Reprinted from ORAL SURGERY, ORAL MEDICINE, ORAL PATHOLOGY, St. Louis
Vol. 63, No. 6, pp. 637-644, June, 1987, (Printed in the U.S.A.)

Balanced facial growth: a schematic interpretation

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Balanced facial growth is a complex process that involves maxillary, mandibular, dental, and cranial growth. Growth of the maxilla is due to special movements of translation, rotation, and elongation as well as to growth of its skeletal units and skeletal structures. Growth of the mandible is the sum of growth of all of its skeletal units. Cranial growth influences both maxillary and mandibular positions, which themselves can vary interdependently, in part because of the mutual influences of the maxillary and mandibular dentitions.
(ORAL SURG. ORAL MED. ORAL PATHOL. 1987;63:637-44)

Among the phenomena responsible for potential craniofacial growth, the most important are the relative movements of skeletal parts. These movements are principally responsible for (1) *growth* of the various skeletal components of the craniofacial complex and, thus, of the face itself and (2) craniofacial *equilibrium,* both normal and pathologic, that is to say, the mutual relationship of the various skeletal elements of the face either in normal subjects or in those who have dentofacial dysmorphoses.

The notion of craniofacial equilibrium concerns not only the skeletal elements but also the soft tissues. In all cases, both normal and pathologic, there exists an equilibrium of all skeletal elements, not only of the face but also of the cranial base and vault and the cervical spine. This skeletal equilibrium is associated with an equilibrium of the soft tissues, which can itself be either normal or pathologic.

It is the purpose of this article to present a review of maxillary and mandibular growth, the understanding of which can aid the clinician both in making clinical diagnoses and in finding therapeutic indications for dentofacial orthopedic and surgical procedures.

MAXILLARY GROWTH

In this section, we shall stress the movements of the maxilla that are responsible for growth of the membranous sutures that unite each maxillary bone to the other bones of the face and cranial base. *Because this sutural growth takes place in response* to maxillary displacement,[1] one can say that movements of the maxilla are themselves the fundamental agents of its growth, particularly in the forward and

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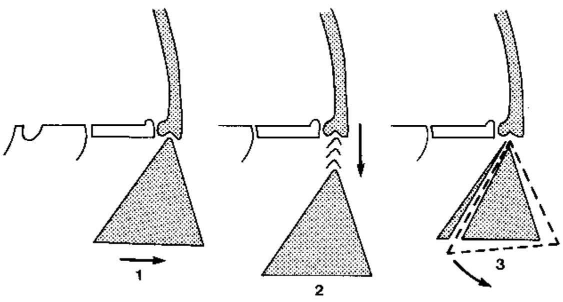

Fig. 1. Three types of maxillary movements: *1,* Translation with the frontal bone. *2,* Vertical elongation. *3,* Anterior rotation, which both advances and elongates the inferior part of the maxilla.

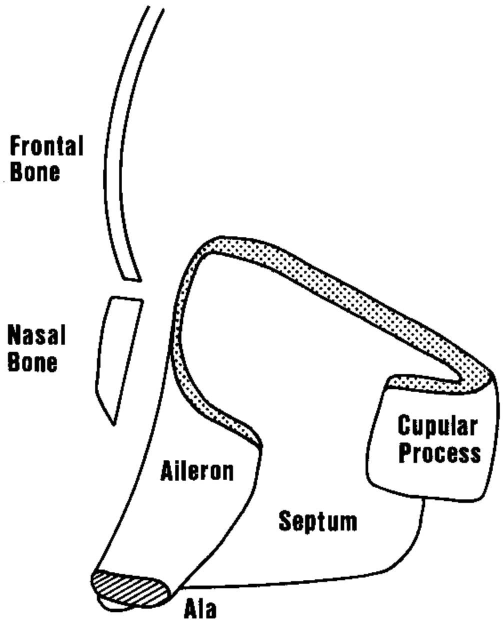

Fig. 2. Schematic representation of cartilaginous mesethmoid of newborn human infant. This structure is the pre- and postnatal tissue developed from the embryonic nasal capsule. (After Couly: Rev. Stomatol. Chir. Maxillofac. 81: 135-151, 1980.)

transverse directions. In the vertical direction, sutural growth is complemented by palatine and alveolar apposition and resorption of bone.

