This article has been peer reviewed

Guiding Atypical Facial Growth Back to Normal Part 1: Understanding Facial Growth

By Steve Galella, DDS, IBO; Daniel Chow, BDS, DDS, MAGD, FIAO, FIAOFE; Earl Jones, DDS,; Donald Enlow, MS, PhD; Ari Masters, DDS

Abstract: *Many practitioners find the complexity of facial growth overwhelming and thus merely observe and accept the clinical features of atypical growth and do not comprehend the long term consequences. Facial growth and development is a strictly controlled biological process. Normal growth involves ongoing bone remodeling and positional displacement. Atypical growth begins when this biological balance is disturbed. With the understanding of these processes, clinicians can adequately assess patients and determine the causes of these atypical facial growth patterns and design effective treatment plans. This is the first of a series of articles which addresses normal facial growth, atypical facial growth, patient assessment, causes of atypical facial growth, and guiding facial growth back to normal.*

Keywords: *Facial growth, bone remodeling, bone displacement, assessment of facial growth.*

This is the first in a series of articles which describes and simplifies facial growth from a clinical perspective. The subsequent articles will identify the characteristics of normal and atypical growth and address the clinical aspects of controlling or guiding facial growth towards normal balance and function using specifically designed growth guidance appliances and other methods of clinical intervention.

Many practitioners find the complexity of facial growth overwhelming and thus merely observe and accept the clinical features of atypical growth and do not comprehend the long term consequences. Such consequences include functional problems, TMD disorders, breathing problems, sleep apnea, and other health issues.[1,2,3] With practical knowledge of the basics of facial growth, practitioners can adequately assess each patient to determine the cause of atypical facial growth and design treatment that will guide atypical growth back to normal.

Facial growth and development is a strictly controlled biological process that is ongoing. Atypical growth begins when this biological balance is disturbed. Normal or balanced facial growth involves the collective effort of several principles and processes. Bone growth is not predetermined within the bone itself but relies on growth-regulating signals derived from the functions of the surrounding soft tissue. The blueprint for facial bone growth lies in the muscles, tongue, lips, cheeks, integument, mucosa, connective tissue, nerves, blood vessels, airway, pharynx, tonsils, adenoids, and other organ masses.[1,2,3,4,5] It is best to examine the source of these controls to understand normal facial growth, then if normal facial growth goes awry, a practitioner can manipulate these controls to guide facial growth back to normal. The direct target for clinical intervention should be the control process regulating the biology of growth and development.[1,2] The reader should understand that the following material has been simplified for clinical application. A reference of reading material for a comprehensive understanding can be found at the end of this article.

Bone remodeling and movement is the cornerstone of the facial growth process.

Bone remodeling has several functions, which include: 1. Changing size and/or shape to accommodate the various functions required. 2. Relocation of functional components to allow for overall enlargement, such as the mandible, nasomaxillary complex, teeth, etc. 3. Adaptation of the comprehensive facial skeleton in response to functional stress placed upon it, and 4. Provide progressive "fitting" of each bone with the facial skeleton and the associated soft tissues.[1,2,5,6,7,8,9,10,11] Most practitioners are familiar with the remodeling process as it relates to changes in size and shape of the face; however, it is critical to understand that facial bone remodeling requires without exception the simultaneous process of resorption and deposition of bone. Relocation of the functional components of the facial skeleton enhances the ability of each individual facial bone to maintain its structure and function while enlarging. An example of this principle is the ability of the ramus to upright during growth while at the same time enlarging the mandible.[1,2,10,12,13,14,15,16] This process will be discussed shortly. Structural modifications include adaptations of facial bones to maintain function because of intrinsic or extrinsic forces as described by Wolf's Law.[7,8] These structural modifications also include aligning separate bones to "fit" one another to maintain continuity and integrity.[1,2,5,9,16,17]

Growth movement of bone includes displacement or physical movement of a facial bone while it simultaneously remodels. Figure 1. It is imperative to understand that the expansive force of all the growing soft tissues that surround and attach to it by anchoring fibers regulates this physical displacement of a facial bone. That is to say, the surrounding soft tissue acts as the trigger or regulator which determines the direction and pattern of displacement. Figure 2. Throughout growth movement, the remodeling process permits new bone deposition which in turn keeps each bone touching the contact surfaces of the surrounding bone.[1,2,5,18,19] One example of this process occurs during growth movement when the maxilla is displaced downward and forward while at the same time an equivalent amount of remodeling occurs simultaneously depositing bone in an upward and backward direction.[1,2,4,5,6,17] Another example is while the mandible is displaced "away" from its articulation in each mandibular fossa, the condyle and ramus remodel upward and backward to relocate into the space created by the displacement process.[1,2,9,12,15,16] During facial bone growth, as displacement occurs, each bone is simultaneously remodeled causing each bone to lengthen primarily at the sites where the facial bone is displaced. Again, keep in mind that facial growth is a strictly controlled biological process which infers that local areas of hard and soft tissue work together to maintain the overall stability and function of the facial skeleton. Without this delicate balance and control, the facial skeleton would be quite asymmetrical and undoubtedly nonfunctional.

