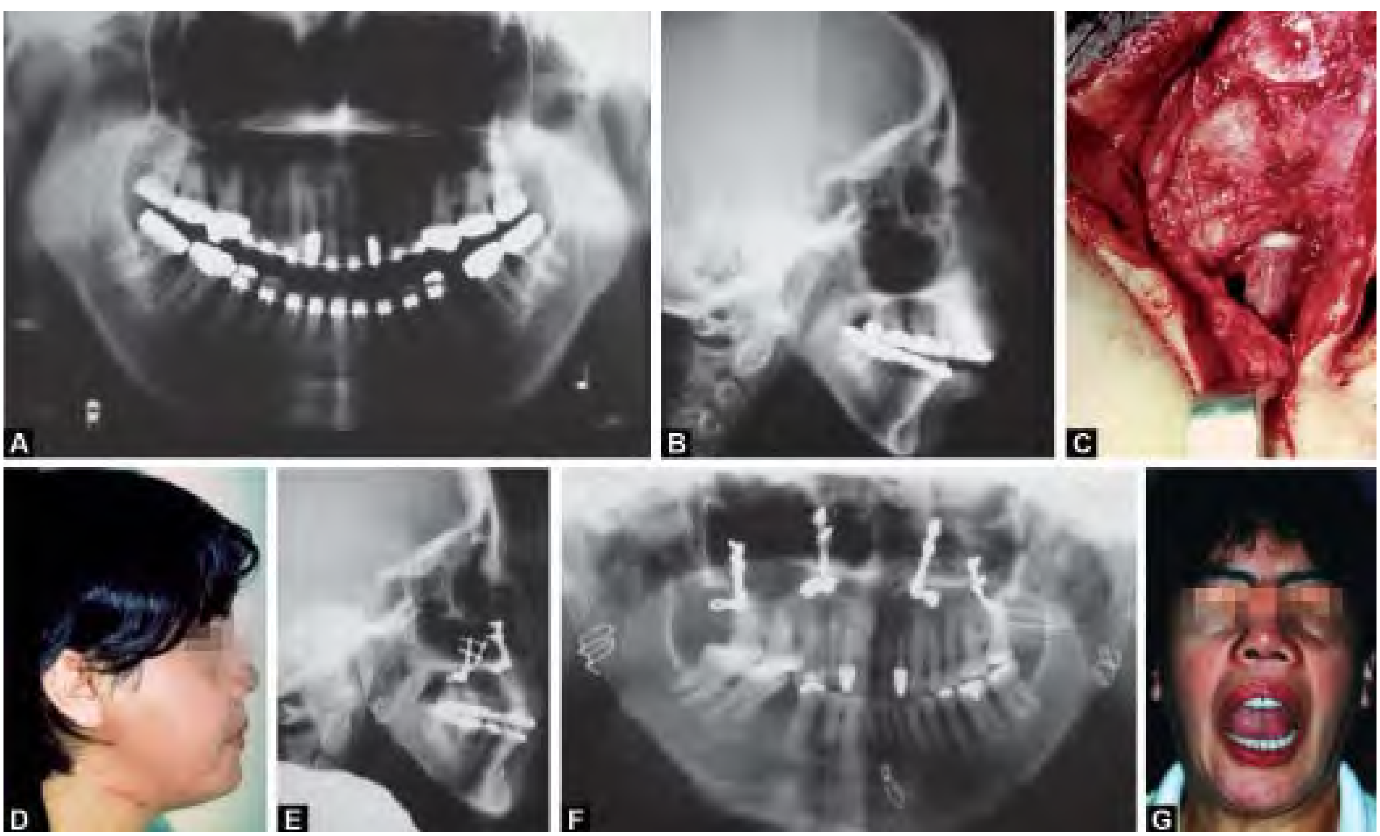
Radioisotope studies utilizing technetium-99 methylene diphosphonate with a single photon emission computerized tomography scan comparing the activity in the condyle with that in the clivus of the skull can be used to detect metabolic activity within the mandibular condyles. As mentioned earlier, radioisotope uptake studies will show if any active metabolic activity is occurring in the mandibular condyles. These isotopes are taken up by areas of active bone formation.[22]

Management

The management of this condition is challenging as there are very few evidence-based guidelines for treatment. It is important to ascertain that condylar resorption has ceased, before surgical correction of the deformity. This can be established by serial radiographs including cephalometric views and tomographic views of the condyles generated by cone beam computed tomography, models of occlusion, and scintigraphic study of condyles.

Orthognathic surgery has been proposed to correct the malocclusion and skeletal deformity caused by condylar resorption, but success has been unpredictable with adverse outcomes due to reactivation or progression of condylar resorption.[10,17] Huang, et al have suggested an alternative treatment consisting of condylectomy and replacement of the affected joints with autogenous costochondral grafts or an alloplastic total joint prosthesis. This treatment can be carried out whether the resorptive process is active or quiescent **(Figures 18-9A to G)**.

Crawford et al[10] reviewed a group of seven patients with progressive condylar resorption following ortho-



Figures 18-9A to G: Shows idiopathic condylar resorption managed by reconstruction of TMJ with costochondral grafts.

gnathic surgery which included a sagittal split osteotomy to advance the mandible. They were all treated by repeat orthognathic surgery which included a sagittal split osteotomy and five showed further skeletal evidence of relapse postoperatively and one of these showed further relapse after a third sagittal split osteotomy. Merkxs and Van Damme[26] treated eight patients who developed condylar resorption after sagittal split osteotomy and noted unsatisfactory results in four patients treated with repeated orthognathic surgery, but more stable results in four patients treated by an occlusal appliance and either orthodontic or prosthodontic management. Arnett and Tamborello reported six patients with progressive condylar resorption treated by orthognathic surgery, of which five had further resorption postoperatively. The one stable case was the only one who had preoperative occlusal appliance therapy to stabilize the TMJ. A second orthognathic surgery group of eight patients had preoperative stabilization with appliances and anti-inflammatory medications before orthognathic surgery, and in seven of these cases the results were stable over the long term. They have proposed that orthognathic surgery should be restricted to the maxilla while treating this condition since mandibular orthognathic surgery has the potential to reactivate resorption by altering the vascular and loading dynamics of the joint.[1-3]

Huang, et al proposed a protocol for management in teenagers with documented evidence of condylar resorption.[20]

1. A preoperative phase of occlusal splint therapy, anti-inflammatory medications, muscle relaxants and physical therapy may be used to manage TMJ symptoms.
2. An observation period of 24 months to evaluate the response to nonsurgical treatment and stability of the condition.
3. Patients who demonstrate no further activity at the condyles on bone scan can be treated with orthognathic surgery.
4. In patients with persistent condylar activity, condylectomy and reconstruction with costochondral grafts is recommended.

Huang, et al reported a series of 28 patients with progressive condylar resorption, of which 24 were treated surgically. 18/ 24 were treated by orthognathic surgery and 6/24 had condylectomy and rib grafts. Of the patients who had orthognathic surgery only 56% (10/18) patients had stable results, the remaining 8/18 had continued resorption or TMJ symptoms. On the other hand, all six patients treated with condylectomy and CC grafts had a stable result.[20] Wolford and Cardenas recommend removal of the hyperplastic synovial tissue and disk repositioning and ligament repair followed by orthognathic surgery to correct the functional and esthetic deformity.[46]

Treatment can be summarized as follows: When relatively small movements are required to close an anterior open bite deformity caused by condylar resorption, orthognathic surgery can be restricted to the maxilla if possible. When mandibular orthognathic surgery is performed (particularly a sagittal split osteotomy to advance the mandible) it should be undertaken with extreme caution. Where the condyles are still actively resorbing despite treatment, or larger movements are necessary to correct the deformity, a condylectomy and condylar reconstruction with costochondral graft is the current treatment of choice.

Summary

The mandibular deformities caused by condylar hyperplasia should be diagnosed properly, and surgical treatment should be timed appropriately to prevent secondary deformities in the maxilla and dentoalveolar complex in a growing individual. In growing individuals early recognition and correction of condylar hyperplasia with a high condylectomy will decrease severity of asymmetric mandibular growth as well as prevent associated compensatory changes in the maxilla and the dentoalveolar process.

At present there are no good evidence-based studies on management of condylar resorption, and further research is needed to understand the etiology better, and propose options for management, and assess the outcome of interventional therapy.

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Chapter

19

Varghese Mani

Introduction

The term open bite or apertognathia is applied to a condition in which teeth fail to occlude when the jaws are brought together. An open bite can be anterior or posterior.

Open bite deformity is generally classified as follows: Simple in which the interdental opening is anterior to canines, compound in which the opening extends back to the premolars and skeletal or infantile in which the deformity extends more posteriorly to involve the molars. When the open bite deformity involves the dentoalveolar component alone it can be termed dental open bite, but if the deformity involves skeletal bases also, it is skeletal open bite.

Etiologic Factors

1. **Thumb sucking and other sucking habits**: Most infants engage in some kind of non-nutritive sucking. This behavior is entirely normal. The frequency and duration decreases with age. But if the habit continues after the age of 6, it can result in open bite. Spontaneous correction of the open bite, after thumb sucking stops, is a common observation.
2. **Tongue pressure or posture**: Position of teeth with dentoalveolar segments depends upon a balance between opposing forces exerted by tongue and extra oral musculature.

   Whether tongue thrust swallow is the cause or the effect of open bite is controversial. The resting posture of tongue and lips is an important etiologic factor in open bite and the resting posture is largely determined by respiratory requirements. The association of mouth breathing with elongation of the face and a tendency towards anterior open bite has long been recognized in patients. Macroglossia is considered an etiological factor in open bite, bimaxillary protrusion and dental arch spacing. This often causes instability after orthodontic treatment. Partial glossectomy to reduce the size of the tongue is a useful method of solving these problems.[13]
3. **TMJ internal derangement** and anterior open bite are found to be associated with decrease in posterior facial height, decrease in ramus height and backward rotation and retruded position of the mandible.[3] TMJ degeneration associated with displaced disks might be a cause leading to the development of acquired anterior open bite.[4]
4. **Amelogenesis imperfecta** patients have got a predilection for open bite though the pathophysiological relationship is not very clear.[20]

Skeletal Influences Resulting in Vertical Skeletal Imbalance

1. An obtuse saddle angle between middle and anterior cranial fossa.
2. Abnormal or short mandibular ramus.
3. A tipped palatal plane higher in front than in the back.
4. Steep mandibular plane angle.
5. Increased anterior facial height.

Vertical skeletal imbalance resulting in an open bite is mainly influenced by genetic factors.

Thus the whole etiologic picture of open bite can be put in such a way that patients with severe anterior open bite have vertical skeletal imbalance, over which neuromuscular disturbances are superimposed which further complicate the situation and contribute to the deformity as it develops.

Around the time of puberty, open bite decreases. This can be attributed to alteration in respiratory requirements and consequent alteration in tongue posture which can be reasoned by:

a. Tendency for the adenoids and tonsils to shrink at the time of puberty.
b. Consequent vertical growth of jaws. These anatomic changes provide more room for tongue, allowing it to be carried higher and more posterior without interfering with respiratory requirements.

The combination of a decrease in sucking habits and a change in resting posture seems to account for the decrease in the open bite.

NHANES III Survey (1988-91) by Proffit, et al observed that severe deep bite is more commonly a problem in the whites and severe open bite is seen more in blacks. They also found that severe deep bite is more than 10 times as prevalent as severe open bite.[19]

Diagnostic Aids

Chief diagnostic aids for open bite are:
1. History taking
2. Morphological analysis
3. Cephalometric analysis.

Clinical History

Open bite confined to dentoalveolar components is associated with certain habits like thumb sucking or tongue thrust swallow, as described earlier, which can be obtained by careful history taking. True skeletal open bite deformity is more closely related to genetic factors.

Morphological Analysis

Clinical evaluation of facial esthetics in individuals with open bite deformity concentrates on the following:

1. ***Lip competence*****:** Lip competence exists when lip closure can be achieved easily without hyperfunction of the perioral musculature. Separation of lips at rest by more than 3 to 4 mm makes this impossible. In individuals with severe open bite lip separation may be as great as 10 to 12 mm.
2. ***Relation of upper teeth to upper lip*****:** Exposure up to one quarter of upper anterior teeth is considered normal when upper lip is at rest. This relationship indicates the vertical position of the maxilla and in turn helps to decide the location of the deformity – maxilla or mandible, and its site.
3. ***Nasolabial angle*****:** Normal nasolabial angle is 90° - 110°. In most of the open bite cases the nasolabial angle is acute.
4. ***Length of lower face*****:** Ideally the upper, middle and lower third facial heights should be approximately equal. Lower third of face is often elongated in open bite deformity.
5. ***Anteroposterior position of chin*****:** Retrusive chin is a frequent finding in open bite deformity. This indicates that the mandible has rotated downwards and backwards.
6. ***Width of alar base*****:** Ideally the alar base width should be about one-fifth of the total width of the face as measured along a line through the pupils of the eyes. Width of the alar base is usually same as the distance between the medial canthi of the eyes.
7. ***Curve of Spee:*** This curve is used to assess antero-posterior plane of the occlusion. From this the location of the defect can be assessed. Exaggerated 'Curve of Spee' is suggestive of the defect at the maxillary region **(Figures 19-1A to C)**.

Individuals with open bite deformity often have narrow alar bases especially when they have mouth breathing habit. In such cases growth component from function is not properly imparted to the nasomaxillary complex.

Figures 19-1A to C: A case of anterior open bite: Exaggerated 'Curve of Spee' and recessive chin and strained lip apposition.

Cephalometric Analysis

The common but variable findings of the skeletal open bite deformity are as follows:

1. Increased anterior facial height.
2. Steep mandibular plane angle and an obtuse genial angle.
3. Normal or reduced mandibular body length.
4. Normal or decreased ascending ramus length.
5. Increased distance from nasal floor to maxillary teeth.
6. Palatal plane tipped superiorly in the anterior region.
7. Low position of mental foramen.
8. Decreased posterior cranial base angle.
9. Flat or reverse curve of mandibular occlusal plane.
10. Excessive curve of maxillary occlusal plane.

An open bite deformity whether due to maxillary skeletal involvement or mandibular skeletal involvement can be assessed by morphological and cephalometric analysis.

A comprehensive clinical analysis based on morphological and dentoskeletal balance of the face can be used for treatment planning. (Refer Chapter 8: Treatment Planning).

Model Studies

It is imperative that model studies, mock surgeries and splint making are to be performed before planning any orthognathic surgical procedure. This is especially true in open bite deformities. Three dimensional understanding of the dentition and alveolus can be well deciphered from model analysis and mock surgery. Vertical movements of the cut segments of the maxillary and mandibular skeleton may sometimes cause plane discrepancies of the occlusion and the alveolar crest. Severe discrepancies of this sort may imperil stability and cause periodontal infections. Periodontal infections at the osteotomy site may result in the loss of adjacent teeth.

Treatment Modalities

The following are the available treatment modalities for open bite deformity:

1. Orthodontic therapy.
2. Anterior segmental dentoalveolar osteotomy of the mandible (Mandibular subapical osteotomy).
3. Mandibular body osteotomy.
4. Ramus osteotomy of the mandible.
5. Posterior segmental dentoalveolar osteotomy of the maxilla (Schuchard's procedure).
6. Le Fort I osteotomy with or without anterior maxillary osteotomy.
7. Anterior maxillary osteotomy.
8. Tongue reduction.

Orthodontic Therapy

Open bite malocclusion that affects primarily the dentoalveolar segment responds well to orthodontic treatment, if concomitant improvement is also achieved in the neuromuscular forces acting on the dentoalveolar structures.

The orthodontic treatment aims at:

1. Redirection of growth
2. Habit control
3. Tooth movement.

Redirection of growth of jaws is the initial treatment of choice in growing patients with moderate open bite. The objective of treatment is to prevent further eruption of posterior teeth while allowing normal eruption of incisors and thereby to achieve a counter clockwise rotation of the mandible during its growth, decreasing the mandibular plane angle.

Growth redirection therapies include: (a) High pull head gear directed to the posterior maxilla, (b) Functional appliance systems (activator or Frankel's appliance). Use of a quad-helix crib appliance was found to be very effective in treating growing patients with thumb sucking habits and dento-skeletal open bites. This protocol produced a clinically significant improvement in the vertical skeletal relationship because of downward rotation of the palatal planer.[5] Pedrin F, et al are of the opinion that high pull chin cap therapy with removable appliance and palatal crib provided no positive skeletal influence on the vertical facial pattern of patients treated for open bite in the mixed dentition.[18] Studies indicate that vertical chin cap is effective in treating skeletal open bite and aids in decreasing the gonial angle in children.[9] According to Peter H Buschang, et al, of the various treatment approaches including high pull head gear, extraction and bite blocks, the vertical chin cap holds the greatest potential for mandibular skeletal modification.[2]

Vertical tooth movement in open bite correction may be divided into two types:

1. Intrusion of teeth that are in occlusion, and
2. Extrusion of teeth at the site of open bite

Direct intrusion of posterior teeth has been discussed as a type of growth redirection. Orthodontic intrusion of the molars to correct open bite appears to be achievable in the maxillary arch, although the amount of evidence is minimal.[11] A study by Sherwood KH, et al found that mini plate anchorage could help to intrude the maxillary molars to a mean range of 1.99 mm (range 1.45-3.22 mm) and a mean closure of incisors was 3.62 mm (Range 3.0-4.5 mm).[22] Micro screw implants placed in the alveolus can be used as anchorage for intruding the posterior teeth to correct the anterior open bite.[17]

Extrusion of teeth at the open bite site can be accomplished readily by orthodontic forces. Anterior vertical or box elastics are used in most instances. In open bite, extraction treatment has greater stability in maintaining the over bite than non-extraction treatment.[10]

Surgical Treatment

Generally anterior open bite is corrected surgically, as dental movements tend to relapse.[23]

Historical Background

Hullihen in 1849 apparently was the first to surgically correct an open bite. The procedure used to correct the deformity acquired as a result of scar contracture, was an operation in the anterior part of the mandible. Since then the operation has been termed anterior mandibular osteotomy and has been modified and popularized by Trauner, Hofer and Kole.[14]

In the late 1950s, numerous variations of the open subcondylar osteotomy in the ascending ramus of the mandible were introduced. Although these procedures were modifications of much older, closed subcondylar and open oblique osteotomy, introduced by Limberg in 1925, it was believed that dissecting and releasing several of the muscles of mastication, during surgery, would reduce the high incidence of relapse noted with the closed procedures. Despite the early claims of success of the procedures, follow-up observation has shown a high incidence of relapse. If counter clockwise rotation of the mandible with ramus surgery must be used to close anterior open bite, it should be undertaken with full knowledge of the tendency to relapse. The use of mandibular surgery to correct anterior open bite was associated with poor outcomes.[1]

The first maxillary procedure used to correct open bite was anterior maxillary osteotomy, which was introduced by Cohn-Stock in 1921 and modified by Wasmund, Wunderer and Cupar. When extrusion of the maxillary anterior segment is necessary this procedure does result in a stable occlusion, but intrusion of the anterior and posterior teeth is more frequently required. A posterior maxillary osteotomy designed to produce intrusion of the posterior teeth was first described as a two stage procedure by Schuchardt in 1959.[21]

Early relapse with Schuchardt techniques seems to have been related to failure to free the posterior segment adequately before intrusion. Kufner described a single stage procedure for posterior maxillary osteotomy.[15a] Posterior maxillary osteotomy has got many indications like posterior maxillary hyperplasia, transverse excess or deficiency of the maxilla, posterior open bite, space creation for eruption of teeth, etc.[16]

Modern techniques for maxillary surgery are based on the Le Fort I down fracture technique to free the entire maxilla. Le Fort I osteotomy is often combined with anterior maxillary segmental osteotomy to obtain the differential movement necessary for optimum correction of the open bite deformity. Orthodontic therapies appear to have slightly lower treatment success than surgical therapy in open bite correction. However, Hnang G J affirms that orthodontic therapy has good stability.[8]

The Le Fort I osteotomy permits a direct approach to the anatomic sites of open bite deformity. Open bites treated by Le Fort I osteotomy in one piece or in multi-segments with or without bilateral sagittal split osteotomy exhibited good skeletal stability of the maxilla. Le Fort I gave the best stability for both maxilla and mandible.[7]

Choice of the appropriate surgical technique, for correction of open bite, whether maxillary or mandibular, requires careful diagnostic evaluation.

Anterior Subapical Osteotomy of the Mandible

Since Hullihen's original operation, the mandibular anterior segmental dentoalveolar osteotomies have been refined by Kole (1959),[15] and Schuchardt (1965).

If open bite manifests in the anterior part of the mandible as a reverse curve of Spee in the mandibular arch and there is transverse maxillomandibular harmony with good esthetic balance between the upper lip and the maxillary teeth, the occlusal deformity can be corrected by elevating the anterior dentoalveolar segment of the mandible into the desired occlusal relationship.

The procedure is a biologically sound surgical technique executed through an intraoral degloving incision. Relapse potential of the repositioned dentoalveolar segment is minimal because the segment is usually moved in the same direction as the pull exerted on it by the attached genioglossus and geniohyoid muscles. Relapse may occasionally be caused by chronic posturing of the tongue against the lingual and occlusal surfaces of the mandibular anterior teeth. Clinically this kind of relapse can be identified by interdental spacing, proclination of the anterior teeth and recurrence of the open bite. When this occurs after surgery strong consideration should be given to the need for partial glossectomy.

In cases of mandibular prognathism with open bite associated with a severely reverse curve of Spee in the mandibular arch and excessive chin height, simultaneous correction of occlusal and esthetic problems is accomplished by body osteotomy of the mandible at the premolar region. If this procedure is used alone, to be successful, the patient must have a functional posterior occlusion without significant transverse deficiency problem in the maxillary arch, as well as satisfactory lip to tooth relationship in the anterior maxilla.

When excessive lower anterior facial height is associated with anterior open bite, the 'Kole procedure' may be used to raise the mandibular anterior teeth and decrease the height of the chin **(Figure 19-2).**

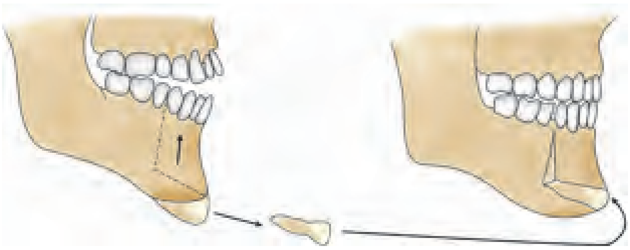


Figure 19-2: Lower subapical osteotomy of the dentoalveolar segment. The gap created while raising the segment is grafted by the graft taken from the inferior border of the chin (Kole's procedure).

The Kole's procedure is feasible and indicated only when the distance between the apices of the mandibular anterior teeth and the inferior border of the symphysis is large enough.

The surgical technique is similar to that for anterior mandibular subapical osteotomy. Along with the mandibular dentoalveolar osteotomy to correct the anterior open bite, chin fragment is resected and grafted into the space between the elevated dentoalveolar process and the remaining mandibular body.

Mandibular Body Osteotomy

Mandibular prognathism with concomitant anterior open bite is the principal indication for mandibular body osteotomy. Body osteotomies can be 'V' shaped or rectangular which are accomplished in a single stage through intraoral degloving incision **(Figure 19-3).**

If there is restricted movement of mobilized segment at the time of surgery, because of attached muscles, genio-

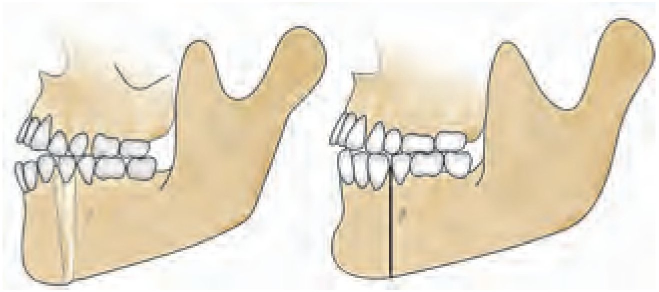


Figure 19-3: 'V' shaped Body osteotomy of the mandible at the premolar region after extracting the 1st premolar, to correct the anterior open bite. This is done when there is a mild prognathism of the mandible along with the anterior open bite.

hyoid and digastric myotomy are accomplished simultaneously with the osteotomy.

Ramus Osteotomy in the Management of Open Bite

Pan occlusal open bite is seen in certain syndromes associated with mandibular deficiency (e.g. Treacher Collin's syndrome). Untreated bilateral condylar fractures can also cause anterior open bite with posterior premature occlusion. Certain mandibular prognathism cases, especially the ones having large tongue or tongue thrusting habit also exhibit anterior open bite. These are the cases suited for correction by ramus osteotomies **(Figures 19-4 and 19-5A to L)**.

Success in treating open bite with sagittal split ramus osteotomy is often unpredictable, because of the increased risk of relapse.

IMF may cause dragging of the condyle. Since the powerful muscle of mastication is attached to the ramus, relapse may occur. Moreover anticlockwise rotation of the segmented distal part of the mandible is often unstable. After the release of intermaxillary fixation, there may be

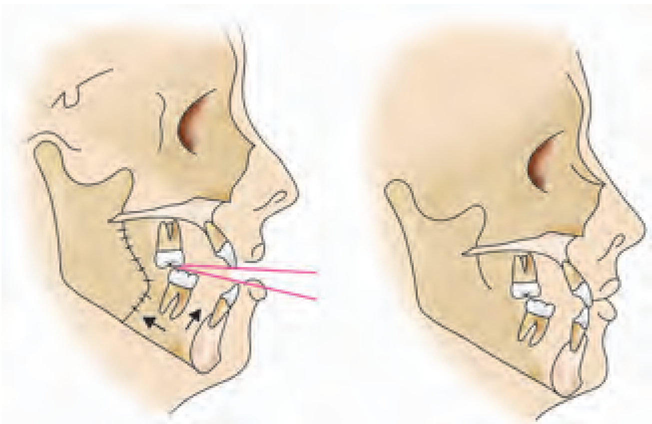


Figure 19-4: Pan occlusal open bite extending from the molars to the anterior region can be corrected by ramus osteotomy.

Figures 19-5A to L: This girl had a complaint of difficulty in apposing the teeth and protrusion of the lower jaw. Clinical and cephalometric analysis revealed, vertical excess of the maxilla, mandibular prognathism and pan open bite extending from the molar to the anteriors (A,C,E,G,I). Two-jaw surgery was planned. 'Le Fort I, superior repositioning and 'bilateral sagittal split osteotomy' to set back the mandible was performed. B, D, F, H and J are the postoperative Front view, Oblique view, Profile view, Occlusion and Cephalogram respectively. K and L are the pre- and postoperative tracings.

a gradual positional change of the mandible which produces complete or partial relapse.

The relapse has been attributed to the forced counter clockwise movement and the stretching of suprahyoid and masticatory musculature as well as displacement of the condyle.

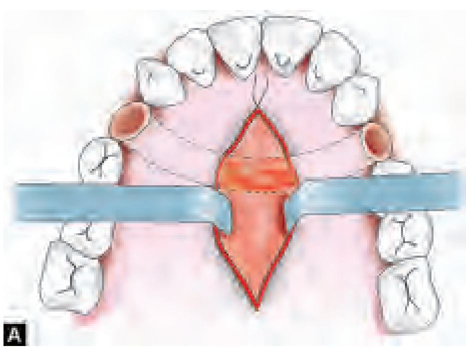
In general it is preferable to correct open bite deformities with maxillary osteotomies.

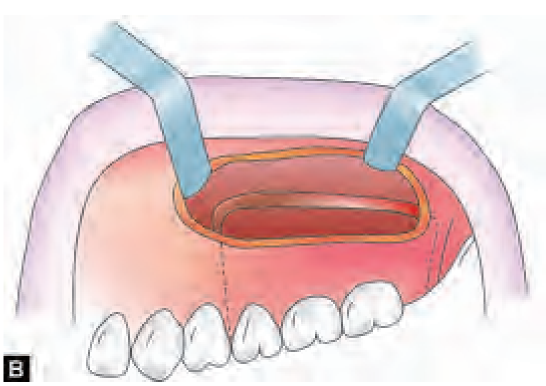
Ramus osteotomies however are important in correcting open bite deformities associated with severe mandibular deficiency or prognathism.

It has been reported that inverted 'L' osteotomy of the mandibular ramus has more long-term stability in the vertical and horizontal dimensions when employed to correct a skeletal open bite deformity.[6]

Posterior Segmental Dentoalveolar Osteotomy of Maxilla

Schuchardt (1959) described a two stage method applicable to the closure of posterior open bite and also to the closure of anterior open bite resulting from the premature contact of over erupted posterior teeth. By the incisions shown in the figure it is possible to do a single stage posterior maxillary osteotomy as the blood supply is not compromised **(Figures 19-6A and B)**.





Figures 19-6A and B: Diagrammatic representation of posterior maxillary segmental osteotomy. (A) Palatal cut, (B) Buccal cut.

Kanno T, et al have described a technique of compression osteogenesis method with two stages corticotomy in the posterior maxilla to treat a woman with severe anterior open bite.[12]

Le Fort I Osteotomy for Correction of Anterior Open Bite

For correction of anterior open bite with Le Fort I osteotomy, the magnitude of superior movement of the posterior portion of the maxilla will usually be greater than the amount of superior movement of the anterior portion of maxilla. This is necessary to level the maxillary occlusal plane and correct the anterior open bite. Consequently, there will be more autorotational movement of the mandible, in the individual with skeletal type open bite, than in the individual with vertical maxillary excess without open bite.

Le Fort I osteotomy is a versatile technique by which the occlusal and facial harmony can be achieved in all three planes (vertical, transverse and sagittal) especially when combined with segmental maxillary osteotomies.

In a case where superior repositioning needed is more than 3 mm, Le Fort I osteotomy is combined with anterior maxillary segmental osteotomy at the level of premolars **(Figures 19-7 and 19-8A to F)**. The same surgical procedure is used to correct anteroposterior, vertical and horizontal manifestations of the open bite deformity.