Movements of the maxilla

There are three types of maxillary movements (Fig. 1):[2] (1) *translation* of the maxilla (posteroanterior) with the frontal bone to which it is attached below the frontal sinus; (2) *elongation* of the maxilla to effect its vertical lowering; and (3) *rotation* (anterior) of the maxilla attached to the frontal bone, which both advances and elongates the inferior part of the maxilla.

Translation. Translation of the maxilla occurs in a different manner before 3 to 4 years than after this age. In the newborn and the young child, the frontal bone, underneath which the maxilla is attached, advances rapidly because of the influence of both the actively growth brain and the cartilaginous mesethmoid (nasal capsule and nasal septum)[3] (Fig. 2).

Toward the end of the third year, cerebral growth slows considerably but the cartilaginous mesethmoid continues to grow actively, resulting in separation of the external cortex of the frontal bone from the internal cortex which, in turn, carries along the formation and development of the frontal sinus (Fig. 3).

The maxilla, which is attached to the external cortex of the frontal bone, continues to be displaced (albeit variably) according, in part, to the degree of activity of growth of the cartilaginous mesethmoid and, in part, to the type of dental occlusion, the forces of which are transmitted to the superior extremity of the vertical process of the maxilla.

This forward migration of the maxilla can continue throughout the duration of growth of the frontal sinus, which is to say, until the end of puberty and even into adulthood.

Elongation (Fig. 4). The lowering of the maxilla, which is responsible for its vertical elongation, is also different before and after 3 to 4 years of age. Before the age of 3 to 4 years, the maxilla receives an active push from the globes and ocular contents, the growth of which parallels that of the brain. The maxilla is, therefore, pushed down from above by the superior part of the face and, at the same time, pulled down from below by its various muscular connections with the mandible, the soft palate, and the tongue. The nasal septum also probably contributes to the lowering of the anterior nasal spine.[5,6]

After the age of 3 to 4 years, the pushing of the globes becomes negligible, and the maxilla is only under the influence of traction from below, which therefore reduces the velocity of its descent. In addition, orbital periosteal apposition-resorption phenomena compensate in the same direction and quantity as the bony apposition, which takes place at the frontomaxillary suture. This results in descent of the nasal floor relative to the level of the orbital floors. Descent of the bony palate also results from the phenomenon of apposition on its inferior surface and from resorption on its superior surface, which further carries along the vertical elongation of the