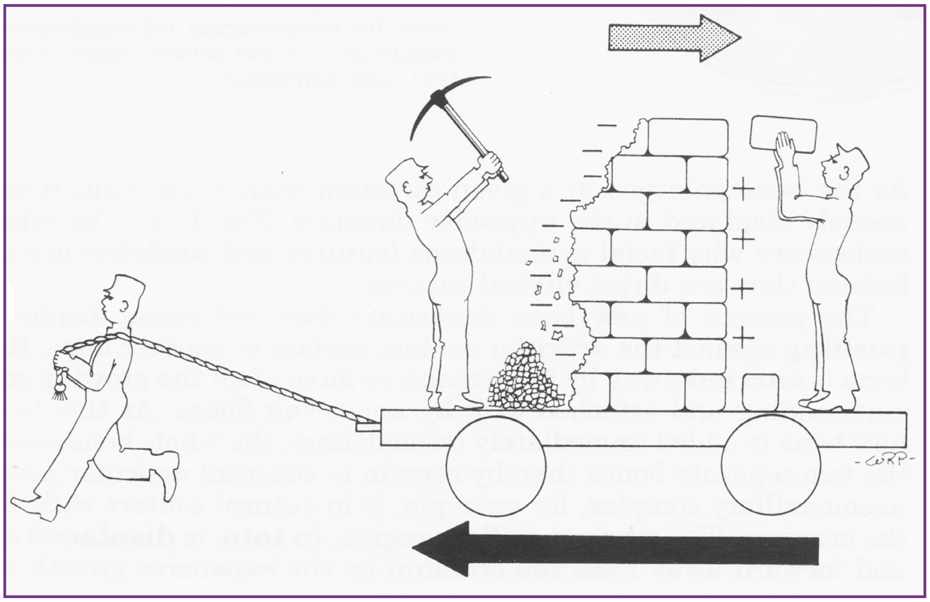

Figure 1

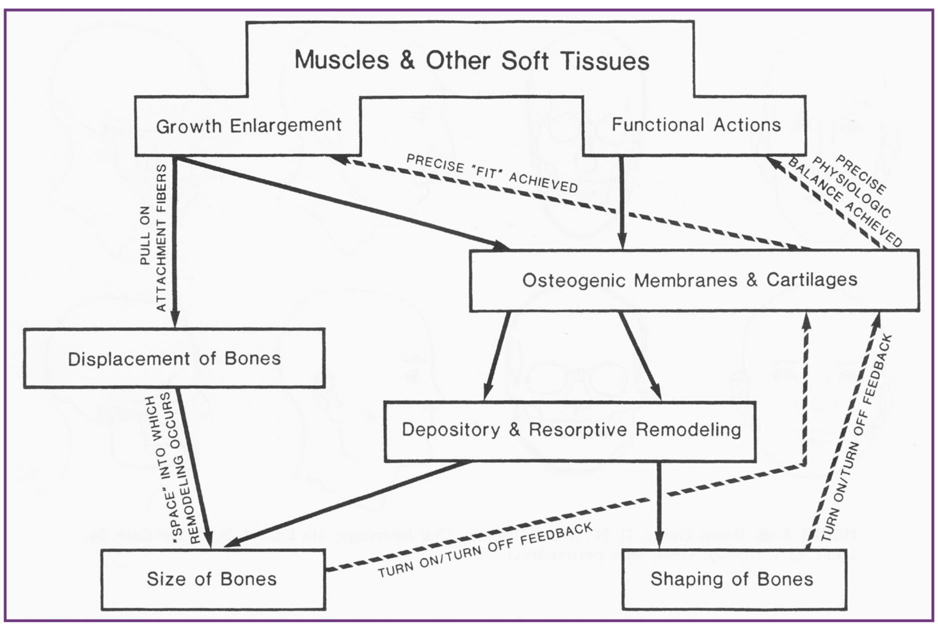

Figure 2

Principal Regions of Facial and Neurocranial Development

There are three principal regions of facial and neurocranial development that guide facial growth and act together to maintain a strict equilibrium of function and stability.

The brain and associated sensory organs and basicranium. The configuration of the neurocranium (and brain as an organ) determines the headform type which, in turn, sets up the corresponding topographic features that characterize a facial type. Those with a brachycephalic headform have a rounder basicranium, which establishes a facial type termed *euryprosopic*, or one that is broader and less protrusive. While those with a dolichocephalic head form have a long and narrow basicranium which establishes a facial type termed *leptoprosopic*, or one that becomes narrow, long, and protrusive. It is important to remember that the basicranium establishes the shape and perimeter of the facial growth field and sets the boundaries of growth. The morphology of the basicranium determines the position of the nasomaxillary complex, the width of the facial airway, and the configuration of the palate and the maxillary arch.[1,2]