The down fractured maxilla though pedicled to the relatively inelastic palatal mucosa, can be widened by 5 to 7 mm by performing a midpalatine split. When lateral expansion required is more than 8 to 10 mm, it is wise to program rapid maxillary expansion in coordination with lateral maxillary osteotomies to widen the maxilla to the desired extent. This treatment approach by increasing the arch length may also obviate the need for

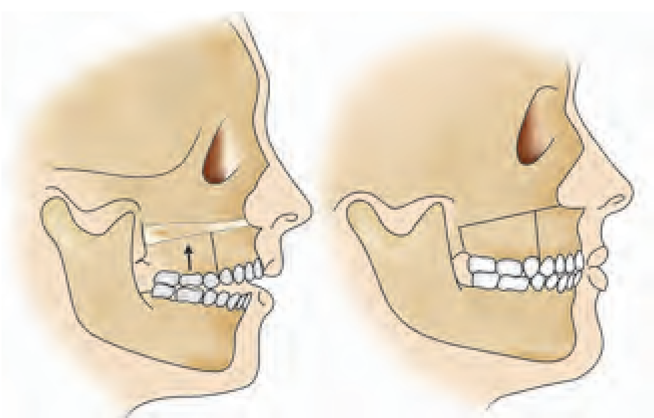


Figure 19-7: Diagrammatic representation of Le Fort I osteotomy with anterior maxillary osteotomy to correct anterior open bite.

Figure 19-8: A case of anterior open bite due to vertical excess of the maxilla at the posterior region. The chin was also deficient. This girl had undergone Le Fort I osteotomy with segmentation and only the posterior segment was pushed up. For the recessive chin, she underwent an augmentation genioplasty as well. (A and B) Pre- and Postoperative front views. (C and D) Pre- and postoperative profile views. (E and F) Preoperative and postoperative radiographs.

extractions, by facilitating alignment of the crowded and rotated anterior teeth.

When Le Fort I osteotomy is combined with AMO to correct the vertical, transverse and anteroposterior manifestations of open bite deformity, excellent stability can be achieved.

Reduction of Tongue

Reduction of tongue is indicated in cases where open bite is associated with true macroglossia as in Down syndrome, acromegaly or in pathologic conditions as lymphangioma.

Case Reports

Case 1 (Figures 19-9A to E)

This patient has got difficulty in apposing the lips. She had vertical excess of the maxilla at the posterior region. The occlusal plane indicates the exaggerated curve of Spee and an anterior open bite. She had undergone Le Fort I with anterior maxillary osteotomy and augmentation genioplasty.

Case 2 (Figures 19-10 A to F)

This girl has got mild mandibular prognathism with anterior open bite extending from the molar region onwards. She had undergone sagittal split osteotomy and genioplasty.

Case 3 (Figures 19-11A to F)

Patient with anterior open bite due to vertical excess of the maxilla. The anterior teeth were visible in repose. Curve of Spee was exaggerated. Chin was deficient. Surgery was Le Fort I superior repositioning with AMO. Genioplasty was also done to augment the chin.

Figures 19-9A to G: (A to C) Preoperative pictures. (D and E) Postoperative pictures. (F) Preoperative cephalogram. (G) Postoperative cephalogram.

Figures 19-10A to F: (A and C) Preoperative pictures. (B and D) Postoperative pictures. (E and F) Pre- and postoperative radiographs.

Figures 19-11A to F: (A and B) Pre- and postoperative profile photographs. (C and D) Pre- and postoperative frontal photographs. (E and F) Pre- and postoperative cephalograms.

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Chapter

20

Varghese Mani

Introduction

Retrusion or hypoplaisa of the midface, without deformity of the cranial vault, is dealt with in this chapter. The deformities are mainly of the maxilla, zygoma and/or nasal bones. These patients require advancement at the subcranial level. Like in other cases orthodontic technique may have to be instituted pre- and postsurgically. The goal of presurgical orthodontic treatment is to put the teeth in the desired position so that postsurgically optimal occlusal relationship is achieved. Depending on the structures that are to be advanced, osteotomy has to be designed.

When the deformity includes the maxillae, malar bones and nasal bones, Le Fort III osteotomy is advised. If the malar bones are not involved, only Le Fort II will suffice. If the nasal complex is not involved, modified Le Fort III is the surgery of choice.

Surgical decision is made depending on the deformity. Prediction tracing is done. Presurgical orthodontic/orthopedic treatment has to be decided and instituted in consultation with an orthodontist. In many of the craniofacial synostosis syndrome deformities, there is premature fusion of the craniofacial sutures. In such cases, orthopedic expansion movements may be difficult and combined orthodontic and surgical expansion has to be considered. After the presurgical orthodontic movement is achieved cephalometric study and prediction tracings are repeated. Feasibility model surgery is also done.

Next step is the construction of occlusal splint for stabilization. Midface deformity correction is mainly for hypoplasia, hence advancement is the aim of surgery. As there is a tendency for relapse, in all cases of advancement, occlusal splint is often constructed in such a way that the occlusion is over-corrected to class II relationship.

Evaluation of the Patient

Routine evaluation for orthognathic surgical procedures is to be followed in this instance also. In general this includes the following:

- Medical and dental history
- Clinical examination
- Model analysis
- Radiographs like OPG, Cephalograms, Paranasal sinus views, etc.
- CT scans in all views and reconstructed three dimensionally
- Photographs.

Treatment Planning

Le Fort II osteotomy is often preferred for midfacial deficiency and the intention is to bring the nasomaxillary complex forward. Usually there is a deficiency in both transverse and anteroposterior dimensions (width and length) of the maxilla resulting in multiple impacted teeth and flaring of anterior teeth.

Functional orthopedic treatment, if started before the fusion of the craniomaxillary sutures, can to a great extent prevent maxillary deficiency. A reverse pull head gear can prevent or even correct mild maxillary deficiencies in a growing child. However, the functional appliances are not effective in early synostosis of sutures like Crouzon's syndrome or Apert's syndrome.

In class III relationship lower incisors are compensated by retroclination and may show crowding. It is not advisable to extract the lower teeth to decrowd. This may further retrocline the lower anteriors. It is advisable to procline the lower anteriors and align the teeth to achieve the normal angulation.

Common indication for Le Fort II osteotomy is naso-maxillary dysplasia (e.g. Binder's syndrome).

Le Fort II Osteotomy

Le Fort II osteotomy simulates Le Fort II fracture which is pyramidal in nature. The area involved is the naso-maxillary complex. Hence Le Fort II osteotomy is indicated in cases where the deficiency or hypoplasia is predominantly in the naso-maxillary area. This surgery was initially introduced by Henderson and Jackson. In Le Fort II osteotomies forward and limited downward movements are possible. Rotational movements are not possible in Le Fort II osteotomy. Length of the nose can be increased by this osteotomy, to some extent.

Nasomaxillary hypoplasia is often observed in cleft lip and palate cases and in Binder's syndrome. In cleft lip and palate cases in association with the hypoplasia of the nasomaxillary complex, the dentoalveolar segment is also hypoplastic, and anterior cross bite is often observed. But in Binder's syndrome often the occlusion is normal. In Le Fort II, the nasomaxillary complex is advanced along with the dentition. This could create an excessive over jet (where dentition was normal). This needs correction later either surgically or orthodontically, depending on the merit of each case.

Surgical Planning

In Le Fort II cases, like in other orthognathic surgery procedures, assessment has to be done in three planes using CT, cephalogram, orthopantomogram and other radiographs. Photocephalometric planning is ideal for prediction tracing. Model surgery will help in understanding the postoperative occlusal situation and in fabricating the splints. Presurgical orthodontics is mainly aimed at decrowding arch, alignment and decompensation (reverse orthodontics).[1]

Surgical Procedure

Incision is made from upper 1st molar to opposite 1st molar for intraoral bony cuts. Paranasal skin incisions are made to reach the medial orbital floor and the nasal bridge. Incision is preferably made in the skin crease so that the scar can be camouflaged.

Osteotomy is pyramidal in nature. Paranasal skin incision is deepened to the bone. Medial canthal ligament is identified. It may be kept intact or divided. Chance for lateral drifting of the medial canthus is high if the ligament is divided.[2] Hence the ligament should be tagged before division, for identification later. Osteotomy is vertically down to the anterior surface of the maxilla midway between the infra orbital nerve and the naso lacrimal duct.

The vertical cut from the orbital floor is taken to the medial corner of the orbital floor behind the lacrimal apparatus. A short small osteotome is ideal for this cut. The cut is continued above the canthal attachment and taken across the nasal bridge (The cut from the inferior orbital border is brought down and is continued as in a Le Fort I osteotomy) **(Figure 20-1).** A similar osteotomy is done on the opposite side.

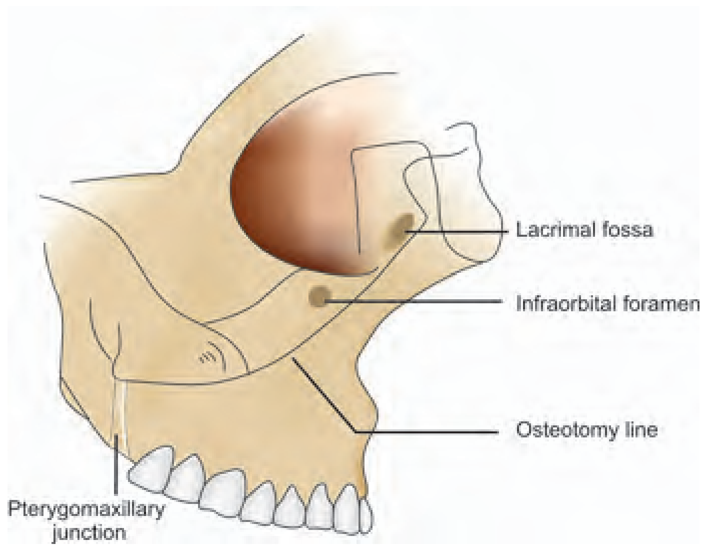


Figure 20-1: Design for Le Fort II osteotomy side view.

Nasal septum is cut from the root of the nasal bone, with a slightly curved osteotome directed to the posterior aspect of the hard palate. The area may be felt by placing a finger intraorally. This helps in directing the osteotome. After the division of the nasal septum the osteotomy is completed as in Le Fort I including the pterygoid disjunction. A set of Rowe's disimpaction forceps is used to mobilize the osteotomized nasomaxillary complex downward. A Tessier mobilizer is used to advance the complex.

The complex is aligned to the pre-planned occlusion using a splint and fixed by intermaxillary fixation. The segment is then stabilized using mini plate rigid fixation. Bone grafts are done and fixed wherever required. The bone may be harvested from the rib, ilium, calvarium or from areas where the surgeon feels comfortable with. Intermaxillary fixation may be removed after rigid fixation.

The wound is closed in layers. Postoperative care is as in other osteotomies.

Le Fort III Osteotomy

Le Fort III osteotomy is mainly intended for advancing the entire middle third of the face forward and sometimes downward. By this method the nasomaxillary zygomatic complex is brought forward. The first midface osteotomy was performed by Sir Harold Gillies in 1942. This was refined and popularized by Tessier. Tessier introduced bone grafting in Le Fort III osteotomies.

(Recently distraction osteogenesis of the midface has found its way into midfacial advancement. The underlying principle is formation of new bone as the cut segment moves forward very slowly. This has been found to be more stable, and is fast becoming the rule in advancements. However the basic osteotomy cuts remain the same)

Indication

Main indications are deficiency of the midface involving the maxilla, nasal complex and the zygoma. This situation is often seen in syndromes like Crouzon's and Apert's. Only a very small number of patients exhibit non-syndromic midface deficiency. Degree of proptosis and maxillary hypoplasia are the primary factors to decide on the type of osteotomy (Le Fort I, Le Fort II, Le Fort III).

Timing of the Surgery

Ideal time for surgery like other orthognathic procedures is after the growth is completed. However due to functional and psychological reasons surgery can be performed earlier. But a repeat surgery may be required later. Of the functional reasons the important one is corneal exposure leading to ulceration and damage. Early surgery is also indicated in patients who suffer from sleep apnea.

Early surgery during the early teens is advocated by some surgeons. By this time most of the facial growth has completed. However the possible need of a second surgery cannot be ruled out and the patient and the parents should be briefed about it in advance.

Presurgical Planning, Prediction and Preparation

Proper assessment of the patient is essential especially regarding the general medical condition, airway problems (sleep apnea), etc. Sometimes tracheostomy may be required. The face is assessed in all the three planes – vertical, sagittal and transverse. In syndromic cases, most of the facial and cephalic parts are abnormal. Hence it is hard to plan the procedure based on stable normal parts. So it is better to plan the case on relative or proportionate terms. An integrated treatment plan is developed while multiple problems like hypertelorism, hypoplastic maxilla, prognathism, nasal deformities, etc. are present.

The ideal method for prediction is photo cephalometric planning described by Henderson. The principle of this technique is enlarging the true lateral photograph to the exact size of a cephalogram, superimposing it on the cephalogram, transferring the architecture of bone, and marking the salient points. Then prediction tracing is done using template cuttings. The soft tissue movements are predicted and traced.

Model surgery is useful to assess the postsurgical occlusion. It also helps in fabrication of the splints. Most of the syndromic patients may have systemic problems affecting especially the cardiovascular and renal systems. A thorough general medical examination is mandatory before the surgery. Craniosynostosis is another problem often associated with Crouzon's or Apert's syndromes. These patients run the risk of increase in intracranial pressure. Fundoscopy could give an indication of intracranial pressure variation. A computerized tomographic survey of the skull is of importance to assess the position and situation of the anterior cranial fossa, cribriform plate, crista galli and the thickness of the skull, and skull defects from previous surgeries and the like.

Presurgical orthodontics is a must, like in other orthognathic surgery procedures. The aim is decompensation like decrowding and alignment of arches, if needed.

Psychological preparation of the patient and the immediate relatives including the parents is important and should be undertaken.

Surgical Procedure

These procedures are preferably done under hypotensive general anesthesia by nasoendotracheal intubation. Prophylatic antibiotic therapy is usually administered. Often steroid is administered preoperatively. This will help in reducing the edema during the postoperative period.

Access to the middle-third of the face is done by different approaches. The one often resorted to is by incision in the coronal area behind the hair line. This approach is known as the bicoronal approach. The incision is extended from the preauricular region to the preauricular region of the opposite side across the scalp. Incision is deepened to the subgaleal region and the bicoronal flap is raised anteriorly in the subgaleal level up to 2 cm above the supraorbital rim. At this point the incision is deepened to the bone and dissection is continued subperiosteally. Subperiosteal incision is connected to the superior part of the attachment of the helix of the ear in a 45° angle. This may enter into the fat compartment of the temporal region. However this direction of the incision avoids frontal branch of the facial nerve.

The dissection is taken down to the zygomatic arch. Superior orbital rims and nasal bones are exposed. Subsequently malar complex is also exposed and the dissection is extended to the lateral orbital rim and the lateral wall of the orbit.

It is difficult to reach the floor of the orbit by bicoronal approach, hence, infraorbital or transconjunctional approach is used. Care should be taken not to injure the lacrimal sac and the lacrimal apparatus.

Medial canthal ligament is identified. If it is to be detached the same may be tagged with ligature wires for identification and fixation later.

Intraoral incision may be required for two reasons—for doing Le Fort I osteotomy if planned simultaneously with Le Fort III osteotomy and for doing pterygomaxillary disjunction. Disjunction of the pterygoid plates can be done by the temporal approach as well, as the area is already exposed.

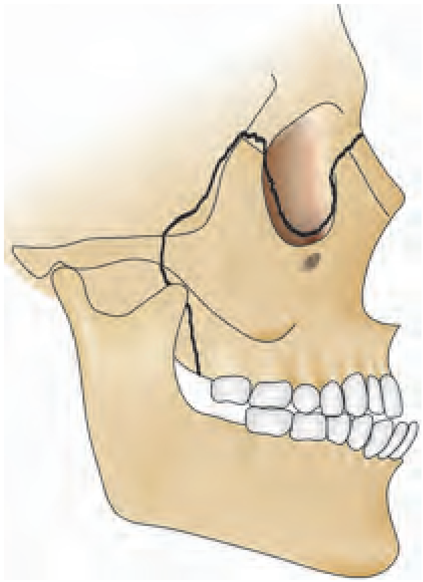


Figure 20-2: Le Fort III osteotomy design. The zygoma is also brought forward. In distraction osteogenesis the osteotomy is the same. Instead of advancing in a single stroke, the osteotomized segment is fixed to a distraction appliance (various types of distraction appliances are available) which is anchored to the cranium and distracted slowly. Distraction of about 1 mm per day can gradually advance the segment and the gap created is automatically filled by new bone formation. This new bone may take two to three months to mature. So the distraction appliance has to be worn till the bone maturation is completed).

Osteotomy (Figure 20-2)

The osteotomy cut is started at the zygomatic arch. Next, the bony cut is done at the frontozygomatic suture. Then cut is taken medially to the inferior orbital fissure. It is carried to the orbital floor in the anterior region and extended posteriorly to the nasolacrimal duct. The infraorbital nerve is to be protected from injury. The osteotomy is carried on the medial wall anterior or posterior to the medial canthal attachment. To take the cut posterior to the cantral attachment, the ligament should be cut and tagged.

The cut is continued across the bridge of the nose and should be below the crista galli. The position of crista galli can be ascertained by a CT.

From the nasal bridge a curved osteotome is malletted towards the direction of the posterior aspect of the post-nasal spine to divide the nasal septum. The direction can be better ascertained by keeping a finger intraorally to feel the posterior portions of the septum. This will help to prevent the cut into the clivus. This is also helpful in protecting the nasoendotracheal tube.

Pterygomaxillary disjunction can be done by using a curved osteotome behind the zygomatic arch. Pterygoid disjunction may also be done intraorally. For this a separate intraoral incision is required.

Mobilization of the osteotomized middle-third of the facial skeleton is started at the frontozygomatic suture. A ‘Smith spreader’ can be used at the osteotomy site to mobilize the segment.

A set of Rowe’s disimpaction forceps can be used to hold the maxilla to down fracture the complex. A Tessier mobilizer may be used to advance the segment.

Various modifications to the above described technique are available and the use of them depends on personal preference of the surgeon. Vertical, horizontal or a butterfly incision at the root of the nose is used to expose nasal bridge. Subconjunctival incision with lateral extensions on the area is sometimes used for the approach to the frontozygomatic area and the infraorbital regions. Certain modifications in the osteotomy may be used for certain additional requirements. Some surgeons prefer to do osteotomy on the zygomatic body in sagittal direction.

Le Fort III osteotomy is sometimes combined with Le Fort I osteotomy. This is helpful in rotating the maxilla and achieving certain occlusal adjustments. While combining, the Le Fort I is done after Le Fort III and stabilization.

While advancing the middle third of the facial skeleton the gaps created at the osteotomy sites are preferably grafted. The graft may be harvested from the outer table of the cranium, rib or iliac crest. These grafts are fixed and stabilized, preferably using screws. The advanced maxilla is fixed to the prefabricated splint in occlusion and inter-maxillary fixation is done. Advanced segment is rigidly fixed using mini plates. Sites to be fixed are the fronto-zygomatic area, nasal bridge and the zygomatic arch. After rigid fixation the intermaxillary fixation is removed and the occlusion is verified and the wounds are closed in layers with vacuum suction in the subgaleal area (if bicoronal flap is used).

Postoperative Care

After extubation the patient is observed for cardio-vascular, respiratory and neurologic status. Nasopharyngeal tube is ideally maintained for 12 hours. Nasogastric tube will help feeding.

Early mobilization and physiotherapy will help fast recovery.

Modified Le Fort III Osteotomy

In 1950 Gillies and Harrison reported the first midface advancement in which the osteotomy line was almost similar to the Le Fort III fracture.[4] Frequently seen midface deformity is the maxillary-malar deficiency, i.e. besides the maxillary deficiency, the malar bone is also deficient. Clinically this is manifested as the deficiency of malar eminence and the infraorbital rim in relation to the globe of the eye. This is an important indication for Le Fort III modified osteotomy.

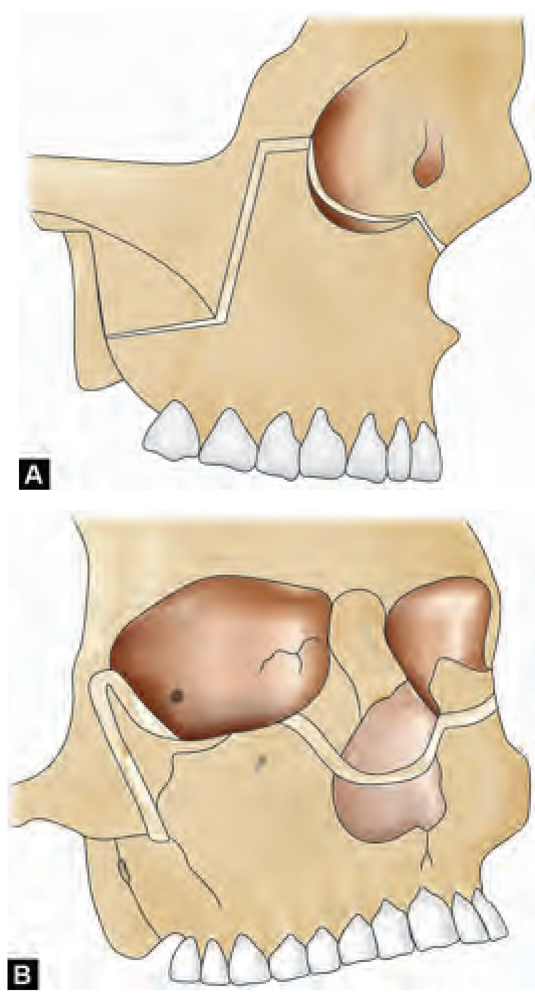
Presurgical prediction tracing, feasibility model surgery and occlusal splint construction, etc. are completed before the surgery.

Surgical Technique

There are three surgical approaches for this technique: (1) transoral, (2) bicoronal-transconjunctival-transoral approach, and (3) subciliary - transoral approach. The widely used technique is subciliary transoral approach. Primary incision is subciliary. A temporary tarsorrhaphy suture is placed to lift the lower eyelid facilitate the surgical procedure. Incision is started a few mm lateral to the inferior punctum and carried below the eyelid about 2 to 3 mm below the margin. Incision may be in the natural skin folds. Skin and subcutaneous tissues are dissected inferiorly superficial to the orbicularis oculi muscle. With a retractor the periorbital tissues are drawn into the orbit. The inferior orbital rim is exposed by incising the periosteum. If the incision is made on the anterior aspect of the rim, chances of the periorbital fat exposure are minimized. Subperiosteal dissection is done on the floor of the orbit and extended medially till the lacrimal fossa, posteriorly to the inferior orbital fissure, and laterally to the lateral canthal tendon. Subperiosteal dissection is done on the facial aspect to expose the lateral aspect of the malar eminence, inferior aspect of the zygomatic arch, the pyriform rim, and the infraorbital nerve.

Osteotomy (Figures 20-3A and B and 20-4)

Osteotomy is started a few mm lateral to the lacrimal fossa and continued through the infraorbital rim and then inferiorly towards the pyriform rim of the nose. It is continued posterolaterally through the orbital floor to the inferior orbital fissure (Care should be taken not to injure the inferior orbital neurovascular bundle). From the anterior aspect of the infraorbital fissure, osteotomy is continued anteriorly and superiorly over the lateral orbital



Figures 20-3A and B: Design of modified Le Fort III osteotomy. A part of the lateral orbital border of the zygoma is included in the osteotomy. The nasal complex is excluded. A: Side view. B: Oblique view.

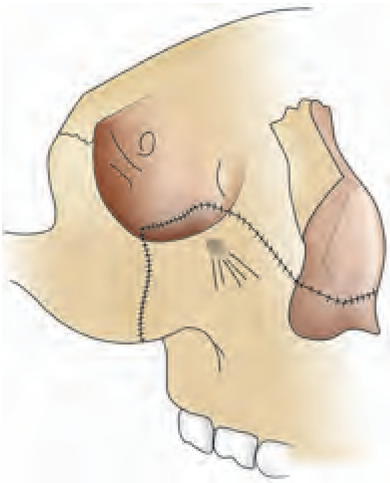


Figure 20-4: Design of Le Fort III modified osteotomy involving only the anterior part of the zygoma. The nasal complex is excluded. Oblique view.

wall to the infratemporal fossa. At the lateral orbital margin the cut is just below the Whitnall's tubercle. The margin is cut horizontally for about two-third and the cut is taken straight down inferiorly through the lateral aspect of the malar prominence and is carried back through the inferior aspect of the zygomatic arch. Osteotomy extends completely through the malar bone to the temporal fossa. Opposite side is also dissected and the osteotomy is performed as far identically as possible.

Next, intraoral incision is made after injecting a local anesthetic with vasoconstrictor into the area. Anterior vestibular incision is made and the nasal floor, lateral rim and anterior nasal spine, etc. are exposed.

Inferior orbital rim osteotomy is extended to the pyriform rim. Osteotomy is used to separate the nasal crest and the septum from the maxilla. Lateral nasal wall is also osteotomized, protecting the nasal mucoperiosteum. Osteotomy is extended only to about 30 mm posteriorly and stopped short of the descending portion of the greater palatine neurovascular bundle.

A separate incision is made just posterior to the zygomatic buttress area to expose the pterygomaxillary junction, and the maxilla is separated from the pterygoid using a pterygoid chisel. The osteotomy is connected to the osteotomy at the inferior orbital fissure. Care should be taken not to injure the internal maxillary artery and the pterygoid venous plexus.

Once the osteotomies are completed, midface mobilization is started. Mobilization forceps (Rowe's disimpaction forceps or Hayton William's disimpaction forceps) are used to down-fracture the complex. All the osteotomy sites are observed at this time to ascertain a clean separation. Once the complex is down-fractured, forward movement is applied with considerable force. This has to be done till the midface is placed passively in the required position into the prefabricated occlusal splint. Occlusion should be over-corrected to a class II relation to counter the postsurgical relapse of about 1 to 3 mm.[1, 3] The occlusal splint may be constructed bearing this in the mind. Intermaxillary fixation is done with wires which has to be maintained for about 6 to 8 weeks.

Autogenous corticocancellous bone grafts from the ileum are used for orbital rim defects and between the pterygoid plate and the maxilla. These bone grafts are wired into place wherever necessary. Dysfunction of the nasolacrimal duct is infrequently encountered. This is often secondary to edema rather than transection.[4]

Wound Closure

The subciliary incision is closed in two-layers. While closing the vestibular incision, upper lip and nasal esthetics are to be considered. Intermaxillary fixation is maintained for 6 to 8 weeks. If stable union does not take place the fixation is continued for another 2 weeks. The occlusal splint is kept in position for another 1 week or more. If proper occlusion is not achieved on removal of the splint, appropriate elastic traction is applied to correct the occlusion to obtain proper relationship. If needed, postsurgical orthodontic treatment is instituted.

Transcranial Le Fort III

In this procedure the frontal bone and the midface are moved as a single bloc. (monobloc procedure).

Sagittal split on the midface can also be done after monobloc surgery (facial bipartition). By this procedure hypertelorism and midface hypoplasia can be corrected in a single surgery. This is considered the ideal technique in Apert's syndrome. Ideally the advancement of the skull may be done during infancy and the advancement of the midface is done after the growth is completed.

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Chapter 21

Krishnamurthy Bonanthaya

Distraction Osteogenesis: The Biologic Process

Definition

Although traditional orthognathic surgery and craniofacial reconstruction have gained generalized acceptance and experienced widespread success, several limitations are associated with acute advancement of osteotomized bone segments. One of the major limitations is the inability of the soft tissues to be acutely stretched. Moreover, many of the congenital deformities require such large skeletal movements that the surrounding soft tissues cannot adapt to their new position, resulting in degenerative changes, relapse, and compromised function and esthetics. In light of these limitations, several new approaches have been developed to correct severe anteroposterior, transverse and vertical deformities of the craniofacial skeleton. One of these alternative approaches is the method of gradual bone distraction known as ***distraction osteogenesis.***

Distraction osteogenesis is the '***Process of generation of new bone in a gap between two bone segments in response to the application of graduated tensile stress across the gap'.*** In other words it is the mechanical induction of new bone between bony surfaces that are gradually distracted.

There have been reports of this principle of distraction being used as early as in 1905, by Codvilla. However it was Ilizarov in the 1950s with a series of experiments, who established the scientific basis of this concept and showed that with this procedure lengthening of long bones without using a graft material was possible. The use of this concept of Distraction Osteogenesis in the Craniofacial skeleton experimentally, was first reported by Snyder in 1973 and it was only in 1992 that McCarthy, et al reported a small clinical series on congenital mandibular deformities, for the first time. In the decade following that, more cases have been carried out for various other indications and this discipline has now become an exciting new frontier.

This consists of 5 sequential periods.

The Osteotomy

It involves the '***creation of a gap between two bone segments'***, across which movement takes place. For e.g. It would involve an osteotomy across the body of the mandible or the ramus of the mandible or the maxilla, midface, etc.

The two ***bone segments are then stabilized by a fixator***. The fixator may be totally intraoral or extraoral or may be partially intra- and extra-oral.

Latency

There is a time lag between the creation of the gap or osteotomy and the start of distraction. This is called ***'The Period of Latency'***. This allows the inflammatory changes following the Osteotomy to subside and for the formation of the reparative callus. This period of latency varies from 0-7 days depending on the clinical setting and the surgeon's preference.

Distraction

After a period of latency the actual distraction is begun, i.e. application of gradual, incremental traction and this should follow a ***'Specific Rate and Rhythm'*** till the desired amount of movement takes place.

Rate is defined as the amount of distraction carried out in a day.

Rhythm is the frequency or time intervals at which the desired rate of 1 mm distraction/day is achieved. For e.g. ¼ mm 4 times a day or ½ mm twice a day.

Consolidation

It is that time between cessation of traction forces and removal of the distraction device.

Once the desired amount of movement/distraction is achieved, the fixator has to be left in place so that ***'Consolidation of the callus formed at the time of active distraction takes place'.*** As a rule of thumb, usually twice the time taken for the initial distraction is considered the period of consolidation. However there are exceptions to this rule.

Remodelling

From the initial application of full functional loading to the completion of regenerate bone, remodelling the initially formed bony scaffold is reinforced by parallel-fibered lamellar bone. During this period both the cortical bone and marrow cavity are restored. Haversian remodelling, representing the last stage of cortical reconstruction, normalizes the bone structure. It takes a year or more before the structure of newly formed bony tissue is comparable to that of the preexisting bone.