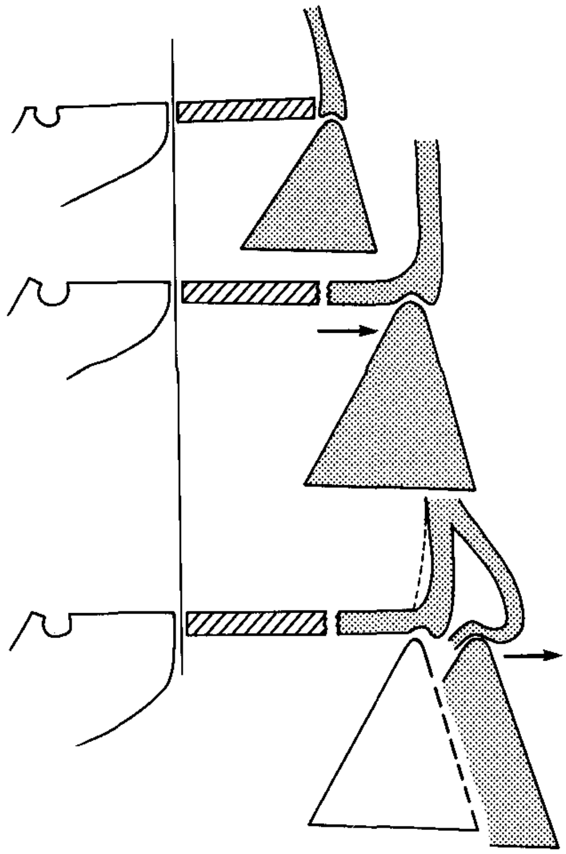

Fig. 3. Translation. From birth to about 3 to 4 years of age, translation (forward migration) of maxilla is influenced by both actively growing brain and cartilaginous mesethmoid. After 3 to 4 years of age, translation of maxilla is carried along by formation and development of frontal sinus.

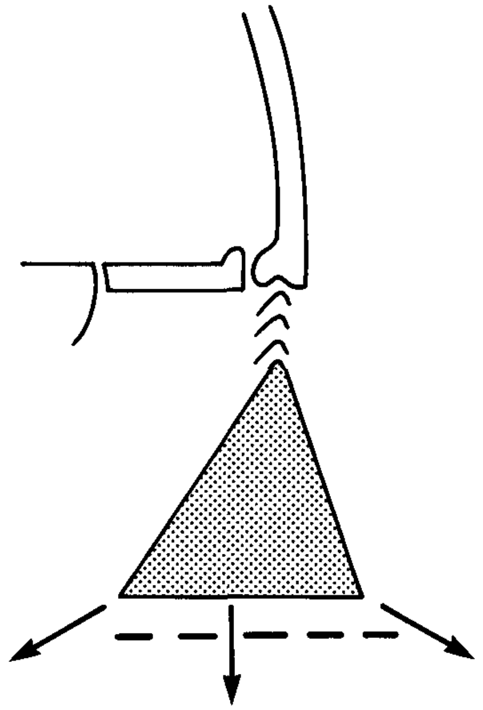

Fig. 4. Vertical elongation of maxilla. Before 3 to 4 years of age, the maxilla not only is pushed down by the influence of the growing globes and ocular contents, but it is also pulled down by its various muscular connections with the mandible, soft palate, and tongue.

nasal fossae. Laterally, the development and pneumatization of the maxillary sinus parallel the formation of the tooth buds and the development of the denture.

Rotation. Anterior rotation of the maxilla is less evident than the preceding maxillary movements for two main reasons. First, its activity varies with age during two periods, from birth to 1½ years and then again at puberty, remaining relatively stable in the interim; with sex, in that it is more important in males; and with functional ambience. Second, it is accompanied by an upward movement of the nasal bones and an ascension of the nose, a movement impossible to observe when one uses only the SNA angle to appreciate the forward position of the maxilla.[7]

We believe that this maxillary rotation has considerable importance in establishing either normal or pathologic facial balance. Normally, there exists a strict correlation between the maxillary orientation and the position of the bony menton, which are in the same alignment when the face is in good balance. Schematically, the orientation of the maxilla can be appreciated by looking at the angle formed between the line drawn from the frontomaxillary articulation to the entrance of the nasopalatine canal, and the line joining the summit of the clinoid process with the frontomaxillary articulation (Fig. 5). The rotation of the maxilla is about 80° at birth, 85° from 2 years of age until puberty, after which the adult female retains about an 85° angle while orthofrontal white adult males attain an angle of about 90° (Fig. 6).[8] This angle is normally variable with cranial type and the form of the cranial base.