The facial and pharyngeal airway. The shape and proportions of the airway are the combination of the growth and development of various hard and soft tissues comprising its enclosing walls situated along its pathway from nares to glottis. The airway is critical in maintaining the functional and anatomic positions of these same parts. Additionally, the airway stabilizes the positions of all of its surrounding parts provided it is the proper shape and size. The airway, being a keystone for the face, regulates the archform of the orbits, the nasal and oral sides of the palate, the maxillary arch, the sinuses, the zygomatic arches, and other arched structures of the face. We are normally nasal breathers; however, when the integrity of the airway is compromised, the tendency towards oral breathing occurs. This ultimately leads to aberrant growth patterns including retrognathism and downward growth of the nasomaxillary complex (mid-face deficiency), underdeveloped lateral orbital rims (downward slant of the lateral canthus), narrow deep palate, various malocclusions, excessive vertical growth of the face, etc.[1,2,3,20] The mechanisms of these growth patterns will be discussed later.

The oral complex. The architecture of the oral complex reflects the stability of the facial and pharyngeal airway and any asymmetry of the basicranium. That is to say, the maxilla and mandible are typical sites for compensation and anatomical modification during facial development. These compensations and modifications result in a state of functional and structural equilibrium for the facial skeleton, the airway, and the stomatognathic system even though the growth is aberrant. Frequently encountered compensatory combinations may involve the ramus of the mandible, variations in maxillary size and shape, palatal rotations, anterior crowding, gonial angle remodeling, occlusal plane rotations, and other variations, which will be addressed later. The oral complex which includes the nasomaxillary region and the mandible serves as an indicator of normal or atypical growth.[1,2]

The basicranium, airway, and oral complex each has its own schedule of growth; however, they are all connected as an integrated process. Facial growth encompasses a well-defined relationship between all constituent parts. No part is independent of the other, and any variation of growth of any part affects all of the others. For facial growth to occur, whether normal or atypical, it is essential that it has collective functional and structural equilibrium. Simply put, if one part changes, every other part must change to maintain such equilibrium.[1,2,6,12,15]

The Developmental Sequence

Before addressing the major clinical structural components that we as clinicians will need to attend to in our efforts to guide growth back to normal, it is prudent to summarize the sequence of facial development

Table 1: Growth Stages Changes

Stage 1	Bony maxillary arch lengthens horizontally in posterior direction Bone deposited on posterior-facing cortical surface of maxillary tuberosity Resorption occurs on opposite side of same cortical plane
Stage 2	Maxillary tuberosity grows & lengthens posteriorly Entire maxilla displaced anteriorly Forward displacement exactly equals amount of posterior lengthening (Stage 1)
Stage 3	Mandibular body lengthens to match maxilla
Stage 4	Mandible displaced anteriorly through posterior remodeling of condyle & posterior portion of ramus
Stage 5	Entire mandible displaced anteriorly by same amount that ramus has relocated posteriorly Simultaneously remodels (i.e., Stage 4) to keep pace with the amount of displacement
Stage 6	Entire mandible displaced anteriorly as it remodels posteriorly Condylar growth (oblique) produces upward & backward projection of condyle corresponding with downward & forward mandibular displacement
Stage 7	Vertical increase and horizontal elongation of maxillary complex (primary displacement)
Stage 8	Vertical growth by primary displacement & bone deposition at sutures of maxilla Teeth move by vertical/horizontal drift and eruption
Stage 9	Vertical separation between upper & lower arches must balance equivalent amount of lengthening in nasomaxillary & dentoalveolar region of mandible
Stage 10	Upward movement of mandibular teeth & remodeling of alveolar sockets Remodeling changes in incisor alveolar region, chin & body of mandible chin and body of mandible
Stage 11	Maxillary complex displaces anterior & inferiorly Malar area is moved anteriorly & inferiorly by primary displacement

Source: adapted from: Enlow DH,Hans MG. *Essentials of Facial Growth*. Philadelphia, PA: WB Saunders; 1996.

giving a simplified overview of the process. Keep in mind that even though this summary describes the various parts of growth separately, all of these processes occur simultaneously. Remember that even though functional and structural equilibrium may exist, certain regional imbalances occur during actual development. These imbalances consequently produce imbalances in structure, which are clinically recognizable. Each face is the aggregate sum of all the many balanced and imbalanced craniofacial parts combined into a composite whole. Compensatory modifications provide for certain latitude of imbalance in some areas in order to offset the effects of disproportions in other regions.