The Scientific Foundation of Distraction

As graded distraction is done, the tension – stress forces exerted on the 'regenerate' in the gap leads to bone formation across the gap. This is primarily a membranous ossification process. The middle of the regenerate consists of a fibrous central zone where osteoid is deposited, with collagen fibers oriented parallel to the direction of distraction. Ossification occurs as a primary mineralization front advances from either end of the fibrous central zone resulting in a bridge of immature bone across the distraction gap. Bone remodelling begins during the consolidation phase and continues over 1-2 years, eventually transforming the regenerate into a mature osseous structure similar in size and shape to the adjacent bone. Distraction osteogenesis is a unique biologic process of new bone formation under the influence of traction forces. Until interrupted by traction forces, new bone formation during distraction osteogenesis is similar to that observed during fracture healing. The application of incremental traction to the soft callus aligns the developing intersegmentary tissues parallel to the axis of distraction. Tension stress provides an environment that maintains the soft callus at the center of the distraction gap, while it allows the progression of routine fracture healing at the periphery of the regenerate. **Therefore distraction osteogenesis represents a continuum of individual stages that, because of tensile force application, occur simultaneously, rather than sequentially as during fracture healing**.

In fact, in addition to bone changes, effects on the adjacent soft tissue occur in response to osseous distraction, and the whole process may be aptly described as 'distraction histogenesis' rather than osteogenesis.

Factors Determining the Process of Distraction

Broadly these can be classified into 2 categories as:
1. Bone factors
2. Distraction factors

Bone Factors

The two most critical factors here are: (i) the osteocyte viability, and (ii) an adequate blood supply to the site of distraction. In the absence of these a fibrous rather than a bony regenerate may form.

The clinician, therefore, must ensure that soft tissues surrounding the site of proposed distraction are well vascularized. Early studies in long bones concluded that both an intact periosteum and endosteum were critical to successful osteogenesis; therefore, it was advocated that a corticotomy be performed only through a minimal periosteal opening. More recently, however, investigators have demonstrated that the periosteum alone can provide sufficient osteogenic capacity for a healthy regenerate, and this is especially true in the well-vascularized membranous bone of the craniofacial skeleton.

Therefore, while some clinicians advocate a corticotomy, most reports of craniofacial DO describe the use of a complete osteotomy (taking care to preserve as much of the surrounding periosteum as possible). Prior radiation therapy to the distraction site does not adversely influence the results of distraction (in the canine model), and when using DO to repair segmental defect, the status of the surrounding soft tissues probably is the key factor influencing outcome.

Distraction Factors

The important parameters that affect the quality of distraction are the latency period, rate and rhythm of distraction and the phase of consolidation.

Latency

Studies on long bones have established around 7 days as the latency period. However this criteria is not clear-cut when the bones of the craniofacial skeleton are considered, and there is a difference of opinion. While most clinicians recommend waiting for 4-7 days after the osteotomy to begin distraction, i.e. the latency period, there are some who use a zero 'latency period' by beginning to distract immediately following the osteotomy. This is done particularly in children where the greater osteogenic potential may result in union at the osteotomy site if a latency period of 4-7 days is followed.

Rate

Once again based on the finding in the long bone, a rate of 1 mm/day of distraction is recommended. It was found that if distracted more rapidly, i.e. > 2 mm/day, then a fibrous union results, and if the rate is slow, i.e. < 0.5 mm/day, a premature bony union takes place.

Rhythm

Rhythm is the frequency at which the 1 mm/day of distraction is achieved, i.e. 1 mm/day at one instant or 1 mm/day over a period of 24 hours continuously. Ilizarov working on the long bones found that the ideal rhythm is a continuous form of distraction which may be impractical in clinical use. In the long bones the optimal rhythm has been to distract the 1 mm in 4 increments, i.e. ¼ mm 4 times daily. However in the craniofacial skeleton the most commonly employed rhythm has been 0.5 mm twice a day.

Consolidation Phase

This is the period of time for which the fixator is left in place after achieving the desired amount of distraction. The general rule holds that the consolidation period should be at least twice the duration of the distraction phase. However in exceptional cases like that of cleft maxilla, the consolidation period may have to be longer.

Indication for Distraction Osteogenesis

Distraction Osteogenesis can be used in a host of deformities in the mandible, the midface and the upper face, in both congenital and acquired conditions. This discipline of distraction osteogenesis is still evolving and some of the indications are better established than the others, and the list below is of the better established indications only. This technique may be used for deformity correction, lengthening, widening, bone transport and alveolar ridge augmentation.

In the Mandible

Congenital Deformities

1. Bilateral advancement of the body for severe micrognathia, particularly in infants and children with airway obstruction, as observed in the Pierre Robin syndrome. Distraction of the mandible here is for improving function (relieving airway obstruction) by widening the upper airway, and not for esthetic purposes. The need for a tracheostomy to maintain the airway may then be avoided in these children.
2. Unilateral distraction of the ramus, angle or posterior body, for hemifacial microsomia.
   Once again in hemifacial microsomia distraction is carried out in the mixed dentition period. The ramus and/or mandibular body on the affected side may be distracted. If an occlusal cant has developed, it may be corrected by a simultaneous maxillary distraction as advocated by Molina or corrected orthodontically by facilitating supraeruption of the teeth on the affected side (Grayson, et al). However this latter mode cannot be adopted if treatment is carried out after growth is completed, i.e. in an older patient, the Molina technique is the best option.
3. Congenital hypoplasia of the condyle/mandible.

Acquired Deformities

1. Unilateral ramus and/or body and bilateral body advancement in deformities secondary to TMJ Ankylosis. If the deformity secondary to ankylosis can be corrected by conventional orthognathic surgery, that should be the method of choice. However a unilateral ramus and/or body distraction in deformities due to unilateral ankylosis, and a bilateral body distraction in bilateral ankylosis, may be carried out.
2. Vertical distraction of alveolar segments to correct an uneven occlusal plane or to facilitate implants into edentulous jaws.
3. 'Transport' distraction for the reconstruction of a segmental defect after ablative surgery for a pathologic lesion, either benign or malignant, or post-traumatic continuity defect. The current 'gold' standard for reconstruction of large defects after ablative surgeries is definitely microvascular reconstruction. However use of a so called transport disk, a segment of bone osteotomized on one or both ends of the defect and distracted across the gap, results in a bridging of the defect with new bone, and is an interesting concept. Currently the fixators needed to achieve this are cumbersome and it requires them to be in place for a considerable period of time. This coupled with the fact that the vector for movement is complex makes good results difficult to obtain.

Midface

Congenital

1. Advancement of the maxilla at a Le Fort I level, for e.g. in a Hypoplastic Maxilla secondary to Cleft Palate deformity. Conventional orthognathic surgery, i.e. maxillary advancement and/or mandibular setback has been the method of choice in treating maxillary hypoplasia secondary to cleft palate deformities. However the rates of relapse are high[13] and movements required my be large. This surgical correction is usually carried out after growth is complete, i.e. in an adult patient.

   Distraction osteogenesis of the cleft maxilla has tried to address both these issues. In cases of severe hypoplasia the maxilla may be advanced at a much younger age, and since the advancement is incremental it is hoped that relapse rates will be less with this technique.

   Initially external fixators, the modified halo frames, i.e. the R.E.D, etc. were used to distract the maxilla and now internal fixators are also available. Both these type of fixators are used following a Le Fort I Osteotomy, down fracture and mobilization. The process of internal Vs external distraction is discussed elsewhere.
2. Complete midfacial advancement at the Le Fort III level in various syndromic cases.

Acquired

1. For alveolar distraction in preparation for prosthetic rehabilitation.
2. Transport distraction to restore continuity defects after loss of bone due to tumor ablation, trauma, etc.

Upper Face (Fronto-orbital, Cranial Vault)

Congenital

In both syndromic and non-syndromic craniosynostosis.

Contraindications

There are no absolute contraindications to the use of this technique. However caution needs to be exercised while selecting patients belonging to the following groups.

1. If for some reason or other, compliance of the patient with the distraction regime cannot be guaranteed, particularly when bulky extra-oral fixators are used.
2. When an adequate bone stock which is necessary to accept the distraction appliances and to provide suitable opposing surfaces capable of generating a healing callus, is not available.

   Also, where a particular deformity can be treated with conventional, time-tested, orthognathic surgery with equivalent result, distraction osteogenesis should never be used.

The General Protocol

Preoperative Work Up

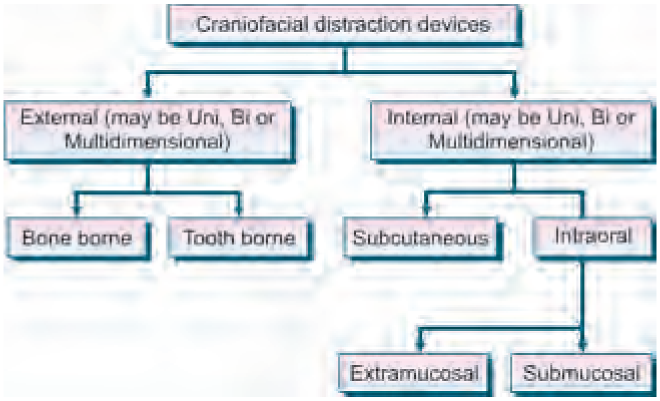
Should include:

1. Careful clinical assessment with photographic documentation and dental cast analysis.
2. OPG, and frontal and lateral cephalograms are essential.
3. Three-dimensional CT scans are also very useful.
4. Stereolithographic acrylic models, wherever available and affordable, provide a life-size three-dimensional reproduction of the facial skeleton and are the ultimate method to study the deformity and plan the proposed surgery.

A precise definition of the existing deformities should be made. Identify the various units of the craniofacial skeleton that need mobilization and repositioning. This will help determine the nature of the desired osteotomies and the desired vector of displacement to be applied to the osteotomized segments during the distraction phase. Wherever appropriate, surgical planning should involve the orthodontist because both pre- and post-surgical orthodontics is essential in these cases as in conventional orthognathic surgery.

The Distraction Device

The selection of an appropriate device is a key element in surgical planning. Two categories of fixators or distraction



devices are available, i.e. internal and external. All the early distractors were external devices, and the initial internal devices were miniature external devices or modification of available orthodontic expansion devices.

External Distractors

Advantages

1. Greater flexibility in the range of movement.
2. Alteration of the vector during distraction is possible (bidirectional/multidirectional).
3. Can be applied to smaller bone segments.
4. Easier to fix, manipulate and remove.

Disadvantages

1. Cumbersome and visible.
2. Soft tissue scars may develop at the pin tracts.

Internal Fixators

The internal devices are located either subcutaneously or within the oral cavity (intraorally). The intraoral devices can be placed above (extra mucosal) or below (submucosal or buried) the soft tissue. These devices are attached to the bone, to the teeth or simultaneously to the teeth and bone.

Advantages

1. For the most part these are buried under soft tissue cover – inconspicuous and no facial scars.
2. Suitable for large bones.

Disadvantages

1. Require a second major surgical procedure for removal.
2. Difficult to apply to small bone fragments.
3. The range of movement is limited.
4. Alternation in the vector of movement during distraction may not be possible.

Operative Procedure

Similar operative exposure as for conventional orthognathic surgery will be required. The Osteotomy here is to be carried out according to a predetermined plan, e.g. a Le Fort I Maxillary Osteotomy or a body osteotomy of the mandible behind the last molar tooth. The distraction appliance should be fixed to either end of the osteotomy before complete mobilization of the fragments. Distraction device orientation is the primary factor that influences the vector of distraction. In order to minimize adverse biomechanical efforts, the devices should be placed parallel to the desired vector of distraction. In fact the screw holes may be drilled before the Osteotomy is actually performed. On fixation of the device and completion of the Osteotomy the bone may be distracted to confirm the movement and then brought back to its original position.

Postoperative Protocol

- Allow a suitable latency period usually of 4-5 days. Could be started earlier in an infant
- Distract the fragments at the optimum rate and rhythm, i.e. 1 mm/day or 0.5 mm twice a day
- In a patient or with a parent, who can be educated, the distraction may be carried out at home, when frequent follow up visits may be arranged
- After the desired movement is achieved, leave the fixator in place for the required period of consolidation, i.e. twice the time needed for distraction, and then remove it.

Complications

Complications encountered during Distraction Osteogenesis can be divided into three groups:

1. Intraoperative
2. Intradistraction
3. Postdistraction.

Intraoperative Complications

a. Incomplete osteotomy
b. Inappropriate fixation and orientation of device.

Intradistraction Complications

Occurring during distraction and consolidation periods and include:

a. Pin infections
b. Pin loosening
c. Device loosening and dislodgement
d. Pin tract formation with scarring
e. Inappropriate vector
f. Premature consolidation
g. Delayed union
h. Fibrous union

Postdistraction Complications

a. Malocclusion
b. Relapse
c. Poor growth after distraction.

Incomplete Osteotomy

Incomplete osteotomy may be associated with pain during distraction, bending of the fixation pin and/or change in the orientation of the device. A radiographic diagnosis at this stage may be very difficult. Hence completion of the osteotomy and segment mobility should be verified intraoperatively.

Pin Tract Infection

This is usually due to instability of the fixation pin. The stability of the fixation pin in the bone as well as to the device should be checked frequently.

Premature Consolidation

This may be due to compressive forces on one side of the regenerate or when the rate of distraction is too slow. This will be apparent when the distraction becomes increasingly difficult to turn. In this situation the daily rate of distraction should be increased.

Delayed Union and Fibrous Union (Delayed Consolidation)

This may occur if the rate of distraction is too fast, e.g. using normal distraction parameters for patients with malnutrition, metabolic disorders, or when the vascularity is compromised. A traumatic osteotomy with damaged osteogenic tissue, excessive initial gap between the osteotomized bone segments or instability of the distraction device may also be responsible.

Malocclusion

Malocclusion is usually due to inappropriate planning, inadequate placement of the distraction device and control of vector. Use of intermaxillary elastics may often be required if this is noticed when it is developing.

The above discussion is only, a very brief introduction to this exciting new discipline of distraction osteogenesis as applied to the Craniofacial skeleton. As mentioned earlier, the techniques and armamentarium are still evolving and a judicious use of this method is recommended.

Illustrated Examples of Distraction

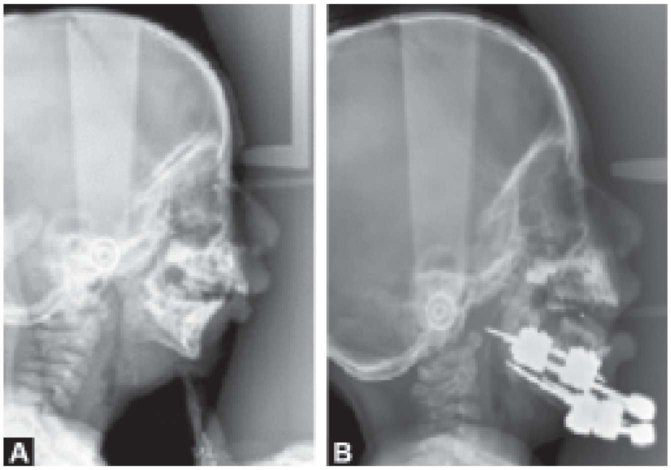
Here are clinical examples of the application of distraction osteogenesis in the craniofacial skeleton.

Case 1

Case of early childhood, bilateral, TMJ ankylosis with severe retrognathia leading to airway obstruction **(Figures 21.1A to 21.3B)**.

Figures 21-1A to D: Preoperative. Simultaneous ankylosis release, followed by bilateral mandibular body elongation with distraction osteogenesis to relieve airway obstruction.

Lateral Cephalogram



Figures 21-2A and B: (A) Preoperative (B) At the end of distraction.

Note the change in the dimensions of the pharyngeal airway (relief in obstructive symptoms obtained immediately after distraction).

Figures 21-3A and B: Postoperative (2 years)

Case 2 (Figures 21.4A to 21.7B)

Figures 21-4A and B: Case of severe, mandibular alveolar ridge resorption and loss of vertical facial height

Figures 21-4C and D: (C) Postoperative frontal view, (D) Postoperative profile view

Figure 21-5: Intraoral vertical alveolar distractor.

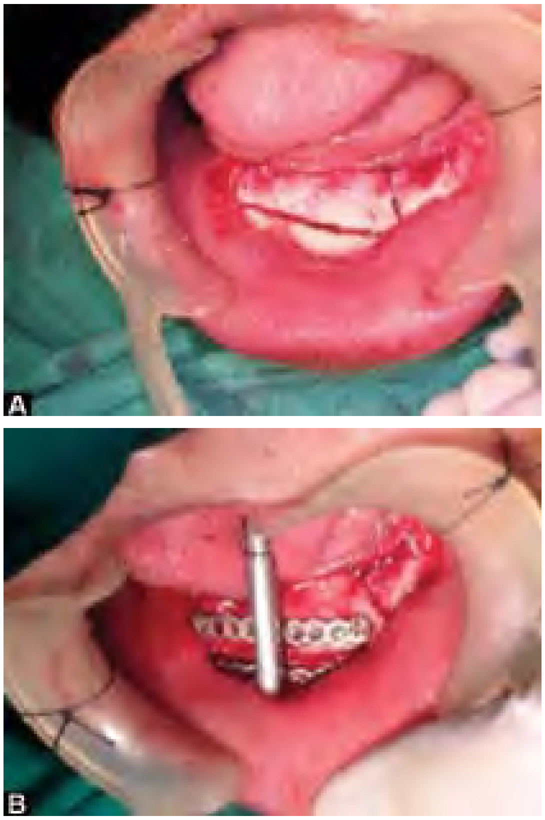
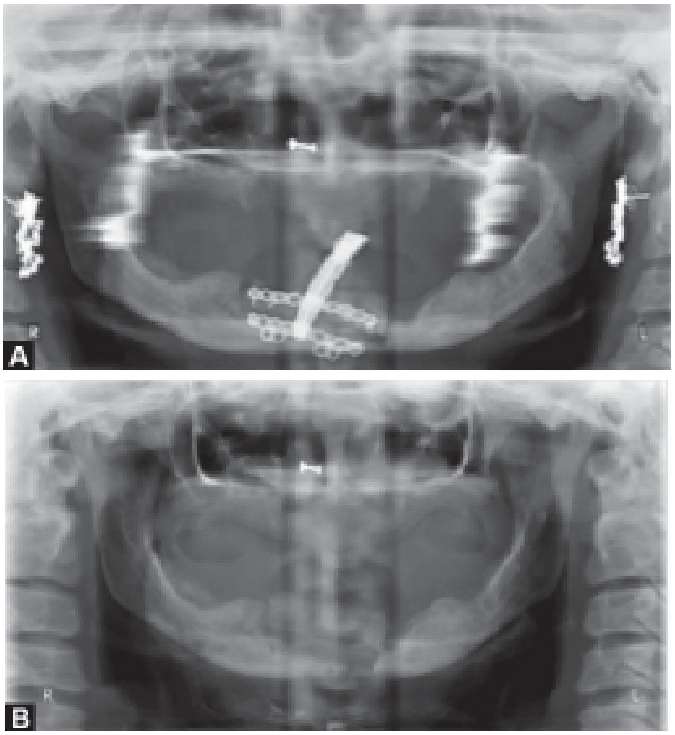


Figure 21-6A and B: Intraoperative pictures showing osteotomy (A) and distractor in place (B).



Figures 21-7A and B: (A) X-ray (start of distraction), (B) Postoperative (3 months).

Case 3

Case of cleft maxillary hypoplasia treated with Le Fort I osteotomy and DO with external fixator **(Figures 21.8A to E).**

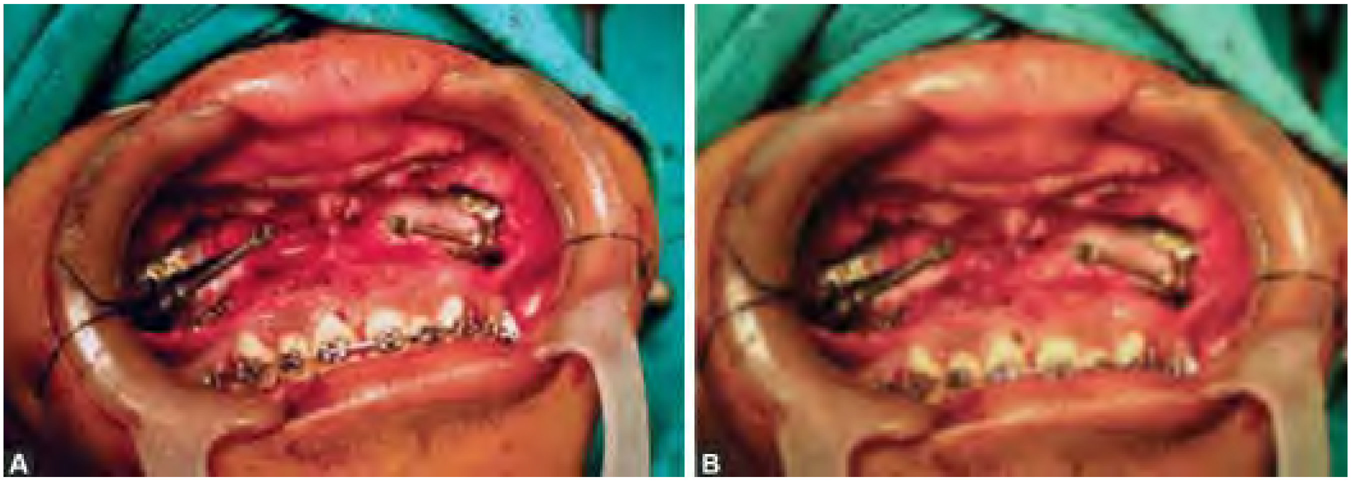
Figures 21-8A to E: (A) Preoperative, (B) Postoperative, (C) Preoperative, (D) During distraction, (E) Postoperative (6 months)

Case 4

Case of severe cleft maxillary hypoplasia treated with Le Fort I osteotomy and DO with an internal distractor **(Figures 21-9A to 21-11B)**

Figures 21-9A and B: Preoperative.

Figures 21-10A and B: Postoperative.



Figures 21-11A and B: Internal distractor in place following the osteotomy.

Case 5

A complex case. A childhood tumor removal resulting in lack of condyle and ramus (L) of the mandible with little bone stock for bi-directional distraction. Treatment in stages (1) (L) body distraction (2) Bi-maxillary osteotomy (Le Fort I and Genioplasty) **(Figures 21-12A to F)**.

Figures 21-12A to F

Further Reading

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Chapter 22

Kishore P Nayak

Introduction

Orthognathic surgery should provide predictable and stable results at the end of the procedure. These two terms—predictability and stability are frequently used interchangeably but it should be understood that they are conceptually different.

Predictability refers to the ability to position and maintain the osteotomized segments in the new space and position and the resultant response and adaptability of the soft tissues to this movement new position. Predictability is influenced by preoperative surgical and orthodontic planning, mode of execution of the surgery as well as the postoperative management.

Stability is the ability of the osteotomized segments to maintain the new position over time. Stability is greatly influenced by the type of procedure done as well as the direction and magnitude of movements attained.

The last two decades have seen the increasing application of rigid fixation devices following Orthognathic procedures and literature seems to suggest that rigid fixation adds to the stability of the procedure.[1, 4] However it has to be borne in mind that rigid fixation has to be precisely applied and is also very unforgiving especially when applied to mandibular osteotomies. In fact one of the prime causes of instability is "micro-motion" at the fixation site[3] which is the most frequent cause of migration or relapse. It is important to understand these two terms as a concept—migration refers to the continued movement of the bony segments in the direction of the initial move whereas relapse is movement toward the original position of the bony segments. It is important from these descriptions to know that the terms are not interchangeable and the effects of each are different and undesirable.[6]

In other words, mandibular setback using a bilateral sagittal split osteotomies with rigid fixation tends to relapse forward whereas a setback using an intraoral vertical ramus osteotomy tends to migrate posteriorly![5]

While there are numerous reasons and causes for relapse related to the type of procedure performed and the extent or magnitude of movement achieved, it is not the intention of this discussion to elaborate on the causes and prevention for long-term relapse. What is needed is a focus on the problems that are faced by the operator in the immediate and perhaps even in the intraoperative phase where there is an extreme need to attain the planned position and the solutions and remedies that need to be applied as appropriate.

Causes of Incorrect Occlusion in the Intraoperative and Immediate Postoperative Phase

It is regular and usual practice to place the teeth in temporary maxillomandibular fixation with the aid of interocclusal wafers and then follow this up with the application of rigid fixation in the maxilla or mandible. In the case of a two jaw surgery this is usually a two step procedure. It is not uncommon to encounter a "disclusion" or a deviation from the planned occlusion immediately after the release of the temporary inter maxilla-mandibular fixation (MMF). This can occur in the intraoperative phase or at the time when the MMF is released or in some cases in the postoperative phase where the MMF is maintained for a longer period of time. It is important to recognize this occurrence and enumerate the possible reasons thereof.

The possible causes of this deviation from the planned occlusion are **(Figure 22-1)**:

1. Mobility at the osteotomy site
2. Shift in occlusion during application of rigid fixation
3. Intra-articular edema or hemarthrosis **(Figure 22-2)**

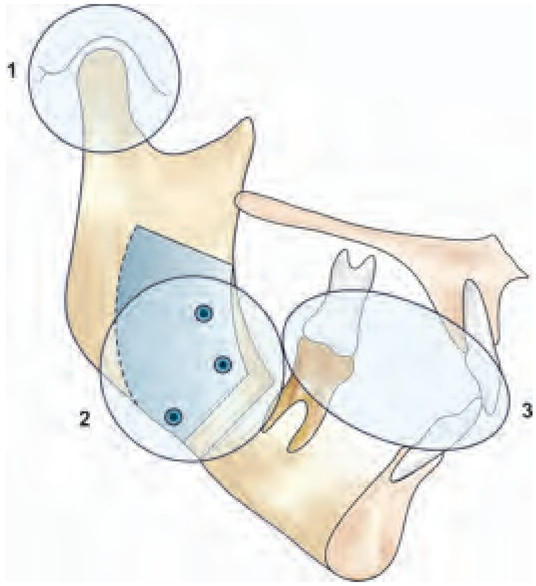


Figure 22-1: The three main causes of malocclusion in the immediate postoperative phase.1—Condylar position/sag, 2—Inadequate fixation, 3—Occlusion shift during appliaction of RIF.

4. Disk displacement **(Figure 22-3)**
5. Condylar sag.

Mobility at the Osteotomy Site

This is usually due to the application of inadequate fixation which leads to mobility at the osteotomy site and is frequently seen after a sagittal split osteotomy. It is easily detectable by application of light and controlled force across the osteotomy site and should be corrected immediately.

Shift in Occlusion during Application of Rigid Fixation

The application of excessive lateral and displacing forces during the application of rigid fixation may displace the occlusion and result in fixation in the displaced position and will go undetected till the release of the temporary MMF. The same can occur with the application of a poorly adapted plate. It is therefore important to check the occlusion prior to the removal of MMF.

Intra-articular Edema or Hemarthrosis

Repeated, rough and indiscriminate manipulation of the proximal segment during sagittal osteotomies of the mandible may result in intracapsular hemorrhage or edema. This can make the accurate positioning of the condyle a difficult proposition in the intraoperative phase. On the resolution of the hemorrhage or edema in the post-operative phase it will cause a superior movement of the condyle in the fossa (akin to Condylar sag to be described later).

A more frequent occurrence is the postoperative accumulation of fluid within the capsule causing an inferior displacement of the condyle and an "opening" up of the posterior occlusion accompanied by pain in the joint area. This however is a transient phenomenon and settles

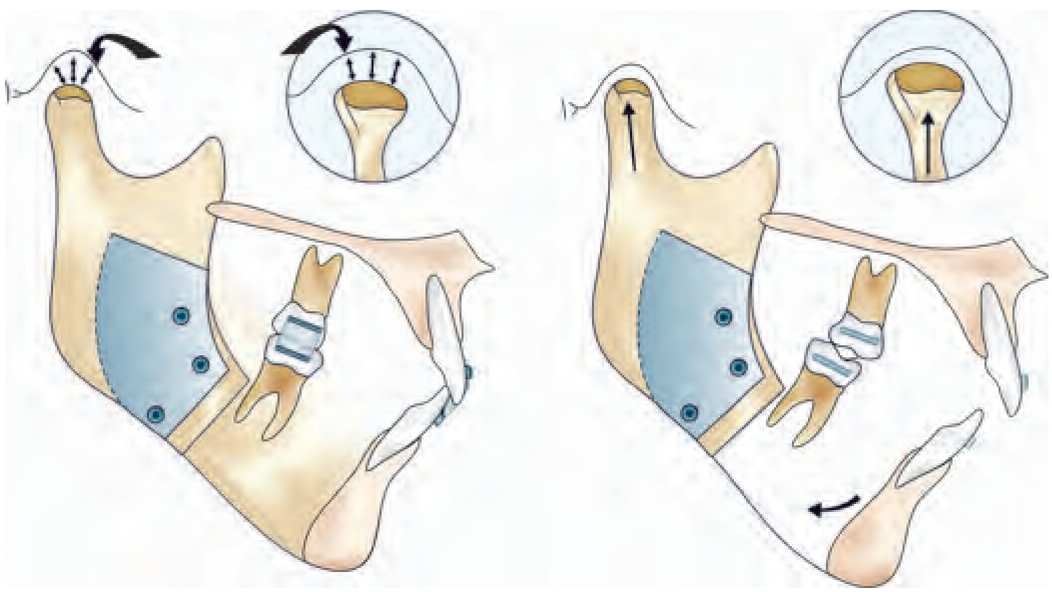


Figure 22-2: Accumulation of intra-articular edema/hematoma will cause inferior displacement of the condyle. Resolution of this in the postoperative phase will cause the condyle to move superiorly very similar to a central condylar sag.

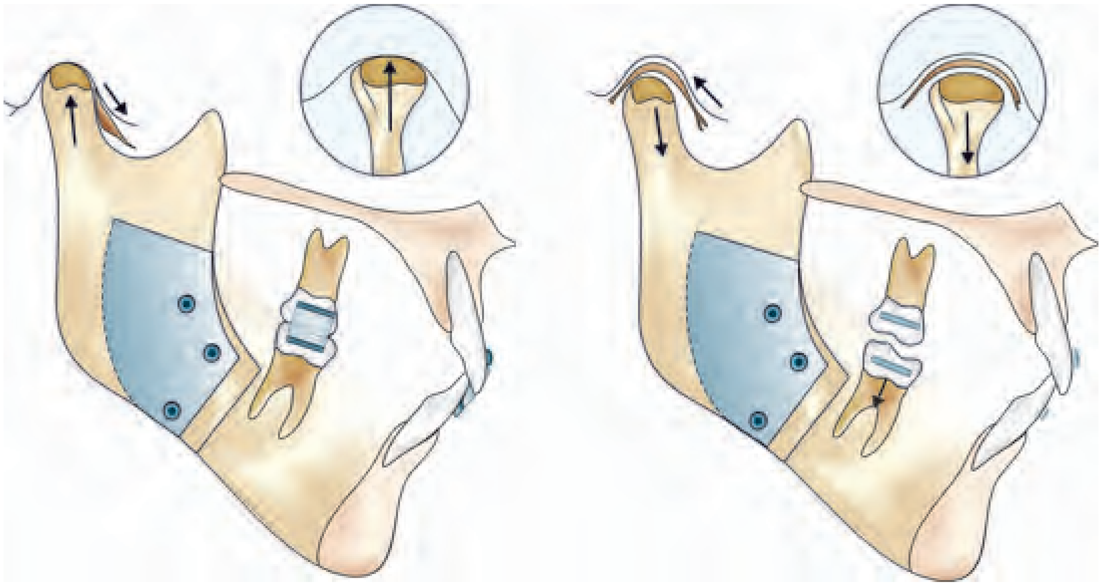


Figure 22-3: An anteriorly displaced articular disk can slide back into its correct position in the postoperative phase causing opening up of the bite as well as an anterior displacement of the mandible.

spontaneously with the resolution of the edema and hemarthrosis.