In craniofacial dysmorphoses, particularly skeletal Class II and III types, and in certain severe craniofacial anomalies, this angle can come under significant variation. In these cases, this variation results in loss of the normal relationship of maxillary orientation relative to the position of the bony menton,

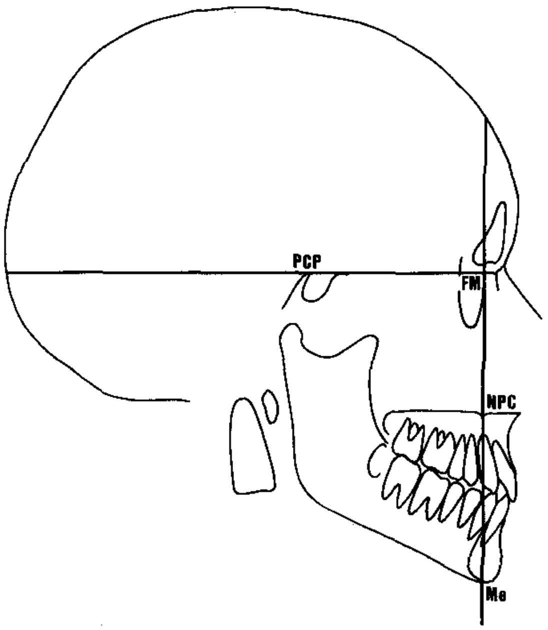

Fig. 5. Orientation of maxilla can be appreciated by angle formed between line drawn from frontomaxillary articulation *(FM)* to entrance of nasopalatine canal *(NPC)* and line joining summit of posterior clinoid process *(PCP)* with frontomaxillary articulation.

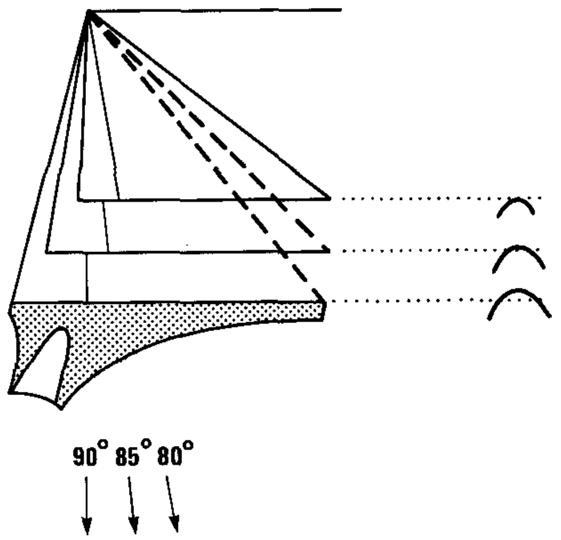

Fig. 6. Degree of maxillary rotation is about 80° at birth, 85° from 2 years of age to puberty, 85° in adult female, and 90° in orthofrontal white adult male. When the face is in good balance, the extended line FM-NPC passes through the inferior point of the bony menton as in Fig. 5.

which we believe to be one of the principal characteristics of pathologic balance of the face.

The transverse maxillopalatine suture is responsible for forward growth of only the lower part of the maxilla and, hence, contributes to both migration and anterior tilting of the maxilla.

Skeletal units and skeletal structures

In addition to maxillary movements, two other important phenomena contribute to maxillary growth. These are augmentation in volume and dimension of the premaxillary and dentoalveolar skeletal units, and augmentation of skeletal structures, particularly the anterior maxillary pillar and the maxillary sinus.

Before reviewing these characteristics, let us define the terms *skeletal part, skeletal unit,* and *skeletal structure.*

A *skeletal part* is an anatomic bone that is completely distinct from other bones—for example, the humerus, the femur, the mandible, and various bones of the face and cranium that are separable along the lines of existing membranous sutures.

A *skeletal unit* is a portion of a skeletal part, which is impossible to separate from it but which possesses an individuality and peculiarities, notably those that concern growth. A skeletal part can be formed by several skeletal units, which have limits that are a bit imprecise but which are different enough to be considered individual entities. (This is the basic concept of Moss,[9] who calls these units, grouped together to form a bone, "microskeletal units"). The premaxilla and the dentoalveolar unit are two skeletal units, the growth of which we shall consider separately.