Below is a summarized version of the Regional Growth Changes as described by Enlow.[1,2]

Growth of the Mandible

After reviewing the summary of the developmental sequence, several other factors should be noted to complete the understanding of the process of mandibular growth. The mandible does not merely grow in all directions, it remodels while being simultaneously displaced in a forward and downward movement. Figure 3 Other factors that should be considered are as follows:

Ramus: The ramus, while providing attachment sites for the muscles of mastication, plays a critical part in fitting the body and dental arch to match the growing maxilla by adjusting alignment, vertical length, and horizontal length. It is most important to realize that the ramus positions the lower arch in occlusion with the maxillary arch, and it is continuously adaptive to the various ever-changing craniofacial forms.[1,2,12,22]

Lingual Tuberosity: The lingual tuberosity is the major growth site of the mandible forming a boundary between the ramus and body of the mandible. As this growth center deposits bone on its posterior aspect, the ramus relocates several centimeters through remodeling. Remodeling includes not only the anterior and posterior aspects but all areas in between, thus causing the ramus to upright or become more vertically aligned. These remodeling modifications change the gonial angle of the mandible and maintain a constant positional relationship between the upper and lower arches. All of these growth modifications must match the modifications of vertical nasomaxillary growth in order to achieve continuing facial balance.[1,2] Clinically, it is imperative that we understand that the remodeling patterns observed are orchestrated by the growing soft tissues and the manner in which they function or cause dysfunction. When these soft tissues cause dysfunction, antigonial notching (a single field of surface resorption on the inferior edge of the mandible) is often seen on radiographs. This is often coupled with an abnormal variation in the gonial region.[1,2]

Mandibular Condyle: The mandibular condyle is a major site of growth and has vital clinical significance.

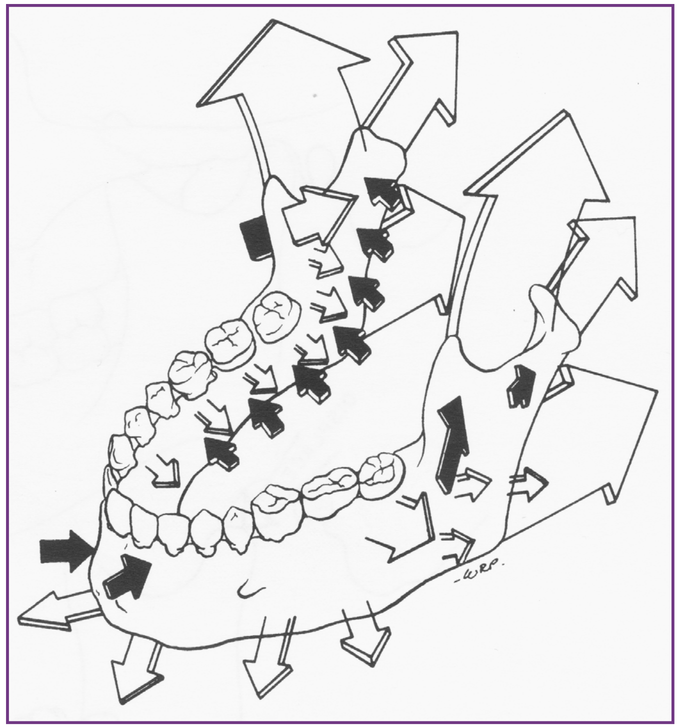

Figure 3: Black arrows are surface resorptive, and white arrows are depository.

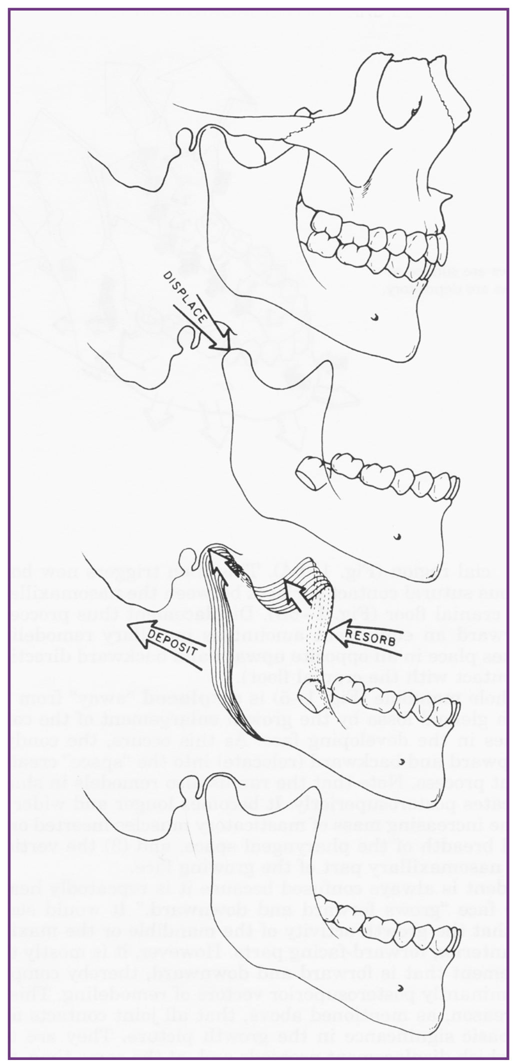

Figure 4

The condyle performs a functional role providing a pressure-tolerant articular contact while at the same time exerting a regional adaptive growth capacity in response to fluctuating circumstances such as occlusal changes, myo-functional habits or airway insufficiency and variations of growth. This proliferative process produces the "upward and backward" growth movement of the condyle, which follows the growth pattern of the ramus. Figure 4.[1,2,9] Because of the complex association between the growth of the ramus and condylar adaptive growth, it is clear that mandibular orthopedics must modify growth signals targeted at both the ramus and condyle to be maximally effective.