Disk Displacement

A preoperative suggestion of internal derangement of the articular disk is an important consideration when manipulation and placement of the proximal segment is considered. In the event of the likelihood of a displaced disk being present it requires even more careful attention than a disk in the normal position. The integrity of the joint structures must be maintained and displacement of the articular disk must be avoided. In the event of the disk being anteriorly displaced, there is a possibility of it returning to its normal anatomic relationship to the condyle and fossa in the postoperative phase. This will surely result in a mildposterior open bite as well as an anterior positioning of the mandible once the disc returns to its normal position **(Figure 22-3)**.

Condylar Sag

Condylar sag as defined by Reyneke[2] refers to "*an immediate or late caudal movement of the condyle in the glenoid fossa after surgical establishment of a pre-planned occlusion and rigid fixation of the bone fragments, leading to a change in the occlusion.*" This movement of the condyle causes an occlusal relapse either immediately on release of MMF or in the late postoperative phase.

Classification and Effects of Condylar Sag

Three types of patterns may follow in the establishment of condylar sag.[2]

- Central condylar sag
- Peripheral condylar sag type 1
- Peripheral condylar sag type 2

Central condylar sag ***(Figure 22-4)***

- The condyle is displaced inferiorly with no contact with any part of the glenoid fossa. On release of MMF, the condyle makes an immediate superior movement leading to malocclusion—in most instances an anterior open bite.

Peripheral condylar sag type 1 ***(Figure 22-5)***

In this situation there is an inferior displacement of the condyle but with some contact with the glenoid fossa either medially, laterally or even on the anterior or posterior aspect with the teeth in temporary MMF and rigid fixation applied. There is no noticeable occlusal change in the immediate phase, however, postoperative resorption and subsequent change in the condylar shape will almost certainly lead to delayed relapse.

Peripheral condylar sag type 2 ***(Figure 22-6)***

In contrast to the above types of malposition of the condyles, here the condyles are correctly situated when the teeth are in occlusion with MMF prior to the application of MMF. The change is induced when RIF is

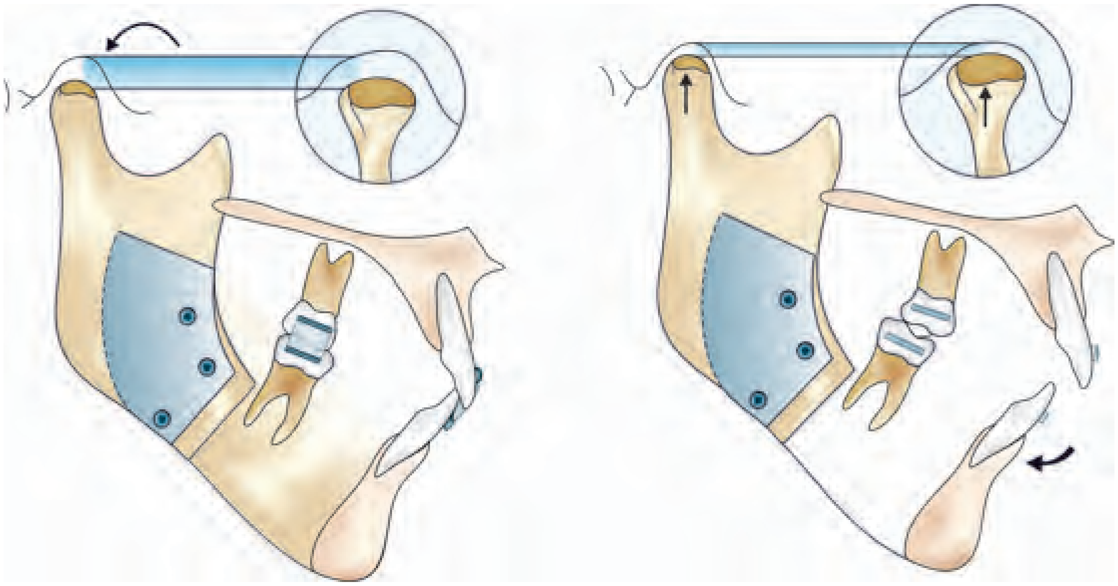


Figure 22-4: Central condylar sag: Condylar head is drawn away from the fossa with no bony contact at the time of application of RIF with teeth in MMF. Release of the MMF causes the condyle to move into its superior original position causing immediate relapse.

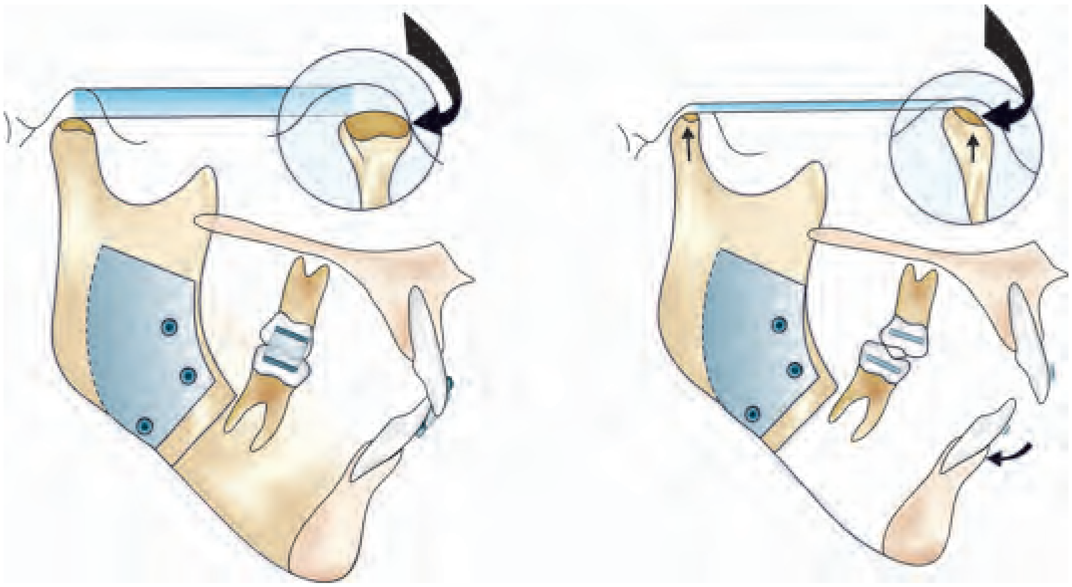


Figure 22-5: Peripheral condylar sag type 1: There is condylar displacement with some bony contact between the joint and the fossa. On release of the MMF this provides some support to the occlusion but delayed condylar resorption will tend to cause late relapse.

applied which induces a torquing force on the condyle and ramus. On release of the MMF, the condyle will move laterally or medially on the inclined plane formed by the fossa. Unlike in the type 1 situation, here the occlusion is altered immediately.

Both types of peripheral sag are common when bilateral sagittal osteotomies are performed on the mandible and even more so when lag screws are used for fixation. While it is easier to maintain passive position and placements between the proximal and distal segments using mini plates, intersegmental defects can be forced together when lag screws are applied resulting in displacement of the condyle within the glenoid fossa.

Special attention is needed when we use the bilateral sagittal osteotomy when correcting large deviations from the midline. As can be seen in the illustration **(Figure 22-7)**, in these cases there is a tendency for the most distal part of the distal fragment to move laterally causing a "flare" of the ramus or proximal fragment. As can be imagined, the application of rigid fixation in this situation, can almost

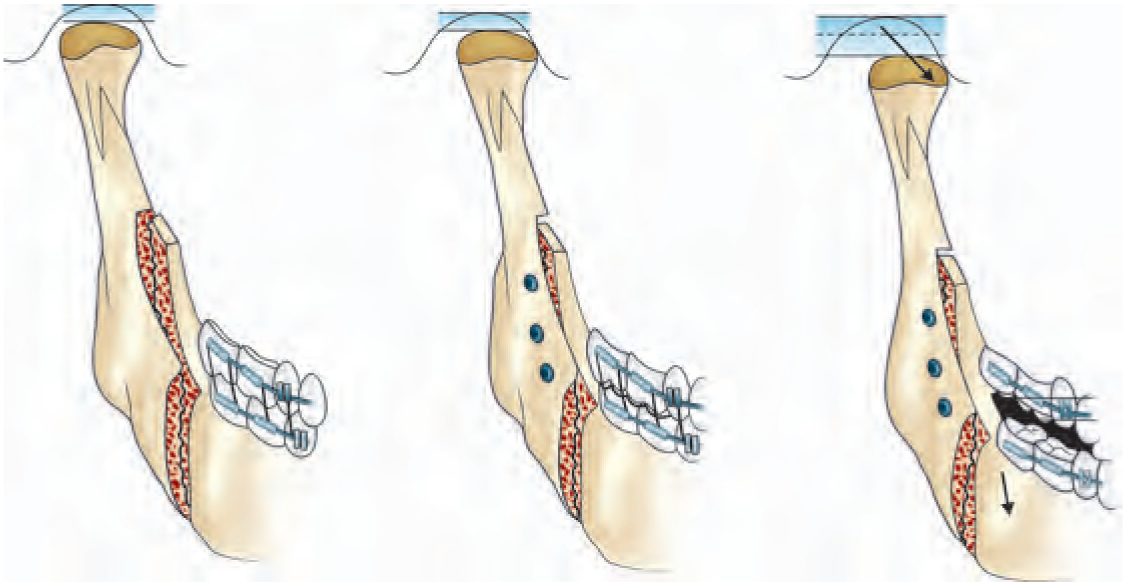


Figure 22-6: Peripheral condylar sag type 2: In this situation the condyle is situated in the correct position initially. However, when RIF is applied this causes the condyle to drift inferiorly based on the contact with the fossa. This causes an immediate opening of the bite on release of the MMF. The extent to which the bite opens is exactly the same distance by which the condyle has moved inferiorly.

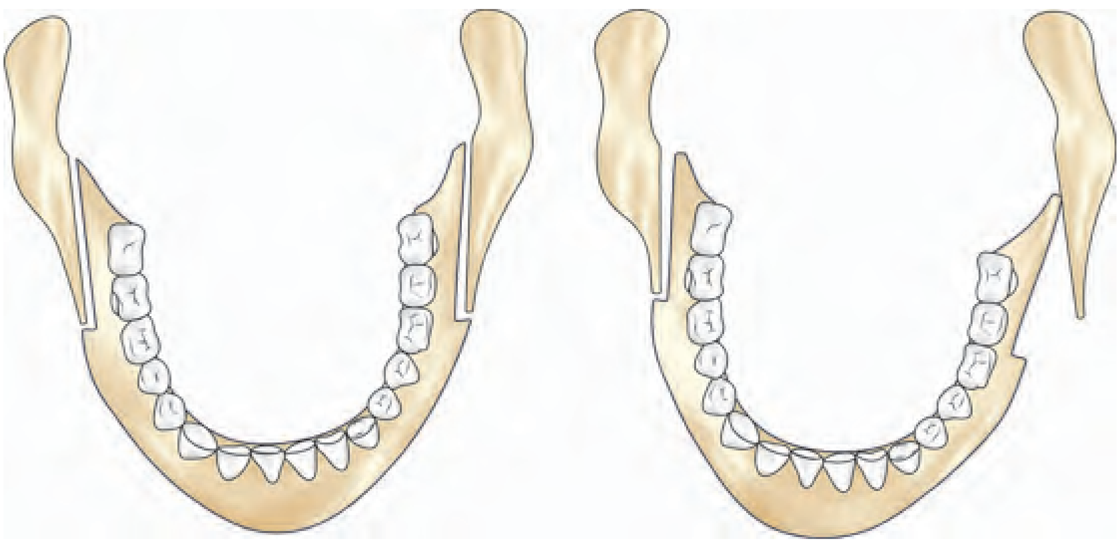


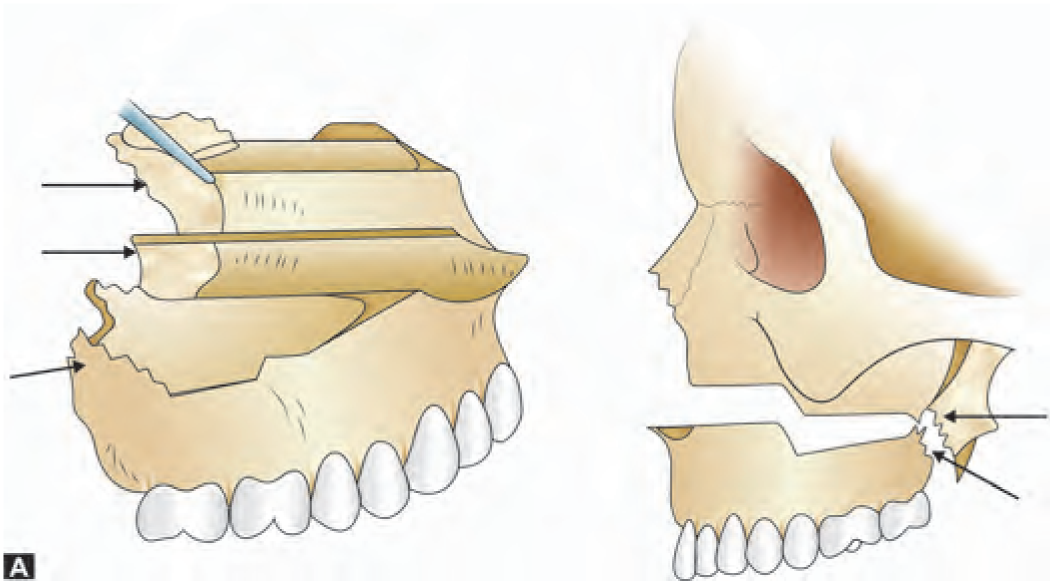
Figure 22-7: Large transverse movements to correct midline deviations cause the most distal part of the distal fragment causing the proximal fragment to "flare" out. This needs to be taken into consideration to maintain passivity when RIF is applied.

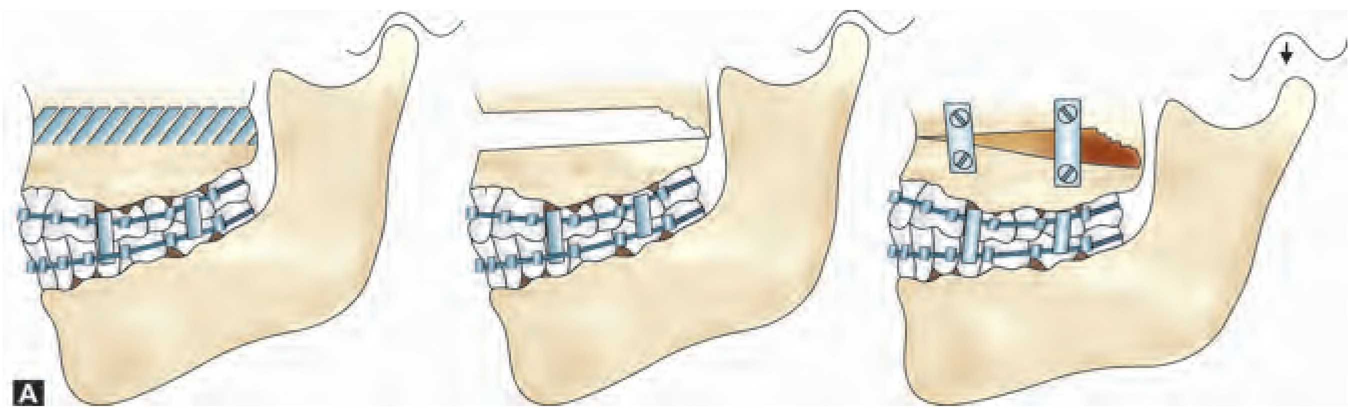
certainly lead to torquing of the segments based on the fulcrum provided by the edge of the distal fragment and will invariably add to the complexity of inducing a peripheral sag with all its implications of immediate and long-term relapse **(Figure 22.10)**.

Is Condylar Sag Restricted to Mandibular Procedures Alone?

While anterior and inferior movements of the maxilla present no problem in terms of interferences with movement, superior repositioning will need the adequate removal of tissues in order to allow intrusion. Care should be taken to gain adequate clearance between the maxillary tuberosity and the cranial aspect of the midface and pterygoid plates in order to avoid posterior gagging of the maxilla.

Undiagnosed posterior interferences in the maxilla will cause distraction of the condyles from the fossa as seen in a central condylar sag **(Figure 22-8)** while it is held in temporary MMF with excessive force applied at the chin





Figures 22-8A and B: Inadequate bone removal in the posterior maxilla with the teeth in MMF and application of RIF can induce a condylar sag.

being the usual culprit **(Figure 22-9)**. Following the rigid fixation of the maxilla and release of the MMF the condyles revert to their normal original positions resulting in an anterior open bite with posterior gagging. It is imperative in these situations that the fixation is released and all posterior interferences removed to allow for correct positioning of the maxilla without upward pressure on the chin thus avoiding the probability of distracting the condyles and inducing central condylar sag.

Relapse and Sagittal Split Osteotomy–Interplay of Technique, Rigid Fixation and Condylar Position?

In the past, non-rigid fixation of osteotomized segments in the form of wire osteosynthesis and long-term IMF was a common practice. Fixation using wire ligatures do not provide functional stability and long-term IMF is required. The inadequate stability is often blamed as the cause of relapse. Long-term IMF is associated with difficulties of airway patency, decreased oral nutritional intake, weight loss, discomfort, inability to talk, oral hygiene problems, increased incidence of TMJ dysfunction, muscle atrophy and fibrosis, as well as associated physiological problems. Rigid skeletal stabilization minimizes these difficulties. Rigid fixation includes the use of bicortical screws—lag screws or positional screws; or mini-plates and mono-cortical screws.

Although bicortical screws are probably just as effective as mini-plates in stabilizing the fragments, there are disadvantages inherent in their use. These include the need for small extra oral incisions for transbuccal placement of screws and damage to the inferior alveolar nerve. Damage to inferior alveolar nerve may be caused due to one of these causes:

1. While drilling the hole.
2. Due to compression of the fragments and medial rotation.

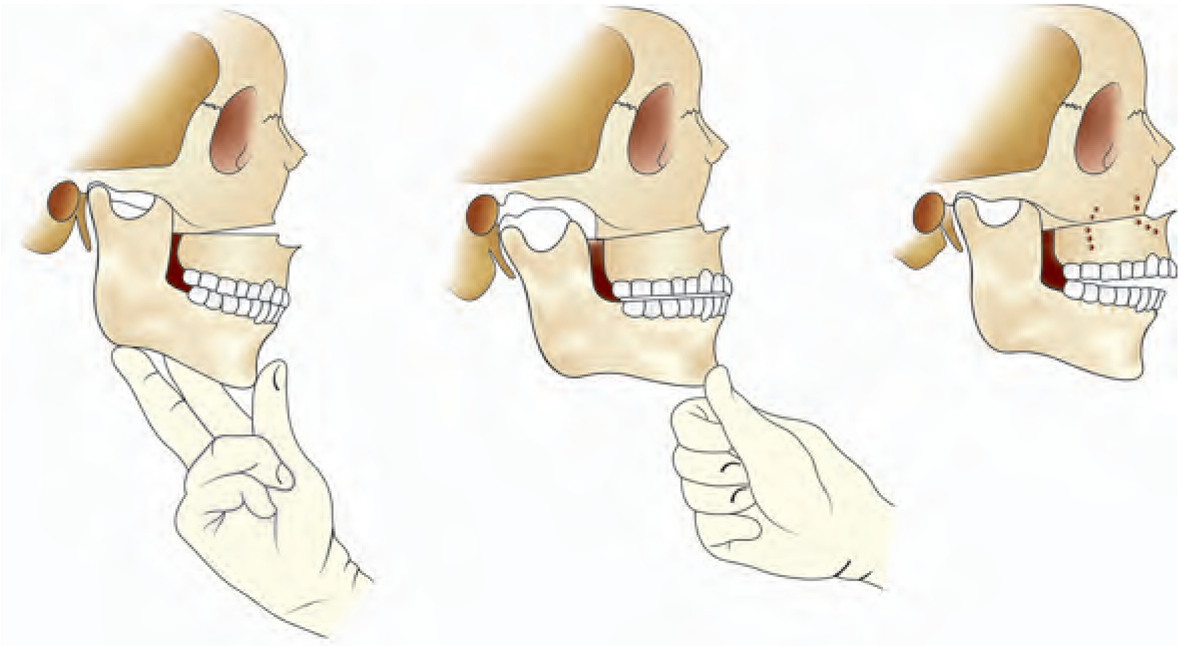


Figure 22-9: Maintaining the teeth in occlusion with undue upward pressure on the chin during maxillary procedures can induce a central condylar sag with opening up of the occlusion in the immediate postoperative phase.

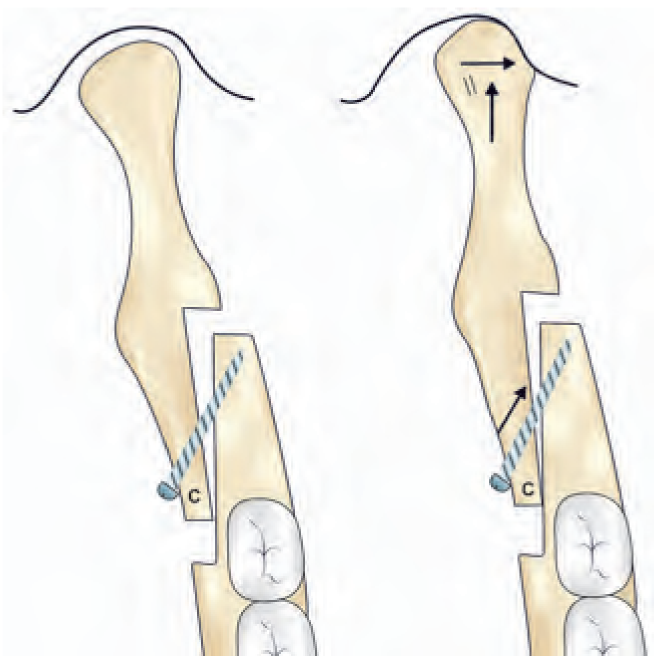


Figure 22-10: Lag screws have a tendency to induce peripheral sag due to the torque they may induce on the condyle as against the use of mini plates with mono cortical fixation.

3. Distraction or posterior displacement of the condyle in the fossa leading to short-term relapse and /or TMJ dysfunction.

The use of intraoral mini-plates obviates the need for skin incisions. Inward rotation of proximal segment can be avoided when mini-plates are used by bending them to fit over the oblique ridge of proximal and distal segments, even when the segments are not perfectly aligned. Damage to inferior alveolar nerve is also avoided by monocortical screws which are used with mini-plates. Further, bending of plates prevents compression of segments. When using mini-plates and monocortical screws to fix the fragments, lingual fractures of the distal fragment will not compromise the result.

The procedure of BSSO is not without its attendant morbidity. The complications associated with BSSO may result from imprecise surgical procedure, poor control of the proximal segment and condyle and unstable fixation of the osteotomized segments. Life threatening complications include edema, airway obstruction and hemorrhage. Disfiguring or potentially disfiguring complications included substantial loss of bone, displacement of bone segments and impairment of the function of the facial nerves. Subjectively, discomforting complications include impairment of function of mandibular and lingual nerves. Regression and relapse after surgery, TMJ dysfunction and condylar resorption are very distressing complications. Miscellaneous complications include ecchymosis, dislocation of condyle, hematoma, infection, limited opening of mouth, non-union of segments, excessive salivation and exposure of fixation material.

Although technical modifications have increased the reliability and stability of this procedure, postoperative relapse is the most commonly mentioned complication.

Factors contributing to skeletal relapse after BSSO include paramandibular connective tissue tension, control of proximal segment during surgery, condylar distraction, inadequate fixation periods, methods of fixation, magnitude of distal segment advancement, unfavorable postsurgical growth, pre-existing internal derangement of TMJ, age at operation, condylar osteolysis and remodeling, inadequate bony healing, and the surgeon's level of experience.

By advancing the mandible the paramandibular soft tissue drape (muscles, periosteum, ligaments, and skin) is stressed together with suprahyoid and infrahyoid muscles. The hyoid, fixed by these muscles, is pulled forward and tend to return to its original position. The stretching of these tissues gives rise to a constant force opposite to the vector of the mandibular advancement. However the muscle complex surrounding the hyoid bone is able to adapt to the changes in its environment. In patients undergoing BSSO with rigid skeletal fixation, recovery tendency of the hyoid bone was not seen. Nevertheless, there are potential areas where these forces might cause alterations of the direct postoperative result.

Due to preoperative orthodontic treatment, there is temporary, extra mobility of the teeth. Therefore, even rigid MMF applied immediate postoperatively will not prevent the mandible moving backwards when this is employed as the only method of fixation.

Despite the use of plates and screws to provide rigid skeletal fixation, bone remodeling takes place soon after fixation. This remodeling, undoubtedly, will allow for some minor movements of the fragments. These movements will result in some backward movement of the distal fragment because of the earlier mentioned soft tissue traction. The consequences become visible within the first few months. Other factors that may play a role are the rigidity of the osteosynthesis plates and the amount of bone contact between the fragments. Early postoperative wound infection may lead to loss of rigid fixation as well.

The condyle position is mainly determined by the muscles, especially the mandibular elevators, which are paralyzed during the anesthesia. When the muscle tone returns to its normal level postoperatively, the condyles assume their preoperative functional position in the glenoid fossa. There might also be the influence of edema or hematoma in the joint following the manipulation which may also explain a different position of the mandible.

Posterior positioning of the condyle has been shown to lead to condylar resorption and/or changes in the articular disk resulting in late relapse, and /or TMJ dysfunction. The most probable cause for resorption of condyle is compression of condyle against the articular fossa. Therefore the control of the condyle bearing proximal segment is the single most important surgical aspect in determining the stability or relapse of the osteotomized mandible. Failure to correctly position the proximal segment can result in a built-in relapse potential, loss of the gonial angle, condylar sag, pain and dysfunction of TMJ, and functional impairment of masticatory system.

The intraoperative diagnosis of an unfavorable condylar position is highly desirable and is the subject of research that has focused primarily on two management philosophies. Either securing the condyle in its pre-operative position prior to BSSO; or alternatively replacing the condyle in its preoperative position with the aid of sophisticated imaging methods or computer assisted navigation. These techniques are very cumbersome and not universally available.

A simple technique that can reliably identify a malpositioned condyle intraoperatively has obvious advantages. Condylar sag, or change in position of condyle in glenoid fossa after surgical establishment of preplanned occlusion and rigid fixation of the bone fragments, produced patterns of occlusal shift that assist in identifying the offending condyle. The diagnosis of condylar sag is made by observing the following clinical signs:

Bilateral condylar sag: Dental midlines are correct; over jet is increased; there is an anterior open bite; and a class II occlusion (bilaterally).

Unilateral condylar sag: The mandibular dental midline is towards the affected side; over jet is increased (more on affected side); there is a class II dental relationship on affected side; and if the mandible is moved until the midline coincide, the over jet is corrected and the correct occlusion can be reestablished.

A stable occlusion after correction of condylar sag implies a corrected condyle-fossa relationship.

Based on the studies in literature, it would seem prudent to maintain the preoperative condyle position during the surgery, especially if rigid fixation is to be used, to achieve permanent and lasting functional results. Numerous methods have been developed to position the condyle during BSSO. They can be divided into four groups:

1. Empirical methods, where the surgeon intuitively repositions the condylar fragment by taking into account the planned mandibular displacement.

2. The use of *in vivo* measurements, which is relatively similar to using the empirical method. Measurement of the distance between two points, one on the proximal condylar fragment and the other on non-specified point of the jaw, whether a tooth or osseous references mark, is used to assist in repositioning.
3. Radiologic methods that are complex, marginal, and of a relatively restricted clinical interest. Ultrasonography has also been investigated but the special resolution of ultrasound at this time doesn't allow precise evaluation of condyle repositioning.
4. Instrument methods, using less complicated appliances set up at the beginning of surgery, removed during the osteotomy, and than reinstalled before osteosynthesis. These appliances are called condylar positioning devices (CPD). They vary according to their proximal anchoring site, which can be an occlusal splint, the teeth, or an osseous part (usually in the maxilla). Main disadvantage of systems anchored on teeth or on an occlusal splint is that they can be used only for isolated mandibular osteotomies. The use of CPDs is controversial due to various factors:
   a. Too time consuming.
   b. Difficult to use.
   c. Necessity to keep IMF as stable as possible during their application.
   d. Risk of partial bone disruption of maxilla.
   e. Prevention of mandibular autorotation.
   f. There would frequently be a bone gap between proximal and distal segments, requiring a bone graft placement.

As previously discussed, the functional position of the condyle is maintained by the mandibular elevator muscles and any change in this condylar position can be diagnosed clinically by examining the occlusal shift.

This author prefers the empirical method which is used to reposition the condylar fragment after mandibular osteotomy. It consists of manually placing the condyle in its most superior and anterior position in the glenoid cavity.

Author's Note

It has been the author's experience to use a nerve stimulator to induce contraction of the masseter muscle at the end of the procedure in order to confirm the correct seating of the condyles within the fossa. This does not imply in any way that the condyle has attained its pre-operative position but only that a stable and functional position has been achieved. The technique is simple and consists of passing the 'current' from the nerve stimulator into the masseter using the electrodes contacting needles inserted into the muscle. The induced contraction of the masseter seems to draw the condyles into their favored position in the fossa and repeated contraction of the muscle simulates occlusal movements under general anesthesia thereby confirming that a functional yet stable position of the condyle has been achieved.