A *skeletal structure* is characterized by modification of osseous material, which can be thickened, as in a structure of reinforcement, or thinned, as in a lightened structure. In the maxilla, the bony pillars of reinforcement (described by Ombredanne and Brocq[10] and Sicher[11]) are typical skeletal structures. Among these, the canine eminence (which we prefer to call the anterior maxillary pillar) and the maxillary sinus are the most important. Skeletal structures are usually organized along systems of reinforcement that often involve several neighboring bones.

Maxillary skeletal units

Premaxillary skeletal unit. The premaxillary skeletal unit has undisputable individuality. From the time of their appearance until the sixth week in utero, the maxilla and the premaxilla are completely separate, but instead of remaining so, as in animals, they fuse at about the eighth week.[12] From this age forward, there no longer exists a truly independent human premaxilla; instead, the fused premaxilla becomes a skeletal unit, conserving its own important peculiarities and even defined limits, relative to the maxilla. In the newborn and the infant, there persists a true membranous premaxillary-maxillary suture that extends transversely across the nasopalatine canal from the alveolus of one canine tooth to the other and from the buccal slope to the nasal slope of the bony palate. With the exception of the vestibular aspect lateral to the canine teeth, this suture is open until the eruption of the maxillary permanent incisors, after which time it progressively closes from without and within.[5] It generally remains visible throughout adolescence in spite of periosteal bony apposition on the buccal surface of the palate, a fact that confirms its physiologic activity (Fig. 7).[5]

Growth of the premaxillary skeletal unit depends, to a great extent, on the formation and development of the primary incisor teeth and then later the permanent incisor teeth, the number, volume, and occlusal relationship of which influence both the actual mass of the premaxilla and its development.

The premaxillary skeletal unit is also influenced by that part of the cartilaginous nasal septum to which it is directly united by the following:

- A fibrous connective tissue band, which Latham[13] has described as the septomaxillary ligament but which we believe forms the cellulous septum of the upper lip.[6]
- Bilateral fibers of the transverse portion of the nasalis, levator labii superioris, levator labii superioris alaeque nasi, oblique bands of the orbicularis oris, and depressor septi muscles which are inserted on the anteroinferior part of the nasal septum.[6]

The chronology of premaxillary growth differs from that of the maxilla in that the former is significantly reduced, both in transverse and posteroanterior expression, after 7 years of age, while the latter continues to grow actively, particularly in the posterior part, as has been so clearly demonstrated by Bjork and Skieller.[14]

Maxillary dentoalveolar skeletal unit. The maxillary dentoalveolar skeletal unit is directly dependent on the development, number, size, and eruption of the teeth. The bone is actually made up of the dentoalveolar ligaments and periosteum. The variable situation, in three dimensions, of this skeletal unit depends on functional influences from the opposing dentition, tongue, cheeks, and lips, and the state of balanced growth of the craniocervical-facial complex in general. Moreover, the maxilla itself, which carries the maxillary dentoalveolar skeletal unit, will be influenced by these biomechanical effects and thus will be subject to variation in skeletal structure.