Growth of the Nasomaxillary Complex

As with the mandible, the nasomaxillary complex remodels while being simultaneously displaced in a forward and downward movement. Additionally, all inside and outside parts, regions, and surfaces participate directly in growth with each region coordinating with all others so that any one region is not developmentally isolated from the others. Of clinical importance, the maxilla remodels posterior-superiorly as it is simultaneously displaced in the opposite direction (anterior-inferior). Figure 5.[1,2,3,6,21]

Maxillary Arch Lengthening

The maxillary tuberosity is a major site of maxillary growth. The posteriorly directed depository displacement produces horizontal lengthening of the bony maxillary arch while a simultaneous remodeling process widens the maxillary arch and increases the size of the maxillary sinuses. The entire maxilla undergoes a simultaneous process of primary displacement in an anterior and inferior direction as it grows and lengthens posteriorly. The tension produced by the displacement of the maxilla requires all surrounding bones of the nasomaxillary complex to remodel and compensate to maintain a three dimensional constant bone-to-bone sutural contact while preserving its structural integrity.[1,2]

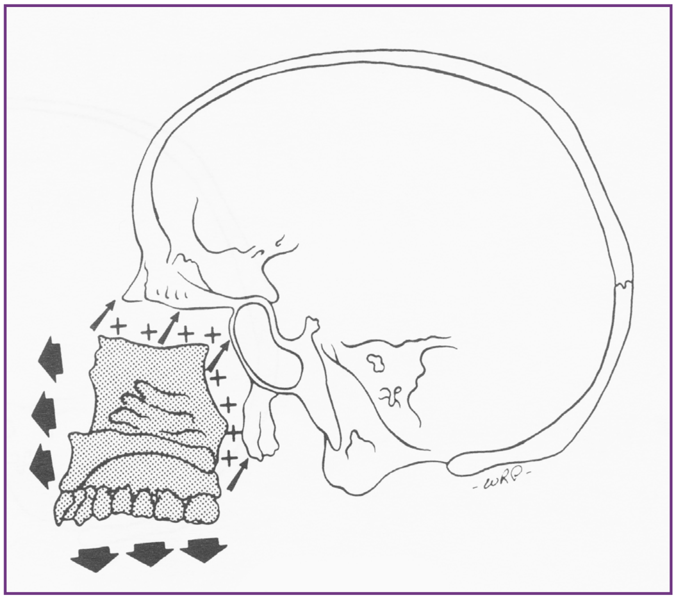

Figure 5

Biomechanical Forces of Maxillary Displacement

The processes and mechanisms that operate to guide growth are essentially multifactorial. This infers that if one component becomes inoperative, the other components have the capacity to compensate. The functional matrix theory developed by Moss deals with the elements of bone and cartilage growth in general. It states that any given bone grows in response to functional relationships established by the sum of all the soft tissues operating in association with that bone.[1,2,17] Therefore, the functional soft tissue matrix is the "epigenic" governing determinant of the skeletal growth process. The functional matrix concept plays an important role as a source for the mechanical force that carries out the process of displacement. The functional matrix concept is established and valid as a generalized representation of what happens during growth. It is clinically important to realize that when evaluating the facial skeleton, one must take into account both function and growth, for one cannot exist without the other.

The Maxillary Tuberosity and the Key Ridge

Growth of the maxillary tuberosity occurs in three directions. It lengthens posteriorly by deposition on the posterior-facing maxillary tuberosity; it grows laterally