Mechanism of action of peripheral nerve stimulator: A nerve stimulator supplies electrons to depolarize a nerve. The number of electrons supplied per stimulus equals the current. It stimulates an electrical impulse in the nerve resulting in contraction of the muscle supplied by the nerve. The muscle response to this stimulus is called a twitch and various stimulation patterns have been developed; single twitch, train-of-four, double burst stimulation, tetanus and post-tetanic count. In deep relaxation a single twitch and train-of-four stimulus will not cause a muscle contraction and thus a tetanus stimulus should be used which causes a continuous tonic contraction of the muscle.

Conclusion

Orthognathic surgery is one of the most versatile branches of maxillofacial surgery. It requires sound knowledge and excellent skills to obtain satisfactory functional and esthetic outcomes after orthognathic surgery. It is important to eliminate all factors that might adversely affect the outcome before the initial operation and develop a sound treatment plan based on establishing both function and esthetics. This will minimize the incidence of relapse, migration and adverse outcomes in most patients.

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Chapter

23

Subramaniyam Iyer

Introduction

The facial features of an individual are defined mainly by the shape and position of the nose and hence it is not surprising to find that correction of nasal deformities is one of the most common aesthetic surgical procedures carried out all over the world. Deformities of the nose could be due to congenital and developmental causes or due to trauma either trivial or associated with major maxillofacial injuries.The deformities, apart from being esthetically displeasing to the individual and the on lookers, could also lead to functional problems like nasal obstruction, and as a sequel recurrent colds and sinusitis. Surgical correction of nasal deformities comprises various steps which might be common to most of the deformities. But many a times it will need to address the individual nose, with specific techniques aimed at the particular deformity it has. The approach to expose the nasal skeleton for doing the corrective steps can be variable with the type of nose and the deformity that is being dealt with. The nasal deformities associated with cleft lip are totally different from the deformities occurring in an otherwise normal individual, and hence the rhinoplasty in these noses has to be carried out with a different perspective. The outcome of rhinoplasty procedures depends upon proper selection of cases, proper planning of surgery and its execution, and to a great extent the physician's expertise and the patients expectations. Some of the patients have unrealistic expectations and many mistakes are committed by the surgeon in his or her early practice due to the pushing and perseverant patient, who would have benefited from a psychological evaluation to start with.

Rhinoplasty: Various Types

Nasal deformities that are confronted by the rhinoplasty surgeon are varied. But there is a distinct group of deformities that differ completely from the otherwise normal group of patients. This is the group of nasal deformities that are associated with either unilateral or bilateral cleft lip. Hence rhinoplasty carried out for the cleft and the non-cleft lip nose deformities are to be classified and discussed separately.

Types of rhinoplasty

- Cleft rhinoplasty
  - Primary or secondary
  - Unilateral or bilateral
- Non-cleft rhinoplasty
  - Aesthetic
    - Complete
    - Augmentation
    - Reduction
  - Functional

In rhinoplasty that is performed for otherwise normal patients, the procedures can be subgrouped into broadly two categories; i.e where it is done only for aesthetic purpose, or where it is done as a part of the surgery for relieving severe nasal block caused by gross septal deviation. In the latter group of functional rhinoplasty the common procedure carried out is septorhinoplasty. The procedures carried out for the purpose of esthetic improvement can be grouped according to the specific steps carried out, mandated by the deformity present and correction requested by the patient. Usually a total refashioning of the nose is requested, where the operative steps will be all inclusive. But sometimes the esthetic deformity will mandate only reduction of a dorsal hump or augmentation of a depressed dorsum.

Assessment and Patient Counselling

The assessment of the rhinoplasty patient should be carried out in a systematic manner and a management plan will have to be made and conveyed to the patient during the initial visit itself. Age and presence of co-morbid factors have important bearing on the management. In general, procedures which require extensive skeletal work on the nose are deferred to the time the patient acquires skeletal maturity. Cursory assessment of the personality and the patient expectations in relation to the deformity present has to be given great importance. This will help to decide either to ask for a psychological assessment or for not accepting the patient for the surgery.

The anatomical defects are systematically looked into and recorded. The nasal vault is in general divided into the upper (nasal bones), middle (upper lateral cartilages), and lower (lower lateral cartilages) thirds, and the deviations, depressions or uneven elevations are noted. Any hump in the dorsum is assessed as to whether it is involving the bony or cartilaginous portion or involving both. The tip is now assessed looking for the deformities with the aim of identifying the need of specific steps of increasing or decreasing the tip projection, sharpening the features in a bulbous tip or changing the columella. The ala of the nose is given attention to see for the need for decreasing the flaring by alar base reduction. The approach to the nasal skeleton either by closed techniques or open rhinoplasty is also decided depending on the type of the correction planned.

Assessment: A Quick Guide	
Dorsum of the nose	
Look for **Bends, Humps and Depressions**	
Look at three areas	
Upper third consisting of nasal bone and bony septum	
Middle third consisting of upper lateral cartilages and cartilaginous septum	
Lower third consisting of Alar cartilages and cartilaginous septum	
Tip of the nose	for symmetry, shape and size
Columella	for width, height and visibility
Alar base	for flaring

The deformities as well as the operative plans are recorded and explained to the patient in detail. The nose is photographed in the standard views which help in assessing the defect, in planning, as well as in assessing postoperative improvement. It is a very usual happening in the practice of esthetic surgery to be facing an unsatisfied patient and relatives since they tend to forget the gross initial deformity. The preoperative photograph will definitely serve as a to remind them of this. There are requests usually made for computer graphics simulation of the expected results, but in general the author prefers to discourage this since such simulated results get imprinted in patient's mind and in practice may not be possible to achieve in many instances. But gross changes expected can be explained with computer projections or by showing the results obtained in a previous patient.

Counselling also involves discussion regarding potential scars (which is important in open approaches and external osteotomies), need for nasal packing and splintage and the occurrence of transient periorbital ecchymosis. The method of anesthesia is discussed. The author prefers to do the procedures mostly under general anesthesia, but many surgeons routinely undertake rhinoplasty under local anesthesia with adjuant intravenous sedative supplementation. The author routinely counsels the patient regarding necessity of minor procedures later on to improve minor deficiencies in the outcome.

Surgical Approaches

Two types of approaches are utilized to expose the nasal framework while performing rhinoplasty of any type. These are the closed group of approaches and the open approach. The essential difference between these is that in the open approach the columella is transected and lifted up so as to give direct visualization of the dorsum.

Open Approach

In open approach the incision has three parts. The initial incision is transversely over the columella which can be given in different shapes, i.e. 'V' or 'inverted V' **(Figure 23-1)**. This now goes up along the lateral aspect of the columella inside the vestibule up to the curve of the dome forming the second part of the incision. The third part starts from this point and goes laterally along the caudal rim of the alar cartilage till its end. The skin envelope is now elevated with sharp dissection baring the alar cartilages, the upper laterals and the nasal bone up to the nasofrontal area. This gives an excellent view of the entire skeletal framework especially the alar cartilages **(Figure 23-2)**. To site the lateral limb of the incision along the caudal edge of the alar cartilage (this caudal edge is not parallel to the alar rim but diverges away from it as it goes laterally) the easy way is to make the incision with sharp scissors following the rim from its medial most aspect. Elevation becomes easier, if it is done with sharp scissors hugging the surface of the cartilage **(Figures 23-3A to C).** Usually troublesome bleeding is encountered at the columella rim incision point as well as while elevating the skin envelope over upper laterals. Bipolar cautery with fine tip is essential and helpful to control these bleeding points.

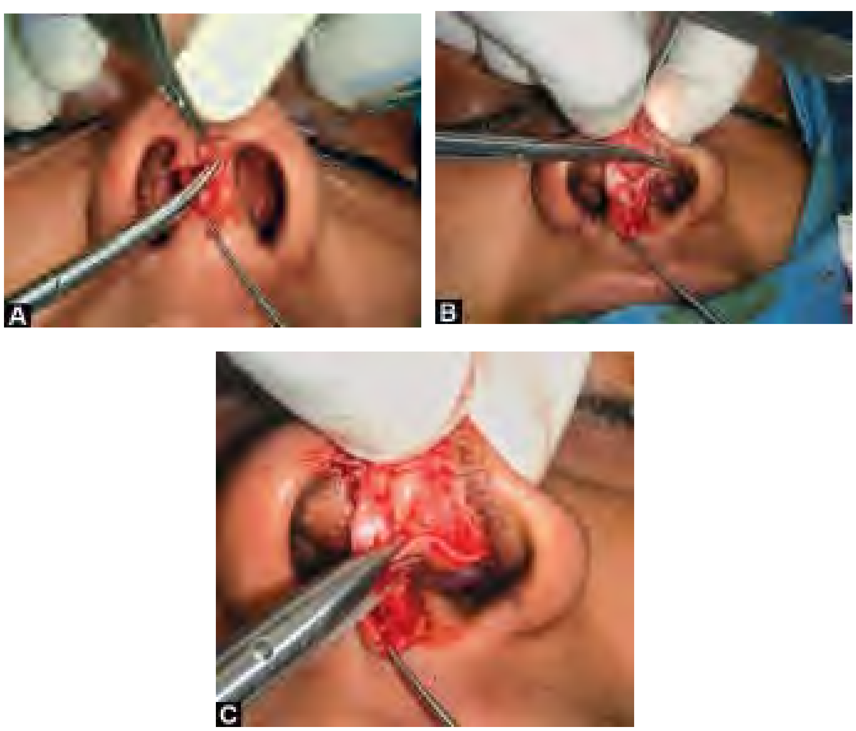
Figure 23-1: Inverted 'V'incision being made.

Figure 23-2: Exposed alar cartilages and the dorsum.

Practical tips for open approach
• Bipolar cautery with fine tip is very helpful • Follow the alar cartilage rim from medial to lateral for making the incision • Elevate the envelope in a plane hugging the cartilage.

Closed Approaches

Closed approaches utilize the combinations of a variety of incisions to expose the nasal skeleton. The medial limb of the incision is common to all the types—called the septal transfixion incision, where the membranous septum anterior to the caudal border of the septal cartilage is cut through and through. Laterally it continues at different levels **(Figure 23-4)**, i.e. intercartilaginous incision in the gap between the alar and upper lateral cartilages, intracartilaginous through the alar cartilage and a rim incision along the caudal border of the alar cartilage.



Figures 23-3A to C: Exposing the alar cartilage rim.

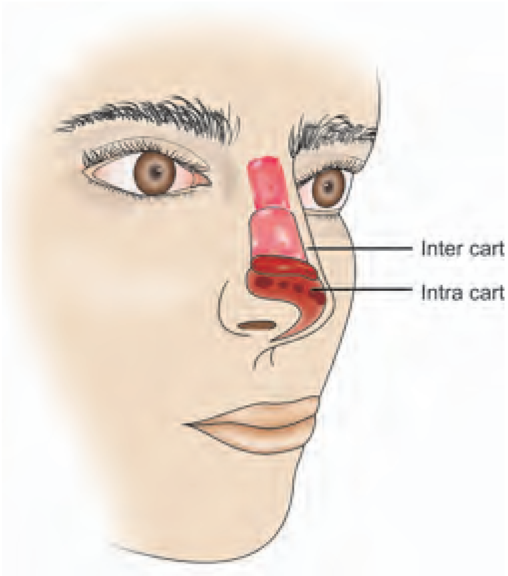


Figure 23-4: Incisions in closed approach.

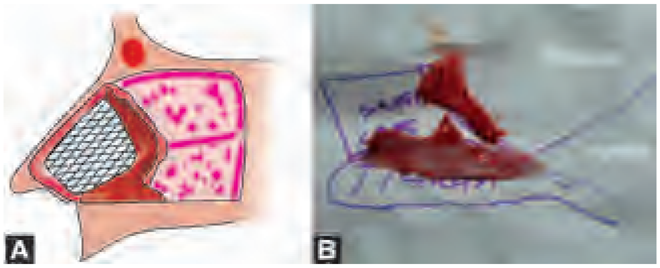
Common Surgical Steps

Most varieties of rhinoplasty utilize some common surgical steps. These will be discussed in detail below.

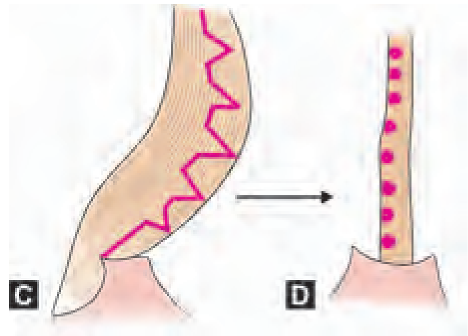
Septoplasty

This step is necessary when there is excess nasal septal deflection leading to functional obstruction or when it leads to dorsal lateralization. The following are the steps of a classical septoplasty, but minor variations in the technique are adopted by individual ENT surgeons.

The septal mucoperichondrium is elevated on the concave side. Another tunnel is made on the side of the maxillary crest lifting up the mucoperiosteum. These are joined now using sharp cutting, exposing the concave side of the septum completely. The septum is dislocated from the maxillary crest (or a strip excised) and the mucoperiosteum of the crest is lifted up on the other side also. A strip of cartilage is excised from the inferior as well as the posterior border of the septal cartilage so as to allow it to be repositioned to the midline **(Figures 23-5A and B).**



Figures 23-5A and B: (A) Excision of posterior and inferior strip (shaded area). (B) Excised strips of cartilage.



Figures 23-5C and D: Scoring the cartilage to straighten it.

The crest as well as bony septum is removed or repositioned now. If needed scoring incisions can be made in the concave side of septum to break its elasticity **(Figures 23-5C and D).**

The variations in the technique include baring the entire septum on either side, excising the bent areas of the cartilage in a liberal fashion or submucus resection of majority of the cartilage. The excision of cartilage in the septoplasty can be modified to suit the requirement of it as a graft elsewhere on the nose.

Correction of Lateralization of the Dorsum

Correction of the lateralized dorsum **(Figure 23-6)** requires separating the attachment of the bony and cartilaginous septum from the nasal bone and the upper lateral cartilages. The nasal bones are osteotomized and their position is now altered by their in fracture. This step effectively narrows the nasal dorsum also.

Separation of the Nasal Septum in the Paramedian Area

The nasal septal cartilage is separated by sharp cut from the upper laterals. This can be done entirely submucusally in which the vestibular lining is separated from the

Figure 23-6: Lateralized dorsum showing marking of medial osteotomy.

Figure 23-7: Separation of septum from upper laterals.

Figure 23-8: Medial osteotomy being done.

cartilages prior to the cut or transmucosally when the nasal vestibular mucosa is also included in the cut. To do this step the author prefers to use a knife with size 11 blade for this with an Aufrtcht retractor guarding the dorsal skin **(Figure 23-7)**.

The nasal bones are separated from the bony dorsum at the paramedian position. This is necessary when gross lateralizations are to be corrected. It is carried out using a chisel blade of 6 mm or more. The osteotomy cut is carried in a cephalic direction up to the frontal bone when the note of the osteotomy tap changes to a duller note **(Figure 23-8)**.

Lateral Osteotomy

This is done by intranasal approach when a Frenchay type of chisel is used or by external approach using a thin 2 mm osteotome after making a stab incision **(Figures 23-9A to C).** The internal osteotomy is done through an incision made just lateral to the root of the inferior turbinate. For the external osteotomy a small incision is given on the lateral nasal wall.

Infracture

After the osteotomy by either method the nasal bones are in fractured by manual pressure **(Figures 23-10A and B)** to centralize them **(Figure 23-11)** and narrow the dorsum.

Hump Reduction

The hump can involve the bony or the cartilaginous dorsum or more commonly both. The removal of the cartilaginous dorsum is by using a sharp instrument (the

Figures 23-9A to C: (A) Lateral osteotomy line, (B) Stab incision, (C) 2 mm Osteotome being used.

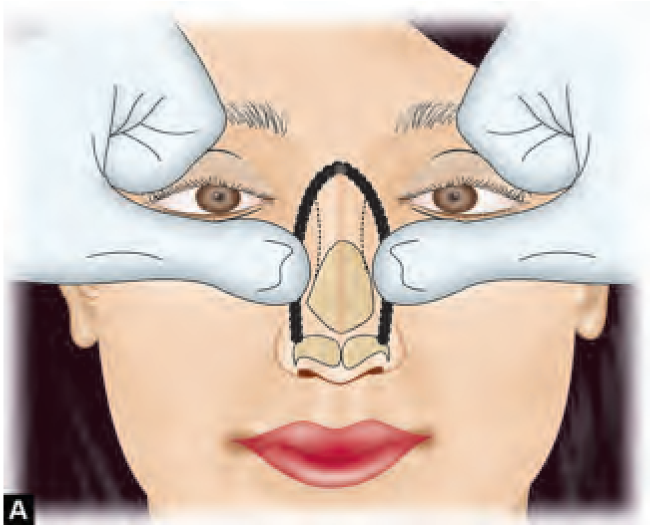
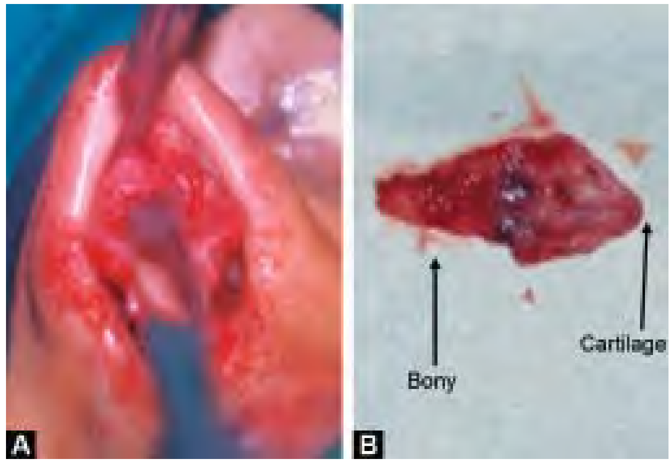


Figure 23-10A: Method of infracture.

Figure 23-10B: Manual pressure being applied.

Figure 23-11: Centralized dorsum after infracture.

author prefers to use a no 11 blade). The bony dorsum can be either cut out with a sharp osteotome **(Figure 23-12A)** or can be reduced by repeated rasping. The latter technique is more controlled and easier to perform. Sharp rasps are used initially followed by rasps with finer teeth which polish the rough surface. When an osteotome is used for cutting out the bony hump both the cartilaginous



Figures 23-12A and B: (A) Removal of hump with osteotome, (B) Removed bony and cartilaginous hump.

and bony hump can be removed in a single piece in continuity **(Figure 23-12B)**. But the operator need to be careful and precise when doing this step since over reduction is possible necessitating use of dorsal grafts later on.

The most important point to be remembered while doing a hump reduction is that irrespective of the method chosen, it results in a broadening of the dorsum, and hence osteotomies and infracture will be essential to narrow the dorsum. It is a common mistake in the early part of the career of a surgeon not to realize this, ending up facing a patient who is unprepared for the osteotomies.

Augmentation

Augmentation of the nasal dorsum is one of the most gratifying steps in rhinoplasty. This is because the deformity of the depressed dorsum is quite obvious and the correction is easy and predictable. In many instances, difficult to correct ancillary problems of the dorsum can be camouflaged by a dorsal graft. There is a big choice for graft materials. These include autograft bone/cartilage, homograft cartilage or alloplastic materials, each having its own merits and demerits. In general, autografts behave better in the long-term with less absorption and rejections. Bone grafts retain the shape and volume, whereas cartilage grafts tend to have a tendency for alteration in shape due to warping, which is more pronounced with rib cartilages. Bone on the other hand is more difficult to sculpture, and offers a harder feeling to the dorsum than needed. Bone compared to cartilage is more liable for resorption as seen in long-term follow-ups. Alloplastic implants include silastic and other newer materials like gortex and medpore. They are easier to fabricate, offer long-term viability (except silastic) and above all avoid donor site morbidity.

Figures 23-13A to C: (A) Iliac crest, (B) Olecranon, (C) Calvarium.

The placement of the grafts can be through open or closed approaches. When open approach is used the grafts can be secured in place through circumferential sutures or by screw fixation. When closed approach is used, limiting the pocket size will help to take care of the stability of the graft.

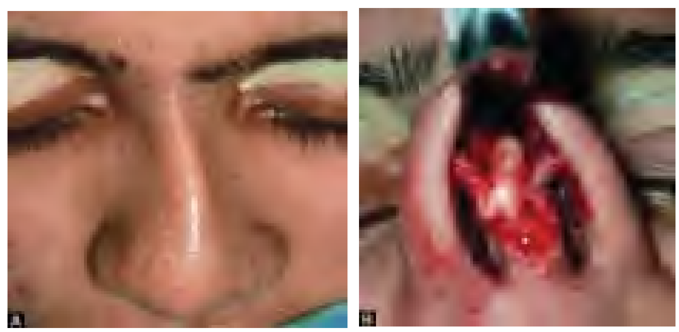
Bone Grafts

The usual donor sites for bone include iliac crest, olecranon, calvarium and tibia **(Figures 23-13A to C)**. The iliac crest offers abundant supply of both cortical and cancellous bone, but may have increased donor site pain during the immediate postoperative period. Its harvest is technically difficult in obese people. The olecranon offers good subcutaneous cortical bone which is easy to harvest, but occasionally the scar may be painful causing discomfort to the patient while keeping the hands on the top of a desk. The quality of calvarial grafts is very good and when long-term survival is taken into account they are the best. Harvesting calvarial grafts is difficult except when the rhinoplasty is carried out in conjunction with cranial procedures.

Cartilage Grafts

The donor sites for cartilage harvest include nasal septum, ribs and the concha. Ribs offer long and sturdy segments of cartilage and are relatively easy to harvest. But the demerits include warping of the cartilage leading to altered shape of the dorsum **(Figures 23-14A and B)**. Steps have been described to avoid warping which include balancing the cross sectional area, dicing the cartilage and injecting it as fine granules or wrapping the diced cartilage in surgical.

The Nasal septum is a very useful donor site with its major advantage of being in the operative field; moreover, the harvesting procedure can be beneficial in surgery to correct septal deflections. The disadvantage is the limited supply as well as the variable thickness and sturdiness of the cartilage. Conchal cartilage has got a very good texture and thickness and the donor scar is easily hidden if posterior approach to harvest it is used. The conchal cartilage has a curve which is less suitable when used in the dorsum, but is of advantage when used for augmenting the supratip or the alar dome.



Figures 23-14A and B: (A) Lateralized dorsum after costal cartilage graft. (B) The warped cartilage exposed.

Materials for augmentation of nasal dorsum
Auto/homografts
Bone
Iliac crest
Olecranon
Calvarium
Cartilage
Rib
Concha
Nasal septum
Synthetic
Silastic
Medpore

Alloplastic Materials

Silastic struts were very commonly used to augment the dorsum or as columellar support, either as prefabricated

Figure 23-15: Silicone implant carved out from block.

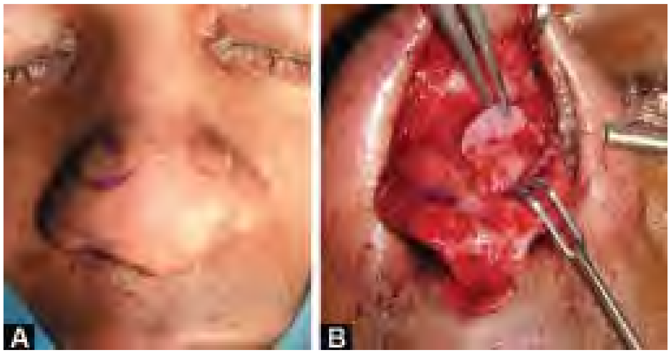
implants or custom made from silicone blocks (**Figure 23-15).** These have gone out of repute owing to excessive long-term rejection rate as well as loosening due to capsule formation. The currently available implant materials include proplast, and gortex which have been found to be safe for long-term use. The advantage is that the sculpturing of these materials is easy and less time consuming. But the main disadvantage are the relatively high cost, the difficulty in availability, and the general dislike for using an alloplast in a relatively thin subcutaneous area.

Tip Corrections

Correction of nasal tip abnormalities is one of the most demanding steps in any rhinoplasty procedure. The surgical steps that may need to be done in an individual case vary from decreasing the width, increasing or decreasing the projection and augmenting the supratip depression. All these corrections are achieved by either remodelling the alar cartilages by excision of part of the cartilage, augmentation using cartilage grafts and/or carefully placed sutures in the cartilage. All these are, as already stated, better carried out with a good exposure of the entire tip region that is accomplished through an open approach. A brief discussion of the tip plasty procedure is given below, with a short description of each surgical step and its effect on the nasal tip. The steps are summarized in the box.

Excision of the Alar Cartilage

One of the most common procedures done on the alar cartilage is cephalic trimming of the cartilage. The amount excised can vary, but it is essential to leave at least 1 cm width in the caudal rim **(Figures 23-16A and B)**. The trimming results in reducing tip bulbosity, helps to make a defined tip and also causes it of dropping of the tip defining point **(Figures 23-17A and B).**



Figures 23-16A and B: (A) Cephalic part of alar cartilage causing excess fullness marked, (B) Cephalic trimming of alar cartilage being performed.

Figures 23-17A and B: (A) Broad tips, (B) After cephalic trimming.

Dome Sutures

Using of sutures for defining the tip is a very effective procedure. There are various methods of dome sutures which bring about subtle changes in the tip architecture. These include intradomal, interdomal, intercrural **(Figure 23-18)** and septocrural sutures. Non-absorbable prolene

Figure 23-18: Intercrural sutures being placed.

sutures are commonly used but clear nylon or undyed polygalactone sutures have also been in use. Expertise in efficient use of domal sutures is achieved only by practice and in each case several trial and error placements may precede a correct placement.

Grafts

Usage of grafts in the tip area is usually in the form of onlay grafts to increase projection, spreader grafts to prevent collapse and struts between the medial crura to provide more tip support, projection and columellar integrity. Cartilage grafts from the concha or the nasal septum are more suitable, since they match the texture and shape. Supratip area depression is a common finding towards the end of other surgical steps and will require augmentation either with a septal cartilage or other homografts **(Figure 23-19)**.

Figure 23-19: Graft to correct supratip depression.

Summary of surgical steps and their effect on the tip	
Step	**Effect**
Cephalic trim	defines tip and reduces lateral flaring
Dome sutures	
Transdomal	reduces bulbosity and width
Interdomal	narrowing of tip
Intercrural	reduces medial crural flare and strengthen columella
septocolumellar	lifts up tip, corrects overhanging columella
Columellar strut	increases projection
Shield graft on the dome	increases projection

Alar Base Corrections

Alar base deformities which require correction include flaring, widening of the sill or both these. Correction of this is one of the most rewarding steps in nasal reshaping and can be achieved by excision of appropriately shaped wedge from the alar base and/or sill area. After excision of the wedge the skin is approximated with fine non-absorbable sutures and leaves back no visible scar provided the excision has not crossed into the upper lip skin, which has to be avoided while designing the wedge.

Nasal Suturing/Packing and Splintage

In the closed approach the septal transfixion incision is closed by a suture passing along all layers, which also helps to keep the septal cartilage in position. Only few sutures are necessary to approximate the edges of the septal incision. The vestibular incision is usually closed with absorbable sutures (catgut preferred by the author). In open approach the columellar incision is carefully sutured using fine non-absorbable material. Packing is done on either side of the septum which helps to keep the septum in position **(Figure 23-20)**. Packing may be unnecessary when isolated dorsal augmentation alone is carried out. An external splint is applied and this can be either a ready made one of Aluminium, or a Plaster of Paris splint. The pack is removed after 24-72 hours and the splint in 7-10 days.

Figure 23-20: Nasal packing in place.

Specific Clinical Situations and the Procedures

Esthetic Rhinoplasty

The common deformities which require correction include hump nose **(Figure 23-21)**, saddling of the dorsum

Figure 23-21: Hump nose—before and after correction.

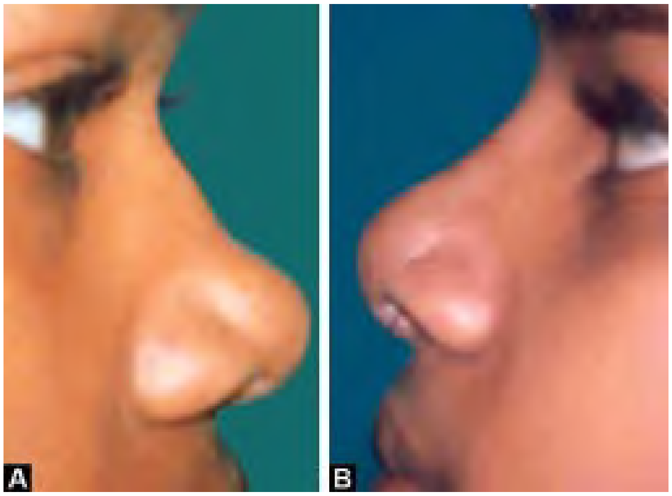
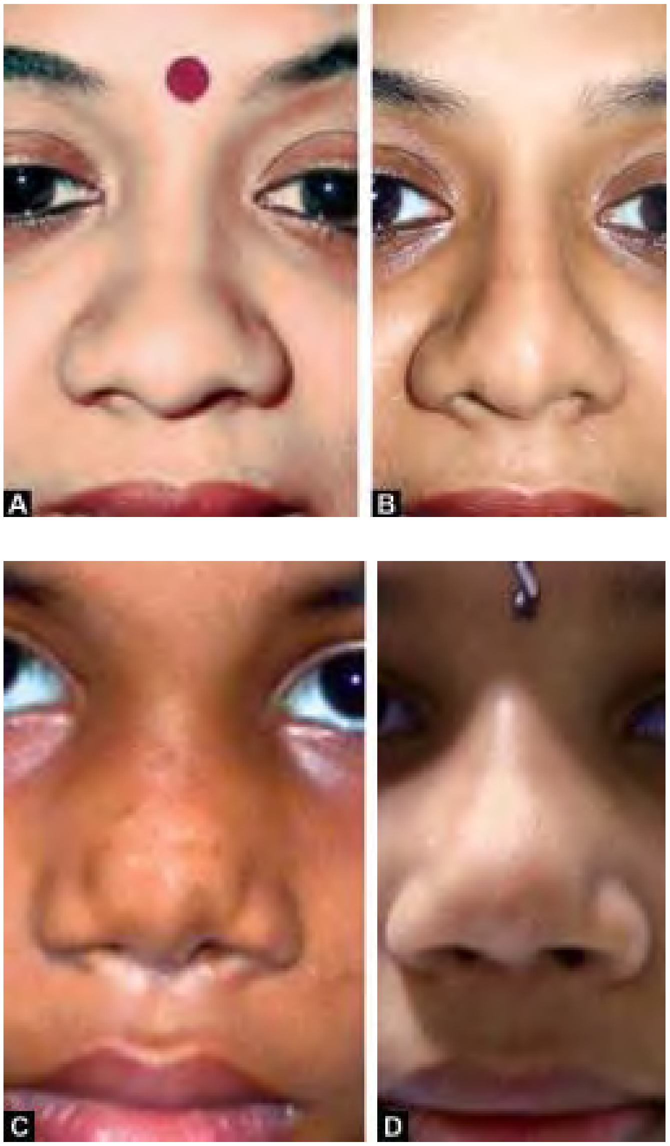


Figure 23-22: Saddle nose—before and after correction.