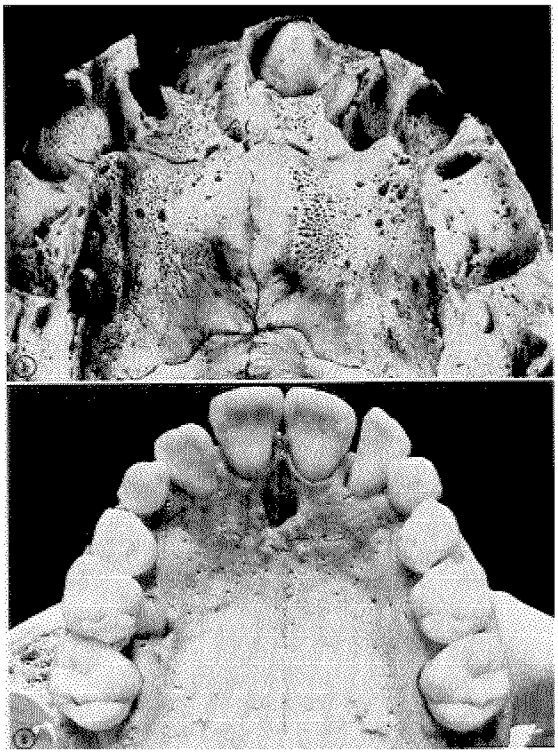

Fig. 7. Premaxillary-maxillary suture in a 10-day-old infant (A) and a child of about 9 years of age (**B**)

Maxillary skeletal structures

Anterior maxillary pillar. The maxillary structure of reinforcement, which is often referred to as the canine eminence, should be termed the anterior maxillary pillar because, contrary to the implication of the term "canine eminence," this pillar depends not only on canine function but also on function of the incisors, premolars, and even, in part, the first permanent molar. External cortical thickenings overlying these teeth sweep up over the apex of the canine tooth, skirt the pyriform aperture, and finally ascend the frontal process of the maxilla (Fig. 8). These ascending spans are joined with others from the malar bone to form the anterior lacrimal crest. Finally, together, the spans arrive just under the frontal sinus where they diverge and spread out in the walls of this sinus. Anteriorly, they participate in the formation of the bulge of the frontal sinus in the region of the glabella, while laterally they form the superciliary ridges. Many maxillary "hypoplasias" are actually hypotrophies caused by hypofunction

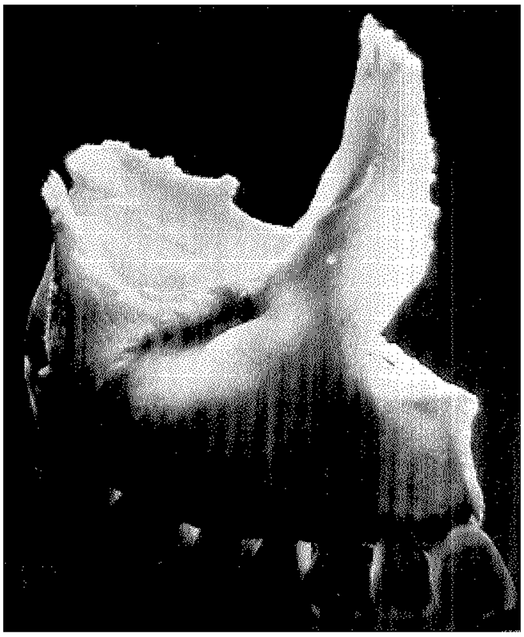

Fig. 8. Anterior maxillary pillar. Note that this pillar receives cortical thickenings which overlie not only the canine tooth but also the incisors and premolars and even the first molar.

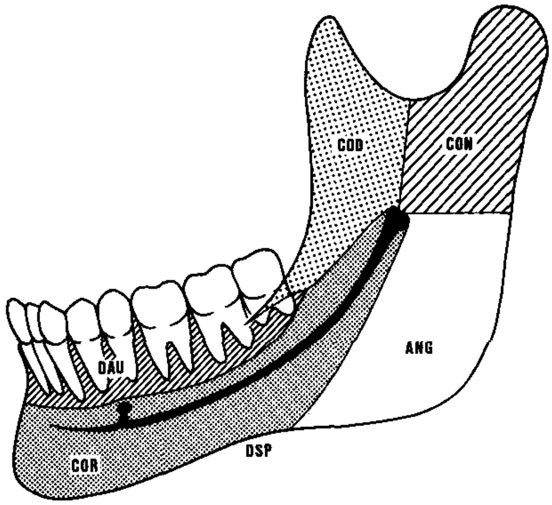

Fig. 9. Skeletal units of mandible; *COR*, corpus; *CON*, condyle; *COD*, coronoid; *ANG*, angle; and *DAU*, dentoalveolar unit. Growth of the mandible is the sum of growth of each of these skeletal units.

and hypodevelopment of the anterior maxillary pillar, a distinction that is important in the timing of therapeutic intervention.