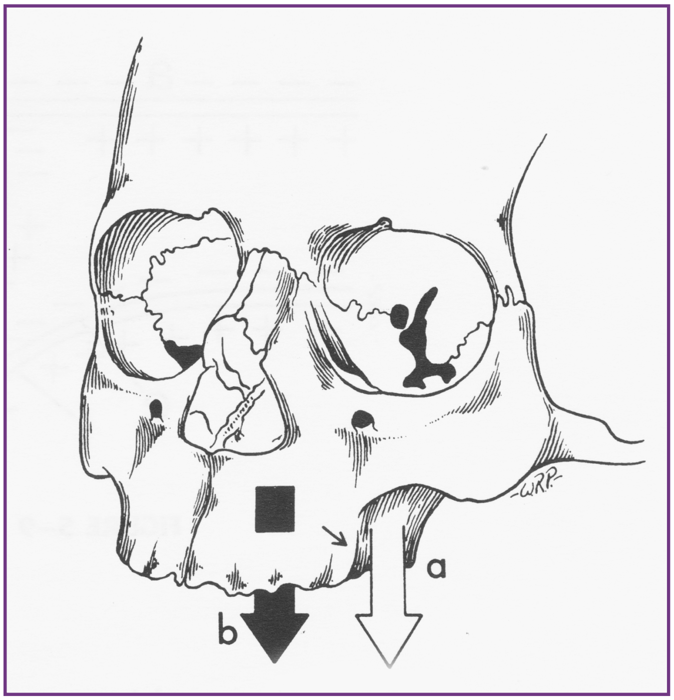

Figure 6

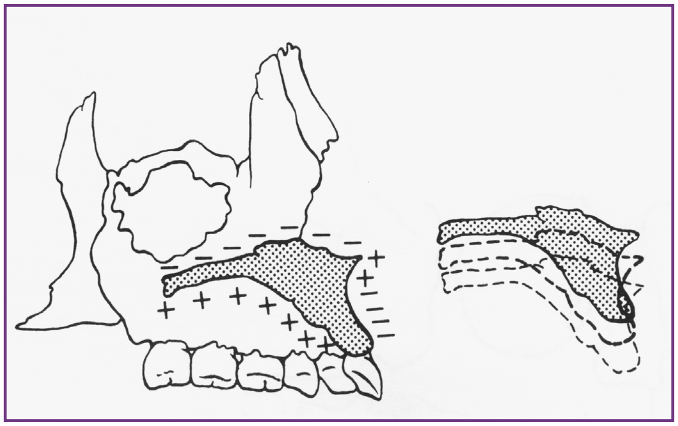

Figure 7

by deposits on the facial surface; and, it grows downward by deposition of bone along the alveolar ridges and on the lateral side. The endosteal surface is resorptive, and this contributes to maxillary sinus enlargement (Figure 6). There is a major change in the surface contour of the maxilla just below the malar protuberance (see arrow) called the key ridge. It is here that a major reversal of maxillary remodeling occurs. Anterior to the key ridge, the external surface of the maxilla is resorptive in nature and provides an inferior direction of arch remodeling in conjunction with the downward growth of the palate. Posterior to the key ridge, the external surface of the maxilla is depository in nature (through periosteal deposition) and is responsible for the posterior remodeling of the tuberosity and malar region.[1,2,22] This contradiction in remodeling principles comes into play clinically when maxillary expansion and tooth movement is required. This will be discussed in subsequent articles.

Vertical Drift of Teeth

As the maxilla and mandible enlarge and develop, the dentition drifts both vertically and horizontally to keep pace in respective anatomic positions. The process of drift moves the whole tooth and its socket as a unit and is not the same as eruption. The periodontal connective tissue membrane (not the ligament) initiates the intramembranous bone remodeling which changes the location of the alveolar socket and moves the tooth itself. The developmental vertical movements of teeth in normal growth serve to guide the teeth to a position where later eruption forms the foundation for a stable occlusion.[1,2,22] After eruption of the primary dentition, the clinician can use functional or growth guidance appliances to influence the vertical drift of the dentition to re-establish a stable functional occlusion.

The Nasal Airway

The surfaces lining the bony walls and floor of the nasal chambers are predominantly resorptive with the exception of the nasal side of the olfactory fossae. This pattern produces a lateral and anterior expansion of the nasal chambers while at the same time causes a downward relocation of the palate in which the oral side is depository.[1,2,23]

Palatal Remodeling

As previously discussed, the external surface of the anterior part of the maxillary arch is resorptive. As bone is added onto the inside of the arch, the arch increases in width, and the palate becomes wider. This is referred to as the "V" principle. Growth along the mid-palatal suture plays a role in the progressive widening of the palate and alveolar arch.[1,2]

As the palate grows inferiorly by the remodeling process, a nearly complete exchange of old-for-new hard and soft tissue occurs. At each descending level, the palate literally becomes another palate occupying a new position with different bone and altered soft tissue components. Figure 7.[1,2]

Natural increases in palatal width are attributed to vertical drift of the posterior teeth and lateral expansion occurring to the V principle of growth. Certain clinically-induced changes of the palate such as rapid or slow transverse expansion go against this biological principal and may lead to unstable consequences. The maxilla can be expanded into an unstable or imbalanced position. When a tooth-born device is used, fenestration of the bicuspid and molar roots is an almost certain consequence. Another important clinical point is that the mid-palatal suture (which such appliances separate) only plays a small role in the displacement of the maxillary alveolus laterally.[1,2,24] Thus, this type of transverse expansion is not biologically sound. There are other ways to clinically affect the maxilla and the alveolus that are biologically stable. These appliances will be discussed in subsequent articles.