(Figure 23-22), broad and ill-defined dorsum **(Figures 23A to D)**, and dorsal lateralizations **(Figure 23-24)**. These are corrected by combinations of the surgical steps described previously in this chapter. Satisfactory results can be obtained by meticulous planning and execution. But still the expectations of a person seeking cosmetic rhinoplasty will be more than in the other types of cases. A result satisfactory to the surgeon may not be interpreted in the same way by the patient or to the equally demanding parents or relatives. In general, case selection needs to be more careful with these patients than with those who approach for functional septorhinoplasty or correction of cleft-related nasal deformities.

Functional Rhinoplasty

Usually these patients present themselves with nasal block to the ENT surgeon and are detected to have a gross



Figures 23-23A to D: Broad and ill defined dorsum—before and after correction.

Figure 23-24: Dorsal lateralization—before and after correction.

Figure 23-25: Septorhinoplasty—before and after correction.

Figure 23-26: Deficient alar area in an unilateral cleft lip nose.

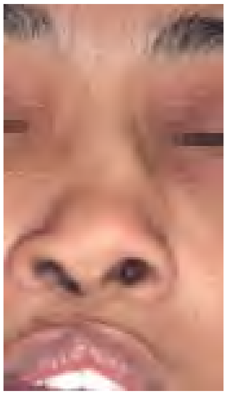


Figure 23-27: Lateralized dorsum.

Figure 23-28: Unilateral cleft lip nose—before and after correction.

deflection of the nasal septum. The deviated septum drags the dorsum along with it resulting in lateralization of the dorsum to various degree and shapes. Even though the primary request by the patient is relief from the nasal block, correction of the deformities is also often sought. A septrorhinoplasty satisfactorily addresses both the functional and sthetic problems **(Figure 23.25)**. As in this procedure the septum is freed from all sides; the septal deflections are corrected better than in simple septoplasty. A closed approach can be utilized without difficulty to perform a septorhinoplasty for functionally compromised nose.

Cleft Lip Nose Rhinoplasty

The cleft lip noses differ in various aspects from the usual 'standard' noses practice. The essential difference is in the anatomical abnormalities that accompany cleft lip associated deformities are much more severe and involve tissue deficiency as well as deformity. The cleft lip noses have an inherent tissue deficit which is more pronounced in the alar cartilages and the columella, necessitating more use of graft tissue. The deformities in unilateral and bilateral cleft lip noses are entirely different, again necessitating different surgical plans for correcting them. Because of this inherent tissue deficit it has to be clearly understood both by the operator and the patient that the ultimate results are not going to be the same as that is expected in 'standard' rhinoplasties. In unilateral cleft lip noses the key steps would be recreating the alar cartilage domes with the aid of sutures, augmenting the deficient alar cartilage **(Figure 23-26)**, doing a proper septorhinoplasty for the associated lateralization **(Figure 23-27),** and correcting the columellar deformity with strut grafts as well as v-y lengthening. The nose can be brought back to satisfactory shape, but some of the deformities, especially the alar hooding, defy most of efforts in the correction **(Figure 23-28)**. In the bilateral cleft lip nose deformity attention is more given to the lengthening of the columella. For this use of the upper lip tissue which in turn is corrected by an 'Abbe flap' may be necessary as preliminary step **(Figures 23-29 and 23-30)**. The columella is augmented by the use of a strut which helps to increase the tip projection, the dorsum is augmented with cartilage or bone grafts, the tip is remodeled and the nasal bones if necessary osteotomised in these cases.

Complications

Rhinoplasty procedures are generally not associated with serious complications other than the impact of a result unsatisfactory to the patient, surgeon or both. But complications do occur and these have been reported to be in the range of 6-8%. Following are few of the complications that could be met with.

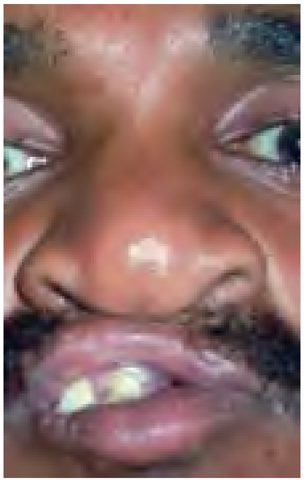


Figure 23-29: Bilateral cleft lip nose showing short columella.

Figure 23-30: Abbe flap to augment the upper lip tissue.

Tears of Mucoperichondrial Flaps

Careful raising the septal mucoperichondrial flap in the correct plane usually prevents this complication, but sometimes it is difficult to avoid this from occurring, especially in noses that have been traumatized or that have had previous operations. Unilateral tears usually heal without incident, but bilateral tears of the septal mucous membrane aligned on opposing surfaces may result in a septal perforation and accompanying symptoms. Suturing these bilateral tears at the time of surgery with an intervening cartilage graft can be done, but may be difficult. Opposing tears of the septum and lateral wall may lead to synechiae formation and nasal obstruction which, if symptomatic, may need subsequent release.

Nasal Block

Most of the patients complain of nasal block to a variable extent after surgery. Vasoconstrictor nasal drops help initially, but excessive use of this is to be discouraged as it may cause more crusting. The patients are forewarned that the nasal block may persist for 3-4 weeks and forceful removal of the crusts are avoided during this time. It is a very good practise to ask for the presence of pre-existing allergic or vasomotor rhinitis in these patients during the initial evaluation and to explain to them that the surgery is not intended to correct these problems.

Residual Deformities

In spite of the best efforts residual deformities occur after rhinoplasty procedures. Approximately 5-15% of the patients may need to have minor or major revision procedures. The possibility of this being needed is also to be explained to the patient, which can make the subsequent execution of these easier. Some of the deformities that can occur include:

Open roof deformity: This happens when the lateral segments fail to align with the septal dorsum following osteotomies, and unilateral deformity may make the nose appear asymmetric.This will need refracturing and centralization.

Step deformity on the side of the nose: Results from a lateral osteotomy performed too far medial to the nasofacial groove. With time it levels out to some extent, but it will be better to identify it in the primary surgery itself and make further osteotomy cuts to decrease the projection.

Polly beak deformity characterized by absence of the supratip dip: The cause usually lies in under correction of the cartilaginous dorsum and the superior septal angle region whose correction may require reduction of these as well as providing a columellar strut.

To summarize, rhinoplasty is a formidable surgical procedure, not because of the enormity of the surgery, but because of its subtlety as well as the interaction of various factors determining the end result. Each case is a challenge and needs surgical dexterity, knowledge and application of anatomical principles, and an esthetic sense balanced with clinical wisdom. But it is a rewarding procedure in terms of the satisfaction derived by the patient as well as the surgeon when the result matches expectation.

Suggested reading

1. McCollough EG, Mangat D. Systematic approach to correction of the nasal tip in rhinoplasty. Arch Otolaryngol 1981;107(1): 12-16.
2. Tebbetts JB. Shaping and positioning the nasal tip without structural disruption: a new, systematic approach. Plast Reconstr Surg 1994;94(1):61-77.

Chapter

24

Varghese Mani

Introduction

Inflammation and the related signs and symptoms are usual sequelae to any injury, surgical or otherwise. But when these exceed the expected limits and untoward mishaps occur, we call them complications. These can be attributed to umpteen number of reasons ranging from iatrogenic to intrinsic. Complications can range from very minor to very severe. The dictum goes "prevention is better than cure". Proper preoperative evaluation of the patient, implementation of remedial and preventive measures and taking utmost care during and after surgery are certain imperatives the surgical team should practice diligently. In short, most, if not all, of the complications can be prevented. Inadvertent mishaps do occur, and the surgeon and his team should be aware of the common as well as rare complications and their management.

Leaving aside the general complications associated with major surgical procedures, the complications specific to orthognathic surgery only are dealt here.

These complications can be broadly grouped under the following sections. However, most of these complications are interconnected, interdependent and mutually contributory.

1. Vessels
2. Infections
3. Nerves
4. Soft tissue, Morphologic changes
5. Occlusion
6. Wrong splits
7. Joints
8. Eyes.

A thorough knowledge of the anatomy, morphology and architecture of the face (a three dimensional understanding of the facial skeleton, the relationship of the nerves, vessels and muscles) is essential for the surgeon before venturing into the practice of orthognathic surgery. It has to be understood that most of the complications can be prevented if proper care is taken. Anatomical and morphological changes from the normal—seen in deformities, syndromes and diseases—need special investigations and care.

Vascular Complications

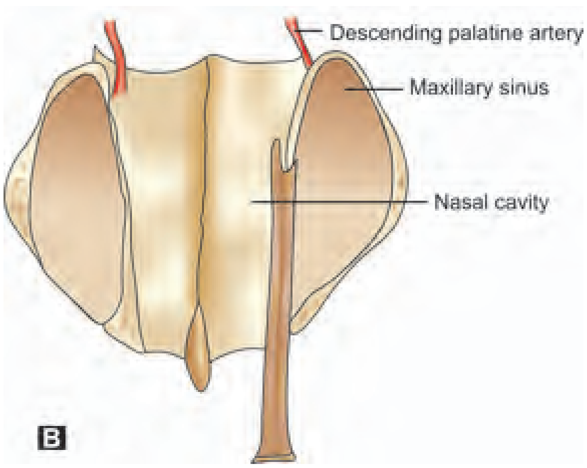
Bleeding

Bleeding could be primary or secondary. Primary bleeding is usually due to injury to the vessels or vascular plexus during the procedure.

The following are the important vessels that could get involved, causing bleeding.

1. Greater palatine artery
2. Internal maxillary artery
3. Posterior superior alveolar artery
4. Inferior alveolar artery
5. Facial artery
6. Pterygoid venous plexus.

Of all these, the most common vessel which cause trouble is the greater palatine artery. This is a branch of the internal maxillary artery which descends through the medial aspect of the perpendicular plate of the palatine bone and comes out through the greater palatine foramen and supplies the palate. While osteotomizing the lateral wall of the nasal cavity, if the thick perpendicular plate is cut deep, chance of injury to the greater palatine vessel is high. This could produce profuse bleeding. So care should be taken while osteotomizing the lateral wall of the nasal cavity. Osteotomy should be limited to the anterior part and is intended to make the plate amenable to down fracturing of the maxilla **(Figures 24-1A and B)**. However, if there is an inadvertent injury to the greater



Figures 24-1A and B: Greater palatine artery is the most vulnerable for bleeding in maxillary osteotomy. This artery runs through the perpendicular plate of the palatine bone. Care should be taken not to injure the vessel while sectioning the lateral wall of the nasal cavity.

palatine vessel a gauze pressure pack in the area could control the bleeding. Once down fracture is done, the vessels can be cauterized, if required. Since the vessel runs in the bony canal, cauterizing the vessel may not be successful. In such a situation bone wax can be used to plug the canal and control the bleeding. Turvey and Fonseca are of the opinion that the vessels at greater risk of injury during maxillary surgery are the internal maxillary artery, the posterior superior alveolar artery and the greater palatine artery.[32]

Though the greater palatine vessel poses the greatest risk of bleeding during sectioning of the lateral wall of the nasal cavity, some authors advocate complete sectioning for fear of inadvertent fracture extension to the orbit. This could cause visual disturbances.

In cleft lip and palate patients who have already undergone palatal surgery, the blood supply to the maxilla is compromised. It is always advisable to take care not to injure the greater palatine vessels.

Life threatening massive hemorrhage has been reported by Newhouse RF, et al after a Le Fort I osteotomy. This was subsequent to injury to the internal carotid artery and the internal jugular vein.[23]

During the mobilization of the maxilla excessive traction of the vessel could weaken the vessel wall and make it susceptible to secondary hemorrhage. In such instances it is better to intentionally ligate the vessel cauterize it, and divide it. Use of oxidized cellulose is excellent to prevent bleeding. Management of secondary hemorrhage often requires re-exploration and cauterization.

When hypotensive anesthesia is used, even if the vessels are injured, bleeding may not be troublesome during the surgery. But, when blood pressure becomes normal, bleeding may ensue. So before closure the blood pressure may be brought to normal, and hemostasis achieved.

Bleeding from the Internal Maxillary Artery is not very common. The vessel to it runs behind the maxilla and injury is rare. However it may get injured from the splintering of the posterior wall of the maxilla and the pterygoid plates after pterygomaxillary disjunction. Rarely the fracture could extend to the base of the skull. This can happen if the chisels are manipulated vigorously or by directing the chisels against the plates.[18] Care should be taken to down fracture the maxilla with minimum effort. Moreover, while osteotomizing the pterygomaxillary junction, directing the pterygoid chisel downward is the accepted technique. The mean distance from the pterygomaxillary junction to the internal maxillary artery in normal cases is 25 mm. So the chance of injury is minimal. However facial anomalies can alter, normal pattern rendering the internal maxillary artery more vulnerable to injury.[32]

In case of bleeding, control can be achieved by packing the maxillary sinus and the pterygoid regions through the subperiosteal tunnel created on the lateral aspect of the maxilla. If this does not control the bleeding, ligation of the external carotid artery is resorted to.

The posterior superior alveolar artery is a branch of the internal maxillary artery, which could occasionally bleed. Serious bleeding is not usually observed.

The Inferior alveolar artery is a branch of the mandibular artery. It enters the mandibular foramen on the medial aspect of the ramus. The foramen is in the same plane as the deepest part of the concavity at the anterior margin of the ramus. The foramen is midway between the posterior and anterior borders of the ramus. While doing sagittal split osteotomy the medial part of the ramus is sub-periosteally dissected. The dissection should be done above the mandibular foramen to prevent injury to the neurovascular bundle. While splitting the ramus the chisel should not be driven more than the mandibular foramen. These precautions can avoid injury to the vessels.

If an injury occurs pressure packing of the area can control the bleeding. Packing oxidized cellulose may also be required to control the bleeding and prevent secondary hemorrhage.

Injury to the facial artery is a very rare occurrence. In extra oral procedures one may rarely encounter facial artery. While cutting the lower border of the mandible the periosteum is protected with the cup of the channel retractor. However unexpected injury of the soft tissue and the facial artery may occur, the artery is approached extra-orally and ligated. Injury to the nasal mucosa occasionally causes excessive bleeding. This can be easily controlled by packing the nasal cavity. If not controlled, endoscopic examination can pin-point the site of bleeding, and cauterization may be done. Tear of the nasal mucosa can be prevented by elevating the nasal mucosa from the floor and the lateral wall of the nasal cavity and protecting it by Howarth periosteal elevator, while osteotomizing. Since the mucosa is friable the chances of tear are relatively high. If an injury or tear occurs the area is repaired by sutures to prevent subsequent complications like bleeding or infection **(Figure 24-2)**.

Figure 24-2: Elevating the floor of the nasal cavity and protecting it with a periosteal elevator prior to the osteotomy can prevent injury to nasal mucosa and subsequent bleeding.

Delayed hemorrhage can occur after 24 hours or even after one week. The most common source of delayed hemorrhage is the greater palatine artery. The others are the pterygoid venous plexus and the internal maxillary artery. If the bleeding occurs routine measures may be tried like pressure packs in the pterygomaxillary junction, nasal cavity, etc. depending on the site of bleeding. If greater palatine vessels are involved cauterization may be tried by endoscope techniques. Otherwise the area is re-explored and the bleeding is controlled.

Though it is better to preserve the greater palatine vessels, if an injury occurs the vessels are to be cauterized.

In severe bleeding angiographic embolization, external carotid artery ligation, etc. may have to be considered.

Thrombosis

Thrombosis of the internal carotid artery is a rare complication which can occur if there is extended period of extension of the head and neck.[5] When the head is over extended the internal carotid artery may stretch and get pressed against the cervical vertibrae and may produce thrombosis.

Loss of Vascularity

Loss of vascularity is a very serious complication, which has to be prevented as there is no definite treatment. The most important preventive measure is to ensure proper vascular pedicle.

Greater palatine vessels are supposed to be the most important in vascular supply to the maxilla. Though this is true, vascular studies have conclusively demonstrated a network of anastomosis of branches of external carotid artery at the distal ends. So sacrificing the greater palatine artery in maxillary osteotomy is not a hazard **(Figure 24-3).**

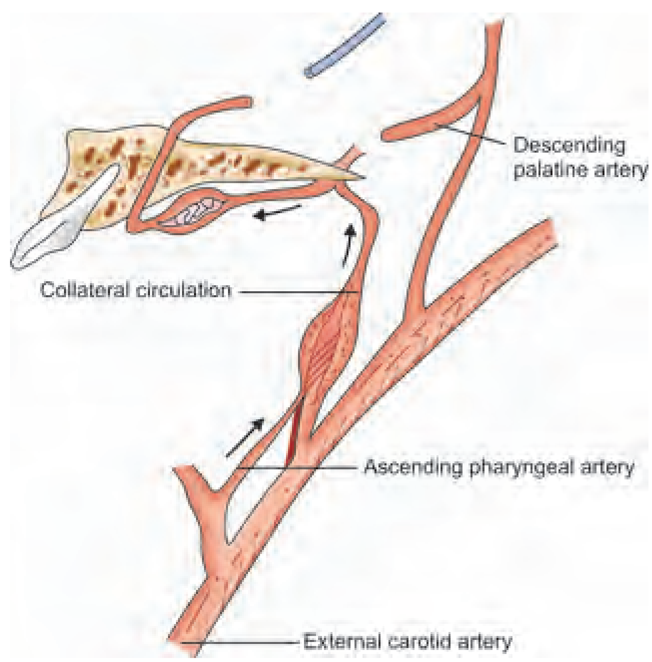


Figure 24-3: Even if the descending palatine artery is cut the ascending palatine and ascending pharyngeal arteries have got anastomosis to the vessels of the palate.

However, in operated cleft palate patients blood supply is already compromised and special care is to be taken to maintain better vascular supply by keeping more pedicles and by not dividing the major vessels. While doing Anterior Maxillary Osteotomy the palatal mucosa is tunnelled subperiosteally. This will prevent tear of the tissue on the palatal side. A tear on the palatal mucoperiosteum could be deleterious to the blood supply, as buccal blood supply is already compromised by the buccal sulcus incision.

Loss of vascularity in segmental procedures can be attributed to various causes like poor stabilization, poor follow up and multiple segmentalizations.[28] In segmental osteotomy, it is always better to have a minimum of three teeth in each segment. Subperiosteal stripping should be minimal. Individual tooth osteotomy is a high risk procedure as this could cause vascular compromise. Individual tooth movement should be left to orthodontics as this speciality can design and execute fine movements of the tooth.

Continuous cold saline irrigation is mandatory during bone cutting. High speed bone cutting with bur or saw can produce heat. Heat production can cause necrosis of the bone which could adversely affect healing, cause infection and may affect vascular supply.

Lack of irrigation during drilling a screw hole, almost for sure, results in loosening of the screw during the healing phase.

Subtle complications like flattening of the papilla, loss of gingiva, periodontal defects at osteotomy sites and exposure of bone are often the result of vascular compromise.[29]

Aseptic Necrosis

Aseptic necrosis and resorption of the bone are sometimes observed if subperiosteal stripping has rendered the bone avascular. This rare complication is occasionally seen in the proximal segment of the mandible after sagittal split osteotomy. This has been attributed to excessive stripping of the segments. The loss of bone may lead to disfigurement.[2] Periosteal stripping of the proximal segment often becomes necessary for proper push back of the mandible. The stripping of the medial pterygoid muscle subperiosteally helps in passive positioning of the osteotomised segment in the preplanned position. Excessive stripping often produces excessive edema and may compromise blood supply.[10,11] Rigid fixation can prevent avascular necrosis to some degree. Avascular necrosis does not often happen in the maxilla. However tearing of the flap or kinking of pedicles can compromise the blood supply. Loss of entire maxilla or segments have been reported.[28] The most common cause is interruption of blood supply.[37] Rigid fixation of segments allows early revascularization. This will minimize avascular necrosis.

In advancement genioplasty if the advanced segment is devoid of soft tissue pedicle, resorption of the segment occurs in varying degrees. Occasionally complete loss of the segment occurs.[8, 21] Leaving the buccal and lingual pedicles minimizes resorption and gives a better chin contour.[3]

Nonunion and Delayed Union

This is often a complication which occurs if the bone contact is not proper. Other reasons for nonunion or delayed union are lack of vascularity, excessive mobility at the contact point and infection. These complications can be prevented to a great degree by irrigating while cutting, ensuring proper bony contact, filling the gaps with bone grafts and doing rigid fixation.

Dental and Periodontal Injuries

Blood supply to the tooth should not be jeopardized while doing an osteotomy. This can be achieved by making the bone cuts 5 mm apically away from tooth apices. It is also advisable to have a 3 mm gap between teeth if an interdental osteotomy is done.[7] The canine is often at risk of nonvitality, owing to its length and position.[28] If teeth are not injured directly during osteotomies they usually respond to pulp testing within six months **(Figure 24-4)**.[33]

Injury to the periodontium is avoided as far as possible. Periodontal infection subsequent to periodontal injury is the common cause for tooth mobility and loss. Schultes

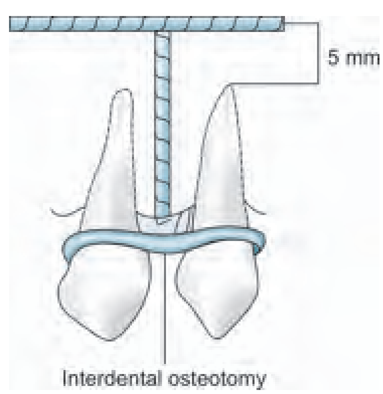


Figure 24-4: 5 mm is a safe distance that is maintained between the osteotomy cut and the tip of the root.

et al reported a high incidence of dental and periodontal trauma in association with vertical osteotomies of the maxilla.[27a] However other reports do not agree with the opinions of Schultes et al. Multisegmentation of the maxilla through vertical osteotomies of the alveolar ridge in combination with Le Fort I osteotomy is a safe and dependable intervention vis-a-vis morbidity of the teeth and their surrounding tissue.[17a] A cut tooth should be root canal treated, and periodontal infection treated by proper periodontal therapy.

Copious irrigation can prevent thermal necrosis of the bone. Fine bone adjustments are done by trimming the bone with large round burs.

The most important measure to prevent infection is to do osteotomy in a healthy mouth only. Hence dental and periodontal infections should be taken care of, much earlier to surgery.

Infections

Oronasal/Oroantral Fistula and Sinus Infections

Though rare, fistula formation is a troublesome complication. Injury to the palatal mucosa is one of the primary causes for the fistula. If any injury of the palatal mucosa occurs during the surgery, primary closure should be done. Injury to the nasal mucosa, if any, should also be closed. During surgery care should be taken not to remove excessive bone at the osteotomy site. Proper bone apposition is important to ensure proper union. Oroantral or oronasal fistula occurs due to improper handling of the tissues and faulty incision design which may compromise blood supply. Postoperative infection, lack of adequate drainage and open fistulae are the major causes for sinus complications. Large clots and debris retained in the maxillary sinus, are other causes of sinus infection.

Measures like frequent cleaning, antiseptic mouth washes and antibiotic therapy are to be instituted to prevent and control infection.

Appliances to seal the fistula can be used. But pressure on the surrounding tissues of the fistula should be avoided. If the fistula persists, surgical closure may be resorted to. But surgery is done only after satisfactory healing has occurred, since the friable tissues are liable to break down. Three to six months of healing time may be given before secondary closure of the fistula.

Nerve Injuries

The common nerves that get encountered in orthognathic surgery are the sensory ones and that too the terminal branches. Hence nerve injury is not a significant complication in orthognathic surgery.

Common nerves that may get injured are:
1. Mandibular nerve and its branch, the mental nerve
2. Greater palatine nerve
3. Infraorbital nerve.

Branches of the facial, a motor nerve, that could get involved are the marginal mandibular, the frontal and the zygomatic. Injury to the greater palatine neurovascular bundle often may occur in Le Fort I osteotomy. This could cause palatal numbness.

The inferior alveolar nerve is at great risk during sagittal split osteotomy. Injury could occur at any of the following stages of the procedure.

a. During medial dissection of the ascending ramus
b. While cutting medially above the mandibular foramen
c. Cutting the buccal cortex on the horizontal ramus
d. Osteotomising the cuts using chisel
e. While splitting the mandible.

However, if the cuts are restricted to the cortex and if the chisels are driven not too deep, injury to the inferior neurovascular bundle can be prevented. Injury to the nerve may result in prolonged numbness of the lower lip and chin. Though this may gradually subside, it could result in bizarre sensations on the lip and chin. After sagittal split osteotomy a short period of anesthesia /paresthesia/ hyperesthesia may occur even if the nerve is not sectioned. This is due to minor trauma during the manipulation. A sectioned nerve is ideally anatomized using microsurgical technique. The cut end of the axon grows through the sheath and the sensation is often regained in time.Turvey in 1985 reported a 3.5% incidence of transection of the inferior alveolar nerve. It was anterior to or in the third molar region in all the cases.[31] Long lasting neurosensory disturbance was often underestimated by the surgeons as compared to the patient's subjective symptoms. Long lasting NSD was reported in 7.5% (questionnaire) and 3.8% (record) after intraoral vertical ramus osteotomy, and 11.6% (questionnaire) and 8.1% (record) after Sagittal split osteotomy.[1]

The mandible is the thickest, and the inferior alveolar nerve is farthest from the lateral cortex, at the 1st and 2nd molar region. Hence this is the ideal location to do a lateral cut.[26]

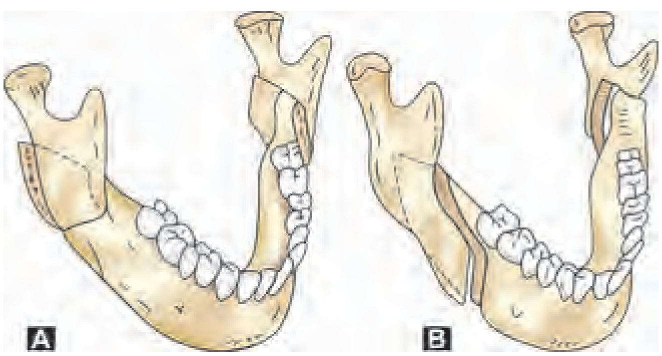
Mental nerve is at risk while doing genioplasty. It is more at risk while doing an extended genioplasty. So, utmost care should be taken to protect the nerve from injury while doing osteotomy.

Facial Nerve

Incision on the temporal region could cause injury to the frontal branch and the zygomatic branch of the facial nerve. This can be prevented by deepening the incision to the temporal fascia and continuing the dissection in this plane anteriorly.

Marginal mandibular nerve is often at risk while doing submandibular dissection. The nerve runs in the submandibular region below the platysma. The incision is always deepened and the dissection done upwards. The platysma along with the nerve is included in the skin flap to prevent injury to the nerve. Though injury to the facial nerve is very rare with intraoral approach, this has been reported in sagittal split and subcondylar osteotomies.[2,8,13,20] Facial nerve involvement may occur during mandibular set back. However, injury is reported in advancements as well.[17]

In 'Hunsuck' modification of sagittal split osteotomy the cut is not taken to the posterior border of vertical ramus. So during 'set back' the distal segment does not jut out of the posterior border. Most of the facial nerve injuries have occurred when 'Hunsuck' modification was not used **(Figures 24-5A and B)**.[15]



Figures 24-5A and B: In Hunsuck modification the cut is not extended to the posterior border. So the complications are minimal. A: Obwegeser's original technique of sagittal split osteotomy. B: Modified osteotomy by Hunsuck.

Care should be taken when a retractor is placed behind the ramus. This could cause either pressure or injury to the facial nerve.

The depth of injury can be assessed by electroneurography and electromyography. Evoked electromyography is a test where the muscle twitch is recorded. If the response is greater than 25% at 5 days the injury is mild and the prognosis is good.

Infraorbital nerve could get involved in high Le Fort I, Le Fort II and Le Fort III osteotomies. The orbital floor is osteotomized using chisel and care is taken not to injure the nerve. Bur cut may be avoided in this region.

Soft Tissue/Morphologic Changes

Nasal Complex

Nose is a prominent structure of the face and consideration of the nose is of utmost importance in midfacial osteotomies. Surgery could cause many changes in the size, shape and function of the nose.

Septum

In Le Fort I superior repositioning of the maxilla, the vertical dimension of the nasal septum has to be reduced, lest nasal deviation may occur. Reduction of the nasal septum is usually done from the inferior margin **(Figure 24-6).**

Figure 24-6: The nasal septum is dissected, exposed and corrected or reduced.

Already existing septal deviation can also be corrected after Le Fort I osteotomy by exposing the septum from below. Septum can be resected and/or scored according to the requirement. The septum is repositioned passively.[33] If septal deviation is recognized immediately after surgery, correction is done by either manipulation or re-surgery. If immediate re-surgery is not feasible, septoplasty may be done at a later date.

Alar Base

Superior repositioning of the maxilla necessitates resection of bone from the lateral margins of the pyriform aperture. This will raise the anterior sill upwards which will result in flaring of the alar base. This could give an unesthetic appearance to the face in general and the nose in particular. Other changes that can occur are increased prominence of the alar groove, up turning of the nasal tip, flattening and thinning of the upper lip and down turning of the labial commissure.[27] Cinch suturing of the alar base by using a non-absorbable suture can prevent or reduce the widening of the alar base **(Figures 24-7A and B)**.[6]

Figures 24-7A and B: Cinch suturing of the alar base prevents alar base flaring. A: Sutures placed at the alar base. B: Suture pulled to assess the narrowing of the alar base.

Deepening the sill of the pyriform aperture to compensate for the osteotomy at the lateral margin may also be done. This can be done by contouring the sill and floor of the pyriform aperture using round trimming bur **(Figures 24-8A and B)**.