Downward Maxillary Displacement

The primary displacement of the whole ethmomaxillary complex in an inferior direction is accompanied by simultaneous remodeling (resorption and deposition) in all areas, inside and out, throughout the entire nasomaxillary region. The process of displacement (by the expanding soft tissue) produces the "space" within which remodeling enlargement occurs. The balance between the greater or lesser amounts of displacement and remodeling growth in the posterior and anterior parts of the maxilla is a response to the clockwise or counterclockwise rotatory displacements caused by the downward and forward growth of the middle cranial fossa.[1,2,6,17]

Tooth Movement Basics

Another key to facial growth is tooth movement. Tooth movement serves several purposes. It positions the dentition into changing functional locations to achieve occlusion. This supports the fluctuating craniofacial relationships as they continue to undergo extensive development. The periodontal ligament serves as a pressure-to-traction adaptive cushion to the forces of mastication.[1,2,22]

The periodontal membrane is osteogenic connective tissue similar to both the periosteal membrane and a sutural histogenic membrane. The periodontal membrane undergoes its own remodeling, just as the bone does to provide movement, and this requires continuous reattachment of the connecting fibers. Upon mastication, the bone surface beneath a tooth is converted directly into tension through fibers within each socket. This translates pressure into direct tensions on alveolar bone affording the following functions: 1. Effective mechanical reinforcement, 2. Resilient stability, 3. Provides a biologic remodeling system for eruption, 4. Permits each tooth to reach a functional occlusial position, 5. Allows growth and remodeling maintenance of the alveolar bone, 6. Delivers vascular, nervous, and undifferentiated tissue which is needed for continued development, 7. Permits the vertical and horizontal drifting of each tooth along with the associated remodeling movements.

Drift of teeth is a three dimensional process. Teeth drift for two practical reasons: 1. To keep pace with the growth and remodeling of the maxilla and mandible and subsequent positioning to maintain occlusion. 2. To consolidate the dental arch during growth and maintain the interproximal contacts as the teeth progressively wear--thus bracing each arch to better withstand masticatory forces. A tooth cannot move itself; it must be physically moved by the soft tissue surrounding its root.[1,2,22]

Tooth movement is a precise process. The periosteal and periodontal connective tissue membranes are stimulated when a field of traction exists. When this occurs, the tension is generally osteoblastic, and the response is new bone deposition on the tension side. The periodontal ligament and alveolar bone simultaneously remodel creating tooth movement. The periodontal ligament and bone remodel until equilibrium is achieved, and the signals activating the movement are turned off. Orthodontic tooth movement manipulates these control systems through clinically-induced signals that override or modify these inherent signals.

Summary

Normal facial growth involves ongoing bone remodeling and displacement. Understanding the precisely controlled biological process of facial growth is essential to every clinician. Atypical growth begins when this biological balance is disturbed. The direct target for clinical intervention must be the control process regulating the biology of facial growth. With this knowledge, clinicians can adequately assess each patient and determine the causes of atypical facial growth patterns. The next article will describe the assessment of atypical facial growth, examine the causes of these atypical patterns, and define the optimal and most effective treatment plans to guide each individual patient back towards normal facial growth.

Recommended reading for a complete understanding of Facial Growth:

1. Enlow DH,Hans MG. Essentials of Facial Growth, 2nd ed. Ann Arbor, MI; Needham Press, Inc.; 2008.
2. Enlow DH, Bang S. Growth and remodeling of the human maxilla. *Am J Orthod* 1965; 51:446.
3. Enlow DH: Mandibular rotation during growth. In: Determinants of Mandibular Form and Growth. Ed. By J. A. McNamara, Jr. University of Michigan, Center for Human Growth and Development, 1975.
4. Enlow DH: Normal and abnormal patterns of craniofacial growth. In: Scientific Foundations and Surgical Treatment of Craniosynostosis. Ed. By J. A. Persing, M. T. Edgerton, and J. Jane. Baltimore; Williams and Wilkins, 1989.

Acknowledgements:

All Images are from: Enlow DH, Hans MG. Essentials of Facial Growth. Philadelphia, PA: WB Saunders; 1996. With permission.

References:

1. Enlow DH,Hans MG. Essentials of Facial Growth. Philadelphia, PA: WB Saunders; 1996.
2. Enlow DH,Hans MG. Essentials of Facial Growth, 2nd ed. Ann Arbor, MI; Needham Press, Inc.; 2008.
3. Rubin RM. Effects of nasal airway obstruction on facial growth. *Ear, Nose & Throat Journal* 1987; 66: 212-219.
4. Enlow DH, Bang S. Growth and remodeling of the human maxilla. *Am J Orthod* 1965; 51:446.
5. Enlow DH, Moyers RE: Growth and architecture of the face. *JADA* 1971; 82:763.
6. Enlow DH: Normal and abnormal patterns of craniofacial growth. In: Scientific Foundations and Surgical Treatment of Craniosynostosis. Ed. By J. A. Persing, M. T. Edgerton, and J. Jane. Baltimore; Williams and Wilkins, 1989.
7. Frost HM. Skeletal structural adaptations to mechanical usage (SATMU). Redefining Wolff's law: The bone modeling problem. Anat Rec 1990; 226:403-413.
8. Frost HM. A 2003 update of bone physiology and Wolff's Law for clinicians. *Angle Orthodontist* 2004; 74(1):3-15.
9. Katsavrias EG. Changes in articular eminence inclination during the craniofacial growth period. *Angle Orthodontist* 2002; 72(3): 258-264.
10. Shaw RB, Katzel EB, Koltz PF, Kahn DM, Girotto JA, & Langstein HN. Aging of the mandible and its aesthetic implications. Plast Reconstr 2010; 125: 332-342.
11. Shaw RB & Kahn DM. Aging of the mid-face bony elements a three dimensional CT study. Plast Reconstr 2007; 119: 675-681.
12. Enlow DH: Mandibular rotation during growth. In: Determinants of Mandibular Form and Growth. Ed. By J. A. McNamara, Jr. University of Michigan, Center for Human Growth and Development, 1975.
13. Enlow DH & Harris DB. A study of the postnatal growth of the human mandible. *AmJ Orthod* 1964; 50:25–50.

14. Frost HM. Mechanical determinants of bone modeling. Metab Bone Dis Rel Res 1982; 4:217-222.
15. Liua Y, Behrents RG, & Buschang PH. Mandibular growth, remodeling, and maturation during infancy and early childhood. *Angle Orthodontist* 2010; 80(1): 97-105.
16. Wanga MK, Buschangb PH, & Behrentsc R. Mandibular rotation and remodeling changes during early childhood. Angle Orthodontist 2009; 79(2):271-275.
17. Ranly DM. Craniofacial growth. Dental Clinics of North America 2000; 44: 457-470.
18. Epker, BN & Frost, HM. Frost. Correlation of bone resorption and formation with the physical behavior of loaded bone. *J Dent Res* 1965; 44:33.
19. Franchi L, Baccettib T, Stahlc F, & McNamara A. Thin-plate spline analysis of craniofacial growth in Class I and Class II subjects. *Angle Orthodontist* 2007; 77(4): 595-601.
20. Tsai H & Tan C. Morphology of the palatal vault of primary dentition in transverse view. *Angle Orthodontist* 2004; 74(6): 774-779.
21. Funatsu MK, Sato K., & Mitani H. Effects of growth hormone on craniofacial growth: Duration of replacement therapy. *Angle Orthodontist* 2006; 76(6):970-977.
22. Azuma M, Enlow DH. Fine structure of fibroblasts in the periodontal membrane and their possible role in tooth drift and eruption. *Japan J. Orthod* 1977;36:1.
23. Kahn DM & Shaw RB. Aging of the bony orbit: A three dimensional CT study. *Aesthet Surg J* 2008; 28:258-264.
24. Frost HM. Some ABCs of skeletal pathophysiology: Microdamage physiology. *Calcif Tissue Int* 1991;49:229-231.

Dr. Steve Galella has worked with Otolaryngologists and Reconstructive Surgeons assisting in trauma surgery on over 3,900 patients impacted by facial trauma. Through the combination of performing surgeries, clinical work, and extensive literature reviews, he developed an innovative approach to orthodontic treatment and beauty enhancement. Dr. Galella is a Diplomate, International Board of Orthodontics, and a Master Senior Instructor and past president of the International Association for Orthodontics. He also is director of the International Association for Orthodontics Instructors Institute and the developer of the ControlledArch® Orthodontic Technique.

Dr. Daniel Chow is a graduate of the University of Liverpool, School of Dental and Oral Surgery in England and a graduate of Columbia University, School of Dental Medicine. He is a Master of the Academy of General Dentistry, Fellow and Past President of the New York Academy of Oral Rehabilitation, Fellow of the International Association of Orthodontics, and Fellow of the International Academy for Dental Facial Esthetics. He is a Certified Senior Instructor for the International Association of Orthodontics, the Facial Beauty Institute, and the International Association for Orthodontics Instructors Institute.

Dr. Earl Jones has an extensive background in anatomy and physiology as well as growth and development. He is an authority on facial aesthetics across various ethnic groups and has dedicated his practice to growth guidance and treating atypical growth in children and adolescents. He is past president of the International Association of Orthodontics, and aSenior Instructor of the IAO Instructors Institute. He is also a senior clinical instructor for the Facial Beauty Institute and the International College of Orthopedics and Orthodontics.

Dr. Donald Enlow is author of numerous papers and books on the growth and organization of bone, including how they relate to human facial development and dentistry. His research in the area of hard tissue biology and bone remodeling helped to establish the principles by which bone is maintained and adapts to its mechanical circumstances. His expertise in craniofacial development, particularly in relation to orthodontics, is also widely recognized as the foundation for understanding the role that bone growth and remodeling mechanisms play in the development of the childhood face.

Dr. Ari Masters is an established clinician of 20 years, an I.A.O Senior Instructor and an international lecturer. He has shown himself to be a forerunner in the development of Dentofacial Orthopedics and its assimilation into more traditional Orthodontics. He is best known for creating big beautiful smiles and full faces, often without using braces and most certainly without extracting adult teeth. The key to his success is his belief in early intervention orthodontic treatment , respecting the airway and TMJ. He addresses general dentists, pediatric dentists and orthodontists on the topics of growth and development , the importance of non-extraction orthodontics, and also forecasts future trends in dentistry.