Nasal Dorsum

As the maxilla is pushed upward the columella also is pushed up. This may cause upward movement of the nasal tip resulting in supratip break. The cinch suturing could

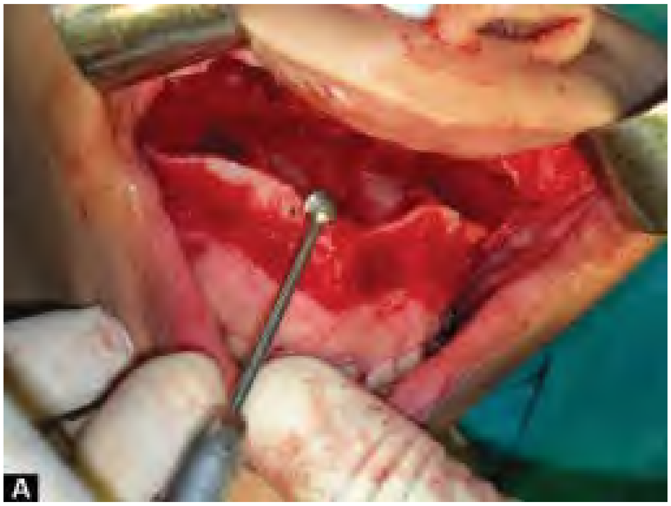


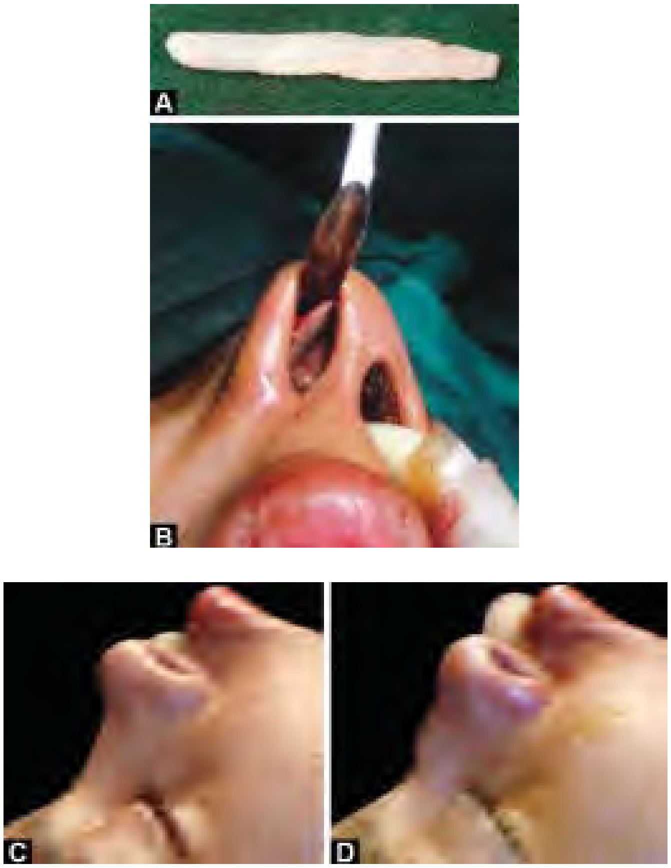
Figure 24-8: Deepening and contouring the sill of the pyriform aperture (pyriform plasty) helps in preventing alar flare and upturning of the nasal tip.

also contribute to the supratip break. Contouring the sill, could control the upturning of the nasal tip.

A dorsal tunnel above the alar cartilage can be made intranasally and a sliver of cartilage (formed from the resected inferior part of the septum) can be placed in the tunnel. This could prevent the supratip break and correct saddling satisfactorily **(Figures 24-9A to D)**.

Nasal Valve

Several studies have been conducted about the effect of superior repositioning of the maxilla on the nasal valve. Some studies have shown reduction in the nasal airway while others have shown increase in the airway.[36] The nasal valve is formed by the floor of the nose, nasal septum, the lateral aspect of the nose and the caudal end of the upper lateral nasal cartilage. The increase in the width of alar base causes widening of the nasal valve and reduces the nasal airway



Figures 24-9A to D: The base of the nasal septum is thicker than the vertical part and the same can be used as a dorsal graft for the nose (A). Through an intranasal, supracartilaginous incision (B) the graft is placed on the dorsum of the nose. Pre- (C) and post- (D) operative photographs after dorsal cartilage graft.

resistance.[12,36] However the change in the airway and flow is not a major issue in midfacial osteotomy.

Bulging of the Zygomatic Region

The vertical dimension of the face is reduced in superior repositioning of the maxilla. When the subperiosteal dissection is done on the maxilla, the facial muscles contract, pulling the periosteum along. This could create a bulge in the subzygomatic region which is unesthetic. Closing the buccal sulcus incision in layers, in the order of periosteum, muscle and mucosa can prevent the unesthetic bulge.

Lip Length

Incision in the labial sulcus often reduces the length of the lip by around 1 mm due to scar contraction. This can be prevented by V-Y closure of the incision. This could cause a mild pouting of the lip which will settle down gradually **(Figure 24-10)**.

Figure 24-10: V-Y closure of the buccal sulcus incision can prevent the contraction of the lip during the healing phase.

Occlusal Disturbances and Relapse

Occlusal discrepancy is a common problem with most of the orthognathic surgical procedures. Preplanned and prefabricated splints are used to maintain proper occlusion.

In Le Fort I osteotomy IMF may drag the mandible forward. This has to be prevented by ensuring the position of the condyle in the glenoid fossa. A backward push on the chin with an upward pressure on the angle of the ramus exerted simultaneously, can ensure the position of the condyle **(Figure 24-11)**.

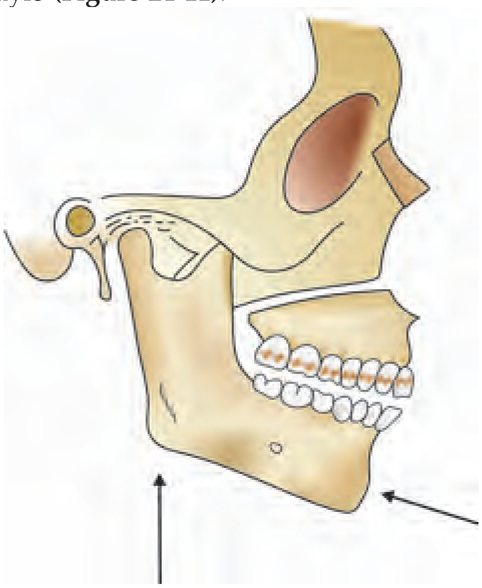


Figure 24-11: The position of the condyle in the glenoid fossa is ensured and intermaxillary fixation is done before stabilizing the maxilla.

It may be sometimes difficult to superiorly reposition the maxilla in the posterior region to the required level. This could sometimes cause premature occlusion of the posteriors and result in anterior open bite. A mid-palatine split will help in manipulating the two halves of the

Figure 24-12: Segmentalizing the maxilla helps in aligning the occlusion.

maxilla independently and align them into proper occlusion **(Figure 24-12)**.

Relapse is one of the reasons for late occlusal disturbance. Factors like tongue thrust, breathing habit, position of the condyle, fixation technique, rotation due to muscular pulls, etc. are supposed to be the reasons for postoperative relapse. Rigid fixation helps prevent/ control relapse. Relapse rate is high in advancement osteotomies. Advancement of less than 6 to 7 mm can be made stable by rigid fixations.[35] Severe occlusal discrepancies may require re-surgery, and minor ones can be managed by aggressive orthodontic treatment. Postoperatively, anterior box elastics may be given for 2 to 6 weeks when open bite is noted postoperatively, in subsigmoid vertical osteotomy.[14] Mobarak compared the skeletal stability of postoperative changes in low angle and high angle Cl II patients following mandibular advancement. High angle had more horizontal skeletal relapse and cause of relapse was condylar movement in a superior direction.[22] Proffit opined that stability is greatest where the soft tissues are relaxed after surgery and least when they are stretched.[25]

Osteotomising pterygoid plates or reducing the tuberosity can push the maxilla backward and help to maneuver the posterior part of the maxilla to better occlusion. Minor occlusal disturbances are later corrected by post surgical orthodontic treatment.

Wrong Splits

Wrong splits in sagittal split osteotomy are often troublesome. Of this, the important one is, when the buccal segment does not include the condyle but only the coronoid process **(Figure 24-13)**. In such cases an extra oral approach may be required and subsigmoid vertical osteotomy may become necessary. The incidence of proximal segment fracture is often more than distal segment fracture.[20]

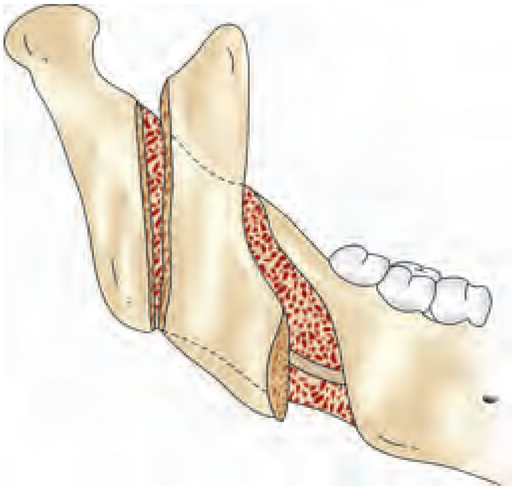


Figure 24-13: Splitting of the condyle and the buccal plate without the inclusion of the condyle is the worst split.

Other wrong splits are relatively minor problems. The most common wrong split that occurs is the splintering of the buccal plate. This can be tackled by using extra plates/wires or long plates to rigidly fix the segment **(Figures 24-14 and 24-15A to C).**

There is a possibility of lingual plate fracture while using chisel on the lingual side of the ramus. The segment is stabilized using wires. Chances of lingual segment fracture are more if the last molar tooth is impacted (Impacted tooth renders the lingual segment more weak).

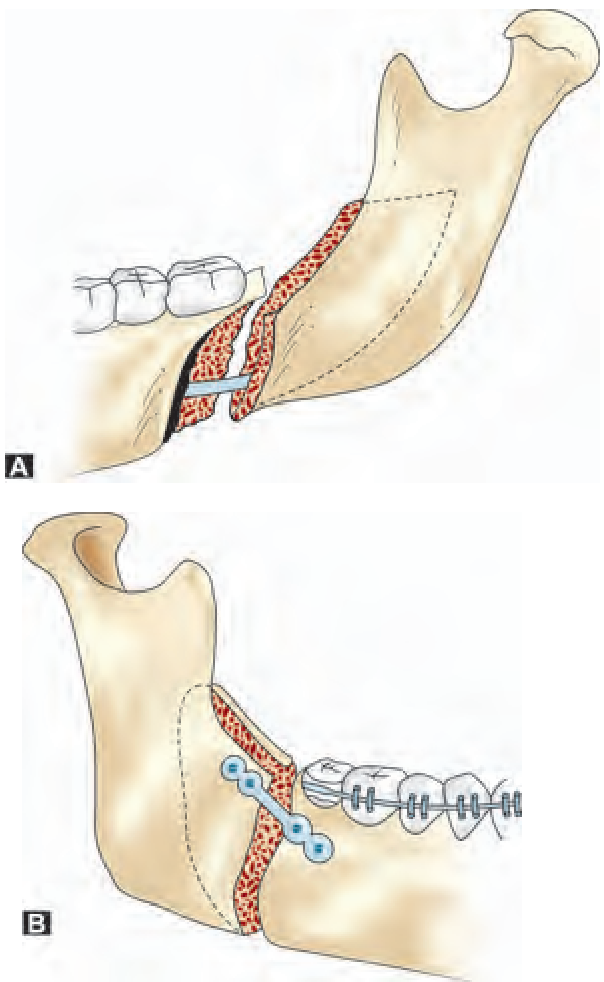
Horizontal fracture of the ramus and angle fracture are rare occurrences. Impacted third molar is a cause for angle fracture. Removal of the impacted third molar is to be done at least 3 to 6 months earlier. If not, it is better to remove the third molar after the split.

Temporomandibular Joint Problems

Many patients presenting themselves for orthognathic surgery may have temporomandibular joint problems. In many of the cases these problems may improve after orthognathic surgery. However orthognathic surgery should not be offered as a treatment for TMJ problems.[16,19,34]

Some patients may experience gradual increase in TMJ symptoms after surgery. They are treated conservatively.

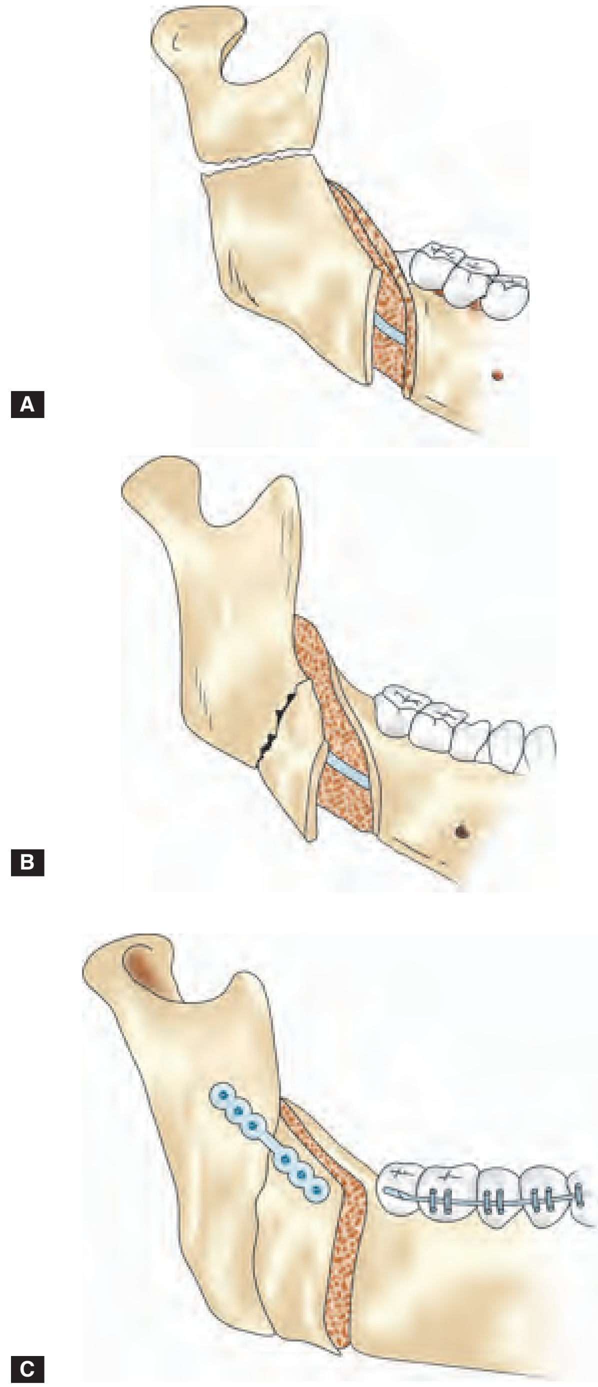
Studies have failed to show significant difference in TMJ problems in relation to rigid fixation or wire osteosynthesis.[24, 30] A study conducted by WB Borstlap, et al in 2005 has shown that in approximately 21% of the patients signs and symptoms of TMJ dysfunction had disappeared after stabilization of sagittal split set back osteotomies with mini plates. In 10% the TMJ dysfunction symptoms developed postoperatively. No condylar remodeling or



Figures 24-14A and B: Fracture of the ramus requires plating and postponement of the surgery. (A) Fractured ramus. (B) Fixation of the fracture.

resorption was seen in this group of patients. They have also observed that 8% of patients showed postoperative condylar resorption. Patients of relatively low age (<14 years) are at risk of condylar alterations or resorption. The occurrence of pain and TMJ sounds in the first few months postoperatively are highly indicative of condylar changes to occur in the next few months.[4] Paulus and Steinhause in their study found that there is no difference in post operative TMJ symptoms in either wire or plate osteosynthesis.[24] They also noted that the symptoms have notably decreased. Martis also opined the same.[20]

Condylar resorption postoperatively is noted in certain cases. Of this majority of cases occur after wire osteosynthesis, though resorption is observed even after rigid fixation. Postoperative relapse in mandibular osteotomy could be due to the position of the condyle or due to movement at the osteotomy site. The latter can be controlled by rigid fixation.



Figures 24-15A to C: Different types of wrong splits.

Ocular Complications

Ocular dysmotility is a rare complication occurring following Le Fort I osteotomy. Newlands, et al feel that etiology in these cases is inadvertent fractures extending towards the base of the skull and posterior aspect of the orbit.[23a] Associated fractures can also involve the internal carotid artery, resulting in carotid cavernous sinus fistula formation and the optic canal resulting in permanent blindness.

Complications may occur in spite of utmost care by the surgical team. The team should be conscious about these contingencies and should be ready to manage them. However it has to be remembered that most of the complications can be prevented.

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Chapter

25

Varghese Mani

Introduction

Ankylosis of the TMJ is a devastating deformity, which predominantly afflicts children, subsequent to trauma or infection. This lesion affects both function and esthetics. The patient will not be able to open the mouth. And due to asymmetrical growth of the jaw, deformity of the face occurs as well.

Anatomy of TMJ

Temporomandibular joint is formed by two bones, the temporal and the mandibular, as the name denotes.

TMJ is a diarthroidal joint with discontinuous articulation directed and controlled by the muscles of mastication and ligaments. Being a synovial joint it has got a fibrous connective tissue capsule. The joint is lined on its inner surface by a synovial membrane, which secretes synovial fluid.

Articular disc divides the joint into upper and lower compartments. The lower compartment permits hinge motion or rotation (ginglymoid) and the upper compartment permits sliding or translating movement (arthroidal) The articular surface of both the bones is covered by articular fibrocartilage which can regenerate and remodel under functional stress **(Figure 25-1)**.

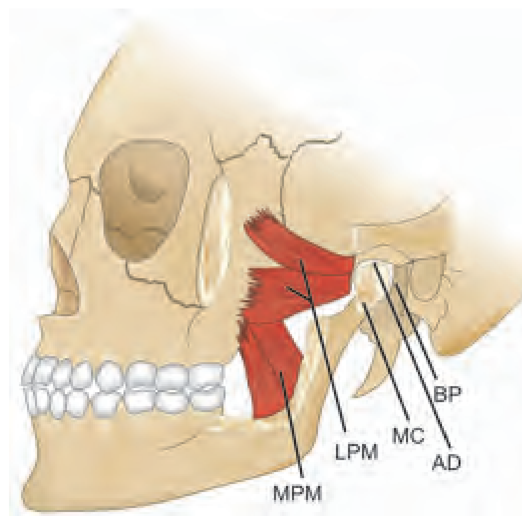


Figure 25-1: Anatomy of the temporomandibular joint. MPM: Medial pterygoid muscle, LPM: Lateral pterygoid muscle. MC: Mandibular condyle. AD: Articular disc. BP. Bilaminar posterior ligament.

True Ankylosis

Severe trismus is observed in cases of intra-articular fibrosis or bony fusion, which is termed true ankylosis.

False Ankylosis

The hypomobility of the mandible or trismus can be due to various reasons. Trismus can be due to extra articular reasons also. This is called false ankylosis. The common reasons are spasm, fibrosis of the masticatory muscles, mechanical obstruction (e.g. depressed fracture zygoma), pathologic conditions like submucus fibrosis, myositis ossificans, tetanus, etc.

Etiology

The two common causes for true ankylosis are: (1) trauma and (2) infection. In places where medical facilities are not satisfactory, the prevalent reason for ankylosis is infection. Infection to the TMJ can be a local spread from mastoiditis, otitis media, etc. or from blood borne infections. Studies show that in countries, where medical facilities are good, infection is not a major factor for ankylosis.[17]

Trauma

Obstetric trauma to the TMJ during 'forceps delivery' was considered one of the major causes of ankylosis of the TMJ in young children. Since forceps delivery is out of vogue, trauma due to forceps is no more a common case of ankylosis of the TMJ. A blow to the chin in children can cause intracapsular fracture or hematoma. The hematoma may get organized and ossified. The high potency for osteogenic activity in children could be the reason for high incidence of ankylosis in children.

Displaced condylar fracture (often to the medial side), may cause mechanical obstruction to the movement of the TMJ. If the condyle gets reunited to the rest of the mandible in this position, trismus may result.

Infection

Local infections like otitis, mastoiditis, etc. can spread to the joint and cause ankylosis.

Other causes are Suppurative arthritis, Rheumatoid arthritis, Still's disease, Ankylosing spondylitis, Marie-Strumpell disease, Hematologic infections, etc.[23]

Rao P Bhasker and Rao Sreepathy, BH (Manipal, India) in 1989 analyzed 15 cases of unilateral ankylosis of TMJ and reported that in 13 cases the etiologic factor was infection, and out of this, 8 were due to blood borne infections. Most of the patients were from rural areas where medical facilities were limited.[17]

Surgery

Surgical intervention of the TMJ for joint pain and other dysfunctions has become an accepted treatment procedure. The invasion of the TMJ is occasionally associated with complications like ankylosis due to postoperative infection, hematoma resulting in fibrosis and ossification. This occurs if the treatment is not followed by proper physiotherapy and mobilization of the joint. There have been even reports of fibrous ankylosis following sagittal-split osteotomy.[11] However, this should be considered a rare complication.

Clinical Features

Clinical features of TMJ ankylosis are so typical that often the diagnosis can be made very easily. The two important features are trismus and facial deformity.

The condyle is supposed to be the growth site for the mandible. However, the functional matrix theory of Moss suggests that growth of the mandible and the adjacent bones and tissues is in response to the functional stimulus.[12,12a,13] The deformity of the face could be due to lack of both epiphyseal growth and functional stimulus.

The deformity of the face varies depending on the age at which the affliction has set in. Growth of the affected side gets retarded from the time of trauma, infection or other causes of ankylosis. Hence, there is a deviation of the jaw to the affected side. There is an apparent fullness of the affected side and a deficiency of the unaffected side. This is because the normal side is dragged to the underdeveloped side. But in bilateral ankylosis where both the sides are affected the growth of the lower jaw on both the sides are affected and the patient may develop severe micrognathia, which gives a 'bird face' appearance.

If the patient is affected during adulthood, trismus may be the main sign and there will not be any deformity since growth has already been completed. From fibrous ankylosis to bony ankylosis the opening may vary from 15 mm to less than 2 mm.

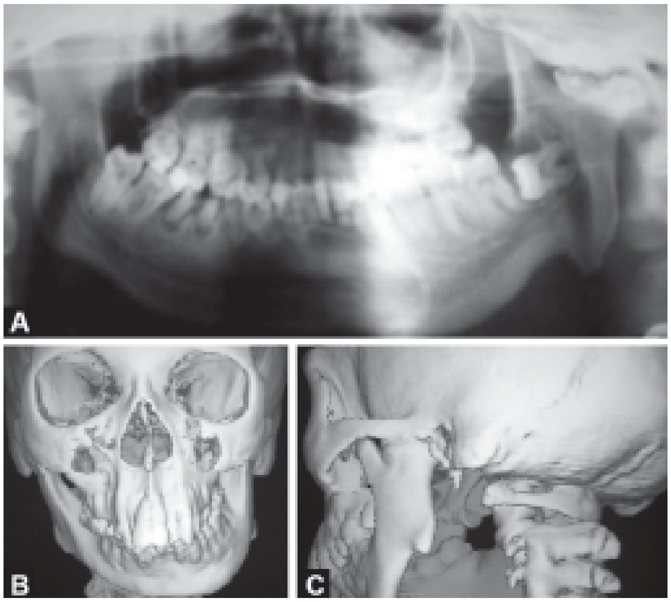
Associated with trismus and deformity of the mandible there will be defects of the maxilla, zygoma, temporal bone and soft tissues. Zygomatic complex on the affected side is minimally underdeveloped and the maxilla usually shows an occlusal cant, with the affected side having less vertical height. Anterior part of the maxilla usually shows a vertical excess and a deep bite is almost often observed. Antegonial notch is observed, and is more pronounced on the affected side. This is due to the restriction to the oppositional growth, brought about by the pterygo-masseteric sling. It also marks the junction between the body and the ramus.

Radiological Investigations

a. Orthopantamography
b. PA view mandible
c. Lateral oblique view mandible
d. Tomography—coronal and sagittal planes
e. Magnetic resonance imaging.

Orthopantamography gives a satisfactory image of the ankylosis. CT Scan and MRI can give a better understanding about the extent of the lesion. A three-dimensional reconstruction can be of much help in planning the surgical treatment **(Figure 25-2).**

A demarcating line between the condyle (flattened and enlarged in size) and the temporal bone may be discerned in the X-ray. However, this demarcating line is often not a true cleavage.



Figures 25-2A to C: Ankylosis of the right Temporomandibular Joint. The condyle is flattened. Even though the ankylosis is bony, a radiolucent cleavage is often seen between the temporal bone and the condyle. The coronoid process is elongated and the sigmoid notch is obliterated. Antegonial notch is pronounced. (A) Orthopantomogram. (B) 3D CT of the skull showing the asymmetry. (C) 3D CT of the TMJ.

Management of TMJ Ankylosis

Management of TMJ ankylosis can be divided into two parts—functional and esthetic.

Functional Correction

The primary aim of management is functional rehabilitation. If this is done at an early age, the stimulus contributed to growth by function, markedly improves the symmetry and appearance of the face.

Preoperative Preparations

Since the patient cannot open the mouth, oral hygiene is usually poor. It is difficult to restore decayed teeth and perform routine oral prophylaxis. However, no effort should be spared to remove any focus of infection in the oral cavity.

Alkayat Bramley's question mark incision is a popular one being widely used. This allows good exposure. Pre-auricular temporal incision, which extends temporally with an anterior angulation may well be used, which is well hidden in the hairy area of the temporal region.

Anesthesia

Release of ankylosis is done almost often under general anesthesia. Intubation is always a challenge to the anesthesiologist. Every time the parents and the patients are briefed about tracheostomy and the set is kept ready for use if needed. Normally, it is the usual practice to flex the neck in adults, and to extend it in children for convenience of intubation. However, it is interesting to note that even in adult patients who are suffering from ankylosis, extension affords better ease of intubation. This could be attributed to the fact that in these patients the pharyngeal growth is compromised and hence, the morphology of the pharynx in them could be similar to that in children.

Insufflation is another technique often employed wherein the tube is kept in the pharynx and general anesthesia administered till the ankylosis is released. Once the mouth is opened, proper intubation is done and the surgery is continued. Fibro-optic intubation is the safest and ideal technique **(Figure 25-3)**.

Figure 25-3: Fibro-optic intubation is the ideal method to administer anesthesia in ankylosis of the TMJ.

Surgical Management

The treatment is planned depending on the extent of ankylosis. Sawhney recognized four types of ankylosis.[22]

Type I

Condyle is flattened, but the joint space is not fully obliterated. The reduced jaw movement is due to fibrous union.

Type II

Condyle is flattened and bony union has ensued.

Type III

Ankylosis is usually due to medially displaced fractured condyle forming a bony union between the ramus and the zygomatic arch

Type IV

TMJ architecture is completely lost. There is bony fusion of the condyle, coronoid process, the glenoid fossa and the zygomatic arch. Sigmoid notch is obliterated.

In Type I and Type II, if the meniscus is not damaged the condyle can be reshaped by a high condylar shave and the meniscus is repositioned and sutured.

In Type III and IV extensive gap is created by removing the condyle and the coronoid process. Mandible is well mobilized and adequate mouth opening is achieved and an interpositional material is used to prevent re-ankylosis.

In children ankylosis results in facial deformity due to reduced growth on the affected side. Aim of the correction is two fold. First is to restore the function by releasing the ankylosis. The other is to provide an active growth centre to compensate for the lost condylar epiphyseal growth. Costochondral grafting is at present the widely accepted technique to replace the lost condyle.

Surgical Procedure

Incision

Approaches to the Temporomandibular joint are many—preauricular, endaural, postauricular, submandibular, coronal, etc. The most popular is the pre-auricular, especially for correction of ankylosis.

For these procedures a good exposure of the area is necessary and the preauricular incision extending to the temporal region is the ideal choice. Blair used an inverted 'L' incision.[2] Others who suggested new incisions were Wakely (T incision), Laupat, Dingman, Rongetti (endaural approach), etc. [4,16] Alkayat Bramley's question mark incision is very popular.[1] This affords a good exposure of the zygomaticotemporal region.

Procedure

The important structures encountered in the procedure are: (1) Superficial temporal artery and vein, (2) Auriculo temporal nerve, (3) Facial nerve and its branches **(Figures 25-4 and 25-5)**. The care of the facial nerve is of utmost importance.

Depending on the extent of surgery the preauricular incision may be modified. The standard procedure is to place the incision at the junction of the external ear and the face extending from the lower border of the pinna upwards to the temporal region. Incision at the temporal region is 45° to the zygomatic arch to the temporal region. Incision is extended depending on the access required. Incision is deepened by blunt dissection to reach the superficial temporal fascia. Branches of superficial temporal artery and vein are often encountered. They are either ligated or cauterized. Temporal myofacial flap is often used for interposing the gap created after excising the ankylosis. To expose the muscle and fascia the incision is deepened to reach the fascia which is a white glistening structure. The scalp above the fascia can be easily peeled by blunt dissection. It is important to remain at the level of the fascia to prevent injury to the upper branches of the facial nerve.

Figure 25-4: Pre auricular incision angulated to the temporal area at the top of the pinna affords excellent exposure of the TMJ and the zygomatico- temporal area.

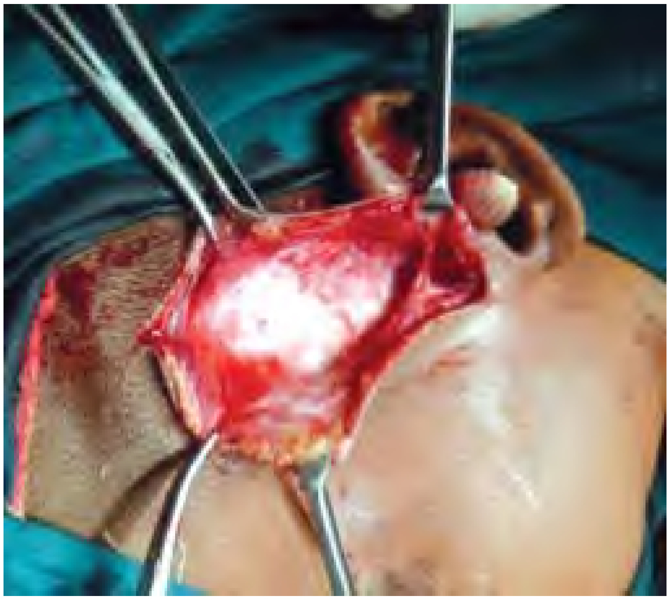


Figure 25-5: The incision is deepened to the temporal fascia, seen as white shining membrane. Further downward dissection should be in this plane. Maintaining the dissection in this plane is important to prevent injury to the branches of the facial nerve.

Preauricular incision is deepened in front of the tragal cartilage. This area is relatively avascular. By blunt

Figure 25-6: The temporal fascia is attached to the zygomatic arch. This is divided and by subperiosteal dissection the ankylosed mass is exposed.

dissection the root of the zygomatic arch is exposed and below the root of the zygomatic arch the periosteum is incised and reflected to expose the arch up to the body of the zygoma. The fascia is divided at the upper border of the arch and retracted to protect the upper branches of the facial nerve. Ankylotic mass is exposed by dissecting subperiosteally downwards.

Submandibular incision may be required to reach the ankylosis, if the ankylotic mass is large. It is also easier to excise the coronoid process through the submandibular approach. Submandibular incision of about 3 cm long is placed just below the lower border of the mandible. After exposing the superficial fascia blunt dissection is done to expose the platysma. Deep fascia is reached by incising the platysma. Marginal mandibular nerve (branch of the facial nerve which gives motor supply to the lower lip) is at this plane. The nerve is preferably identified and protected. Periosteum is exposed and incised. Masseter is reflected subperiosteally to reach the sigmoid notch/ankylosis. It has to be remembered that the anatomy of this region is often distorted due to ankylosis.

Surgical Treatment Protocol

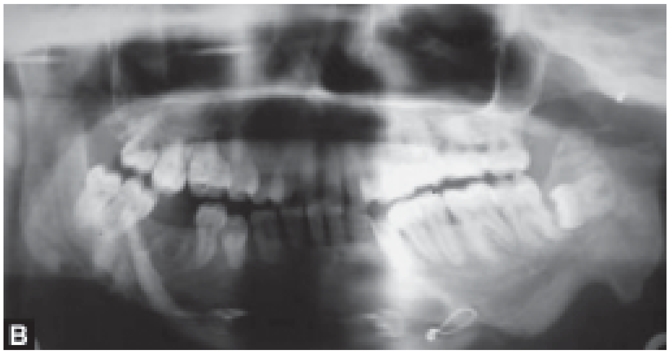
Numerous techniques for correction of TMJ ankylosis are described by many authors. Presently, the widely accepted surgical technique is gap arthroplasty, removal of coronoid process, interposing with temporalis myofascial flap and reconstruction with costochondral graft.

Figures 25-7A and B: Aggressive resection of the ankylosis is done and a gap of 1 to 1.5 cm is created.

Gap arthroplasty: The ankylosed part is excised and a gap of about 1 to 1.5 cm is created **(Figures 25-7A and B)**. Bur is used to cut the superficial bone and chisel is used to complete the cut on the medial part (If bur is used to transect the entire bone, chance of injury to the vessels is high. Mandibular and maxillary artery run medial to the neck of the condyle). A spreader or a Ferguson mouth gag is used to distract the fragments and mobilize the mandible. Minimum mouth opening of 2.5 cm is to be achieved **(Figure 25-8).**

Gap arthroplasty alone was ridden with a high percentage of recurrence. The medial pterygoid and the masseter muscles exert a pulling effect on the mandible and the gap gets reduced. If the gap created is less, the ends will come closer and appose again and re-ankylosis may ensue. Active exercises could prevent re-ankylosis to a great extent.

Figure 25-8: A mouth gag can be used to force open the mouth. About 2.5cm is the ideal minimum mouth opening to be achieved.



Figures 25-9A and B: Ipsilateral coronoidectomy can be done through the existing pre auricular incision. If not possible, submandibular approach may be used. Contralateral coronoidectomy can be done intra orally

Coronoidectomy: Long standing ankylosis usually causes fibrosis of the temporalis tendon and elongation of the coronoid process. This is more pronounced on the ankylosed side. In Type III ankylosis the coronoid is also involved in the ankylosis. Depending on the extent of the ankylosis an ipsilateral coronoidectomy is done. This procedure can be done either through the already existing preauricular incision, or by submandibular approach. Submandibular approach gives better access to the region. In cases where a costochondral grafting is planned submandibular incision is preferred.

If the mouth opening is not satisfactory, even after gap arthroplasty and ipsilateral coronoidectomy, contralateral coronoidectomy is advocated. This can be done as an intra-oral procedure. Incision is made on the anterior border of the ramus. Subperiosteal dissection is done to reach the sigmoid notch and the coronoid is held and cut from the sigmoid notch. This procedure relieves the holding force of the temporalis and the mouth opening improves drastically **(Figures 25-9A and B).**

Temporal Myofascial Flap Interposing

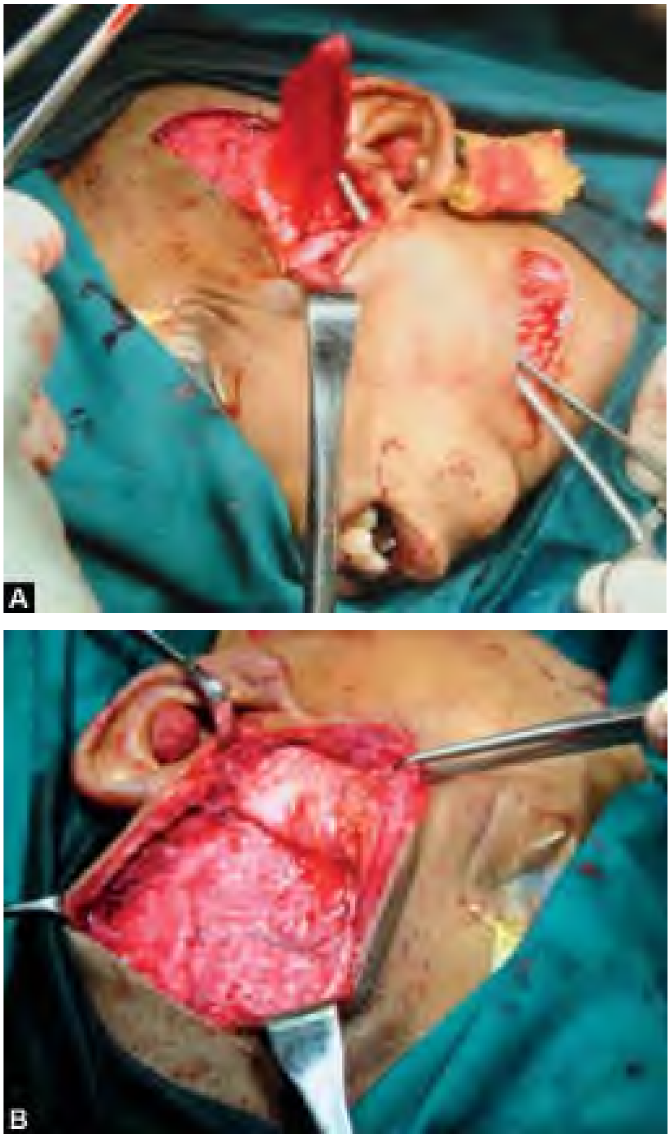
High recurrence rate after gap arthroplasty necessitated interposing of materials in the gap. Many materials were tried by various surgeons. The materials tried were the following: Acrylic balls, silastic pulley or sheet, dermis, fascia, muscles, cartilage, prosthesis, etc.[7]

Temporal myofascial, a versatile flap, can be put to use in many situations. It can be used as a predictable graft for reconstruction after maxillectomy, for closure of oro-antral or oronasal fistulae, treatment of submucus fibrosis, reconstruction of mandibular and floor of the mouth defects, and as an interposing material in TMJ ankylosis correction.

Preauricular incision and dissection, which extends to the temporal region, exposes the temporal fascia as a white glistening sheet. It is important to remain in the fascial plane during dissection, to prevent injury to the branches of the facial nerve. Underneath is the muscle. A tongue shaped flap of the muscle and fascia having a width of about 3 to 4 cm, is elevated and rotated over the zygomatic arch and interposed in between the temporal bone and the stump of the cut mandible. This is done before placing the costochondral graft. Through the submandibular incision the muscle is pulled down medial to the ramus so that it forms a curtain. The flap is spread out and sutured to the sides, so that, any possibility of recurrent ankylosis is obviated **(Figures 25-10A and B)**.

Costochondral Grafting

Costochondral grafting is a widely accepted and very effective technique to prevent re-ankylosis. Contralateral 5th, 6th or 7th rib is harvested with about 1.0 cm of the cartilage. Costochondral graft is placed on the lateral surface of the ramus and fixed with screws/wires/plates, with



Figures 25-10A and B: The myofascial flap is interposed between the cut ends over the zygomatic arch.

the chondral end articulating with the skull (Temporal bone) or the interposing material. In children the cartilage serves three major purposes: (1) There is a growth center in the cartilage and this will help the downward and forward growth of the mandible if the graft retains the viability, (2) The vertical dimension of the ramus is maintained, countering the pull of the muscles (Masseter and medial pterygoid), (3) The cartilage acts as an interposing material preventing re-ankylosis. Contralateral rib will have a better contour simulating the normal condyle. The length of the cartilage is ideally 0.5 to 1.00 cm.

The amount of cartilage in the graft may influence the growth of the mandible. Many cases are reported where there is an excessive growth of the costochondral graft.[6,14,21]

Costochondral Graft Harvesting

5th, 6th or 7th contralateral rib is the ideal for grafting. Rib is harvested through a submammary incision. In females the surgeon should estimate the position of the submammary crease and plan the incision so that it is masked when the child is fully grown **(Figures 25-11A and B).**

Figures 25-11A and B: The rib is harvested through a submammary incision.

The manubriosternal junction (the angle of Louis) is the level of the 2nd rib. From there the ribs can be counted through the chest wall. Usually the incision is marked over the 7th rib. The incision is made through the skin, superficial fascia, pectoralis major and the external intercostal muscles. The rib is harvested with about 1 cm of cartilage. The perichondrium at the costochondral junction is preferably maintained to prevent fracture at the junction. Care should be taken not to perforate the pleura. An easy way to detect perforation is to inflate the lungs, after flooding the wound with saline. Bubbling of air indicates perforation. If there is perforation chest tube with under water drain is maintained. In minor breaches it is possible to close the wound without a drain.

Graft is fixed rigidly to the ramus with the chondral end facing the interposed flap **(Figure 25-12).**

R Gunaseelan has used the resected segment as an autograft after recontouring, in extensive ankylosis of

Figure 25-12: The graft is fixed to the ramus with the chondral end facing the interposed flap.

Figure 25-13: Pre- (A) and post- (B) operative mouth opening (after 4 years) of a girl who has undergone release of ankylosis.

temporomandiblular joint. The graft is rotated 90°s, so that the cortical surface faces the temporal bone.[5] John N Kent has devised a temporomandibular joint condylar prosthesis and published a ten year report in 1983.[7] Full thickness skin graft was also used as an interpositioning material.[3] Acrylic, silastic, temporal fascia and muscle, fascia lata, etc. was suggested as interpositioning materials.

Leonard B Kaban has published a protocol for the management of TMJ ankylosis in 1990.[8] His protocol outlines the following: (1) Aggressive resection, (2) ipsilateral coronoidectomy, (3) contralateral coronoidectomy when necessary, (4) lining of the TMJ with temporal fascia or muscle, (5) reconstruction of the joint with costochondral graft, (6) rigid fixation, and (7) early mobilization and aggressive physiotherapy.

This protocol is widely accepted and employed by many maxillofacial surgeons.

Paul C Salins, for the correction of TMJ ankylosis, makes a horizontal cut on the ramus below the ankylosed mass (below the sigmoid notch). No bone is removed. However, the segments are distracted. The gap is interposed by temporal fascia, cartilage, or silastic. Contralateral coronoidectomy is done in long standing cases.[19] He reported excellent result. However the follow-up was only for one year.

Postoperative exercise is very important in maintaining the mouth opening. Several methods are advocated for exercising. Spring loaded acrylic plates, mouth gags, wooden slivers, etc. are used to promote and increase mouth opening. The basic idea is to provide active movement in the joint area to prevent any re-ankylosis.

The minimum opening expected immediately after surgery is 2.5 cm. Periodic review is mandatory to evaluate the mouth opening.

Esthetic Correction

Costochondral grafting has got the advantage of lengthening the mandible and increasing the vertical dimension of the ramus. In children since the function is reestablished, growth usually takes place. The asymmetry is reduced to minimal as the child reaches adulthood. But in cases where ankylosis starts in childhood and is not treated till adulthood, the facial deformity is very severe and unsightly. In bilateral ankylosis the patient will have a bird face deformity with very small lower jaw and chin. In unilateral ankylosis too, the lower jaw is retruded and under developed. But the severity of under development is more pronounced on the affected side. The ankylosed side appears full and the normal side appears sunken since the normal side is dragged to the under developed side.

Surgical Correction Techniques

Ramus Osteotomies

An inverted 'L' or 'C' osteotomy with bone grafting on the affected side and a subsigmoid vertical or sagittal split osteotomy on the opposite side of the ramus is a widely suggested technique for correcting the asymmetry. This has to be followed by splinting and orthodontic treatment.[15]

Extended Lateral Sliding Genioplasty

This technique was briefly described by this author (Verghese Mani) in the book "Orthognathic Surgery - Esthetic Surgery of the Face". The author was using this technique from 1990 onwards and had long-term gratifying results. This technique is used simultaneously with ankylosis release in adults.[9,10]

Technique: A degloving incision is placed on the buccal sulcus of the lower jaw from the retromolar area to the retromolar area of the opposite side. Degloving of the mandible is done from the buccal side. Maintaining the mental foramen as a landmark, the inferior border of mandible is cut below the inferior alveolar canal, taking care not to injure the Mandibular nerve and its branch, the Mental nerve. The full thickness cut on the bone is extended from antegonial angle to the opposite antegonial angle. If bur is used, multiple holes are made through the inner cortex taking care not to injure the lingual soft tissue. Using a split spreader the inferior segment of the mandible is separated from the tooth bearing part **(Figures 25-15A to 25-16D)**.

The horseshoe shaped lower part remains attached to the lingual tissues and to the genioglossus and geniohyoid muscles. Myotomy is not mandatory. However, it can give better mobilization of the segment and may prevent relapse tendencies. The segment is pulled forward to augment the chin. It is slided laterally to the unaffected side to correct the asymmetry, a step will be formed at this side which can be grafted with autogeneous bone. Diagrammatic representation of the technique is shown in the **Figures 25-14A and B.**

Most of the TMJ ankylosed patients suffer from sleep apnea and snoring. Extended sliding genioplasty brings the chin forward along with the genioglossus and geniohyoid. This gives a marked relief to the sleep apnea and snoring

Certain modifications to the original technique are also suggested. In not so severe cases bone grafting is not necessary. The extent of the inferior border osteotomy need not be beyond the first molar/second premolar region on the affected side. This limitation of the extension of osteotomy is not going to affect the final outcome since the facial contour and fullness is satisfactory on this side, though this is the deficient side.

Figures 25-15A to D: (A) Pre operative before functional correction. (B) Post operative after functional correction. (C) Front photograph before aesthetic correction. (D) Post operative after extended sliding genioplasty.

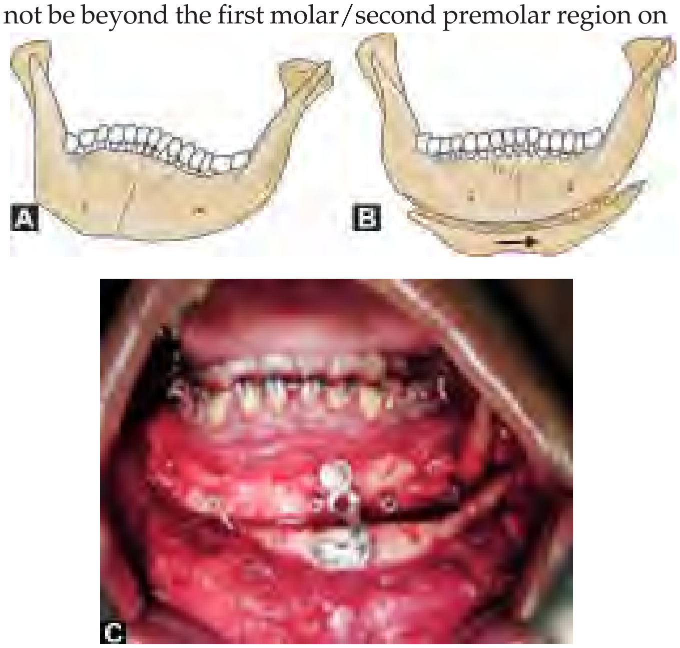


Figure 25-14: Extended sliding genioplasty can be used to augment the entire lower border of mandible and sliding the segment laterally can correct the asymmetry also.

The advantages of extended sliding genioplasty are the following:

1. The dental component (occlusion) is not disturbed.
2. The affected side of the mandible is lengthened.
3. The chin is brought to the facial midline and augmented.
4. The depression on the unaffected side is corrected and fullness is achieved.

In most of the bilateral ankylosis, the submental soft tissue is formed as a double chin or a lump. This soft tissue can be brought forward and replaced on the chin to give a better contour. This technique is described by PC Salins.[20] Dissection is done in the subplatysmal plane and the platysma is sectioned in the neck region and brought forward and sutured to the inferior border of the chin. This technique can be used in association with other mandibular osteotomies.

Figure 25-16: For this patient simultaneous functional and esthetic correction has been done. For esthetic correction bilateral sagittal split osteotomy and extended lateral sliding genioplasty have been done together.

Conclusion

Temporomandibular joint ankylosis is a devastating deformity, which affects function, esthetics and psychological development of the patients. The treatment should be instituted as early as possible. Earlier the treatment better the growth and chances of a normal facial balance in adulthood. Gap orthoplasty with bilateral coronoidectomy with temporal myofascial flap interposing and costochondral grafting is the widely accepted surgical protocol with predictable results.

Planning of esthetic rehabilitation is challenging. Extended sliding genioplasty, along with functional correction gives excellent result without disturbing the already existing occlusion. In bilateral ankylosis with severe deformity bilateral ramus osteotomies and/or extended genioplasty along with the functional correction can be done.

Meticulous planning is essential for the management of ankylosis of the TMJ. It is one of the most gratifying surgeries for the patients, parents and surgeons.

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Chapter 26

Informed Consent for Orthognathic Surgery

George Paul

Introduction

Consent to medical treatment as an ethical and moral principle is probably as old as medical science. It is inconceivable that a medical practitioner at any point in history would have treated or operated on a patient without his or her permission. However, consent to treat as a legally binding entity is of recent origin. Today, it is validated by multiple principles drawn from social and behavioural sciences, moral philosophy, human rights, ethics and laws of a particular country. One of the guiding principles of Informed consent involves the rights of patients to make clear assertions of what can or cannot be done to their bodies based on unbiased and full disclosure of the benefits and risks that will ensue from treatment. While most diagnostic treatment procedures are today performed only with a clear informed consent, there are some which attract particular attention. As an elective procedure with significant cosmetic and functional outcomes, orthognathic surgery is a procedure that needs special mention in the context of informed consent.

Definition and Principles of Informed Consent

Farlex's free online dictionary[1] has a simple definition of informed consent. It is "Consent by a patient to a surgical or medical procedure or participation in a clinical study after achieving an understanding of the relevant medical facts and the risks involved". A more descriptive definition is sometimes employed to capture the nuances of informed consent. It may thus be defined as "Consent given by a patient after understanding his/her condition, procedure, risks and alternatives based on unbiased information by the medical professional in a language and manner which is unambiguous, lucid."

History and Theory of Informed Consent[2]

The key historical signposts in the evolution of informed consent as a valid legal document can be traced to cases from the US judicial system though the basic principles find their roots in English Common law.

- While consent has been a well known moral requirement before treatment, it gained legal sanctity only in 1914 with the case of *Schloendorf Vs Society of New York Hospitals*. It set the tone for a legally acceptable premise of self determination.[2] Justice Benjamin Cardoza summarized the basic philosophy in his judgment thus " Every human being of adult years and sound mind has a right to determine what shall be done with his own body and a surgeon who performs an operation without his patients consent commits an assault for which he is liable".
- However it was with a series of case in the 1960s and 70s that self determination came to be legally binding as a legal principle and more importantly the importance of full divulgence by the doctor based on which a consent can be made became a dictum. It thus became ***informed*** consent. Important cases include the *Salgo Vs Le Land Stanford Jr Case* (1972) and the *Canterbury Vs Spence Case* (1972).[3] Informed consent thereafter became a legal necessity without which a doctor could be said to have a liability equivalent to 'battery'.
- With the advent of new technology (stem cell research and gene therapy) and emergence of new diseases like HIV, informed consent documents are constantly being upgraded to include new medical issues.

- Informed consent in research evolved largely due to the World War II atrocities in Nazi concentration camps. The IC documents in research have been formulated and reviewed by the Nuremburg conference and the Helsinki declaration. They are closely monitored for content by organizations such as the WHO, FDA and the ICMR in India.

Types of Informed Consent[4]

1. Implied
2. Oral or written consent

Implied consent: This is given by the behaviour of the patient. Actions, such as entering the clinic and the opening of the mouth to be examined can be construed as implied consent.

Oral consent: It is an acceptable form of consent for inconsequential procedures such as examination, taking of impressions or even routine low exposure X-rays.

Written consent: While oral consent is an acceptable consent it can often be challenged and the giving of consent cannot often be proved or validated. It is more binding to obtain a written consent with full disclosure of risks in the presence of an independent witness.

Informed Consent in Orthognathic Surgery

Informed Consent for orthognathic surgery is particularly important because of the nature of the procedure. It is an elective procedure and the patient often seeks treatment for enhancement of esthetics and function. The expectations are high and therefore the scope for disillusionment is significant.

Orthognathic surgery is a highly skilled procedure in a complex anatomical area. Treatment often involves multiple specialists including orthodontists, anesthetists, general dentists and other specialists. In addition to results falling below expectations, which is largely subjective, patients may also have morbidity in the form of non-vital teeth, neurological deficit, occlusal discrepancy, TMJ problems, avascular necrosis and in rare situations, excessive exsanguinations and even death. Considering that it is an ‘enhancement’ procedure, the informed consent document is a crucial and critical part of the surgical planning.

Since orthognathic surgery is a form of plastic surgery the recommendations of the American Society of Plastic Surgery is very appropriate. It calls for components of an informed consent that includes the following:

1. The purpose of the proposed procedure.
2. A summary of the surgical approach.
3. Expected benefits and limitations.
4. A description of postoperative recovery, possible complications and known side-effects, including those that are rare.
5. Risks associated with anesthetics, analgesics, and antibiotics and appropriate alternatives, including the option of no treatment or surgery at all.

Orthognathic surgery often involves pre-surgical orthodontics, general anesthesia and postsurgical orthodontics and other specialty inputs. It may be advisable to take separate informed consent, which includes chance of injury or consequences that have disutility for the patient, for each of the treatment protocols. Gasparini G, Boniello R, et al suggest a three part informed consent to include preoperative orthodontics, orthognathic surgery and post-operative orthodontics.[4]

The informed consent document may need to include the following principles and the surgeon and his team can make appropriate changes to accommodate them. These have been enunciated by Lord Scarman in the case of *Sidaway v Board of Governors of Bethlehem Royal Hospital*.[5]

1. The individual should be of adult years (18 years in India) and sound mind and should have the legal mental capacity to choose what happens to his/her body.
2. It should offer a choice that entails an opportunity to evaluate knowledgeably the options available and the risks attendant on each (including no surgery option).
3. The doctor should therefore disclose all material risks. The material risks are determined by the ‘prudent patient test’ which determines what a ‘reasonable’ patient in a position of a plaintiff (complainant) would attach significance to, in coming to a decision on the treatment given.

In addition to this, in the Indian context:

4. All informed consent must be in a language understood by the patient (vernaculars like Tamil, Malayalam, Bhojpuri, Kannada, etc).
5. In case of illiterates, the informed consent must be read to them in the presence of an independent witness who must sign in the space provided.
6. In children below 18, a parent or guardian can sign on behalf of the child

Recent concerns have suggested that informed consent should also cover diagnostic tests. It is a common practice in some countries including India to do a routine HIV testing. These can be undertaken only with an informed consent including pre-testing counseling. Many countries also insist on informed consent for multiple high dose radiation especially with the use of CT scan.

**A standard Informed Consent form is attached and can be used as a template. Any change depending on local conditions can be added.

Informed Consent and Negligence in Orthognathic Surgery

Informed consent regulations today are largely governed by the principles of medical negligence rather than the tort of battery, as in the early days. Any injury, even expected, may be considered a negligent act if there is no informed consent, e.g. Paresthesia following BSSO. The situation can be defended only if the patient was informed and consent obtained. In the absence of informed consent, the civil liability for causing injury, will be similar to the liability for medical negligence.

Similarly, informed consent does not absolve the surgeon from liability for negligence if it is proved that it could have been avoided if the surgeon had exercised reasonable care.

In short liability for negligence can be mitigated by an informed consent but informed consent cannot totally absolve a surgeon for an obvious negligent act.

Defense for Noninformation

Sometimes the surgeon may encounter a non-reported or rarely reported complication despite reasonable care. In these situations they can take defense in the principle of 'Act of God!!'. These are complications or sequels that may not have been anticipated by a reasonable surgeon.

Exceptions for the Use of Informed Consent

- Life threatening situations, e.g. carotid ligation, tracheostomy, etc.
- Incapacity of patient by virtue of age or mental status (It is taken from the guardian/parent).

Informed Consent for Clinical Trials and New Techniques

Informed consent has to be obtained if the patient undergoing the surgery is the subject of a new device, implant or technique which is not a standard one. In India, devices are not covered by the DCGI (Drug Controller General of India). New techniques on an experimental basis particularly in teaching institutions must be communicated to the patient and should be cleared by an Institutional Review Board (IRB) or Independent Ethics Committee (IEC). The Informed Consent Documentation (ICD) requirements for research are clearly enunciated in India by the ICMR.

Conclusion

Informed Consent Documentation (ICD) is an important and critical part of all treatment plans and often includes invasive or potentially harmful investigations. A proper informed consent should be realistic and should involve full disclosure if the patient is exposed to a chance of injury for which he has no utility. It is a necessary part of all treatment protocols. Informed consent documents respect the right of patients to take a decision on how their body is treated based on all available information. It is a moral, ethical and legal obligation especially in procedures such as orthognathic surgery. It also provides a safety net for the surgeon when unexpected adverse events are encountered.

CONSENT FOR ORTHOGNATHIC SURGERY (SHOULD BE IN THE LANGUAGE THAT THE PATIENT READS, WRITES AND UNDERSTANDS)

I (Patient's Name)

Aged——————————————————————and resident of (Address__________________________

____

1. do hereby authorize Dr.____________________and his associates to treat me for____________________________________
2. The surgical procedure planned to treat the above condition has been explained to me, and I fully understand the procedure as explained to me as:____
3. I have been informed of possible alternative forms of treatment (if any), including:__________________________________
4. I understand the potential risks and complications, both major and minor and am aware that they include but are not limited to:
   - A. Bleeding during the operation which may require transfusion of blood or blood products from an authorized blood bank with screened blood.
   - B. Swelling of the face for at least 1 week or more.
   - C. Bruising and discoloration of the skin around the jaws, eyes and nose including bruising of the angle of mouth making feeding difficult for several days.
   - D. Loss of sensation to the lips, cheek, teeth, etc which are usually of a temporary nature but may rarely be permanent. There may be tingling or altered sensation.
   - E. That my jaws may be wired together if needed and held in place by wires or elastics for a limited period of time which may extend to up to a month.
   - F. That healing may be unsatisfactory causing movement of bones which may require a second operation and bone grafts.
   - G. That there may be a relapse or opening of the bite which may need additional surgery.
   - H. Diminished sense of smell (if upper jaw surgery is done) and taste in lower jaw which will be usually of a temporary nature but may also be permanent in rare situations.
   - I. I am aware of some expected change in my appearance. I understand that certain cosmetic changes may not be totally predictable. There may also be changes in speech patterns which may require additional treatment.
   - J. Possible decreased function of muscles of facial expression.
   - K. Scarring if external skin incisions are put or external fixation devices are put.
   - L. Possible need for additional procedures to remove fixation devices, pins, screws, plates or splints.
   - M. In certain cases where bone cuts may be made in the marrow space between teeth, there is the possibility of devitalization of those teeth which may require later root canal procedures, and may result in the loss of those teeth.
   - N. In upper jaw surgery, the sinus maybe affected and there may be a need for further sinus surgery to remedy any problem.
   - O. Infection which may cause loss of adjacent bone and/or teeth and which may require additional treatment including replacement, implants, etc.
   - P. Jaw position changes may cause discomfort to the joints of the jaw (TMJ). This may temporarily or rarely permanently cause pain and difficulty in chewing.
5. General anesthesia will be used for this surgery and I have been told of the risks, including bronchitis, pneumonia, hoarseness or voice changes, cardiac irregularities, heart attack or death. I am aware of the importance of not having anything by mouth (including clear liquids unless specifically authorized by my doctor or anesthesiologist) FOR 6 HOURS PRIOR TO MY ANESTHETIC. **TO DO OTHERWISE MAY BE LIFE-THREATENING!**
6. I realize the importance of providing true and accurate information about my health, especially concerning possible pregnancy, allergies, medications and history of drug or alcohol use. If I misinform my doctor I understand the consequences may be life-threatening or otherwise adversely affect the results of my surgery.

Information for Female Patients: I have been advised that certain antibiotics and other medications may neutralize the preventive effect of birth control pills, allowing for conception and pregnancy and that I can use other contraception techniques if needed.

Consent—Sample Form: By signing this consent form, I acknowledge that I have read it completely and understand the procedure to be performed, the risks, and the alternatives to surgery. I have had all my questions answered to my satisfaction. I was under no pressure to sign this form and have made a voluntary choice to proceed with surgery. I am fully aware that no guarantee or warranty can be made regarding the results of treatment. I certify that I speak, read and write ……….. (language of Patient)

____

Patient's (or Legal Guardian's) Signature Date

(in the event of the patient being illiterate a thumb impression should be appended and the signature of an independent witness taken attesting that it was explained in his presence)

____

Doctor's Signature Date

____

Witness Signature Date

Orthognathic surgery is being planned for you, and it is important that you understand the benefits and risks of such surgery. This is NOT minor surgery and you have the right to be fully informed about your condition and the recommended treatment plan. The disclosures in this consent are not meant to alarm you, but rather to provide information you need in order to give or withhold your consent to the planned surgery.

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