Periosteum. There is important periosteal bony apposition on the posterior surfaces of the maxilla but, as Enlow and Dale[15] have shown, the anterior maxillary surface is one of resorption. As the maxilla advances, posterior appositional compensation takes place and forms the maxillary tuberosity, for which posterior limits are determined by the soft tissues of the pterygomaxillary fossa, notably the pterygoid muscles.

MANDIBULAR GROWTH

Hall[16] stated, "The cells that will ultimately form Meckel cartilage, the dental lamina and teeth, condylar secondary cartilage and the corrective tissue of the mandible arise in the embryonic neural crest." *Although Meckel's cartilage is intimately associated* with the developing human mandible, it makes no direct contribution to it, as Ten Cate[17] has stated.

By 10 weeks, the rudimentary mandible is formed entirely by membranous ossification (not by endochondral ossification of Meckel's centilage). Three secondary cartilages now appear: the condylar, coronoid, and symphyseal cartilages. The condylar cartílage appears at about 12 weeks as a cone-shaped structure that occupies almost all of the developing ramus. By 20 weeks, most of the condylar cartilage has undergone endochondral ossification, leaving only a thin cap of cartilage over the condylar head.

The coronoid cartilage, which appears at about 4 months in utero, is transient in that it forms the coronoid process and the anterior border of the ramus but disappears long before birth.

The two symphyseal cartilages, which arise independent of—but between—the two ends of Meckel's cartilage, undergo endochondral ossification and then disappear within the first year after birth.[17]

Although one commonly held view is that the mandibular corpus is formed by relocation of the mandibular ramus, we have frequently observed patients who have congenital malformation or osteomyelitis of the condyle or, indeed, sometimes an absence of all of the condyle coronoid and angle, and yet have a corpus that is only slightly reduced in dimension. Let us recall that the first ossification in the mandible appears during the seventh embryonic week, *at the point of bifurcation of the inferior* alveolar nerve into its incisive and mental branches. Also, we should recall that the corpus is already well formed when the condylar cartilage appears between the twelfth and fourteenth weeks, nearly 1½ months later. Thus, we do not believe that the mandibular corpus is formed by relocation of the ramus.

Growth of the mandible, in its totality, is the sum of growth of each one of the mandibular skeletal units (corpus, condyle, coronoid, angle, and dentoalveolar unit), *all of which have been well described by* Moss (Fig. 9).[18]

The coronoid process is dependent for growth on its attachment to the temporalis muscle, and the mandibular angle similarly depends to a great extent on the masseter and medial pterygoid muscles as well as the activity of neighboring skeletal units.

As soon as the corpus is formed, it elongates posteriorly around the inferior alveolar neurovascular bundle, which serves as a guide. Thus, there exists an active site of bony growth of periosteal type in the region of the future entry of the inferior dental canal. Later, when the condylar cartilage forms, this growth site will constitute, in our opinion, the principal factor responsible for growth of the corpus.

According to this concept, the condylar cartilage will be responsible for growth of only that segment which extends from the condylar summit to the entry of the inferior dental canal.

Mandibular length will increase as a result of two different but related growth activities, one of the condylar unit and the other of the corpus. Each of these growth activities is variable in both quantity and direction, which explains the wide variation not only in the length and form of the human mandible but also in the degree of posterior or anterior rotation, which Bjork and Skieller[19] described so well.

The inferior dentoalveolar skeletal unit, which sits on top of the corpus, can also be variably situated according to the number and position of the teeth, occlusal function, and stimuli received from the tongue, lips, and cheeks.

Like the maxilla, the mandible is carried by the base of the skull at the mandibular articulation with the temporal bone. The temporal bones, particularly the petrous pyramids, are very mobile in the newborn and young infant. The situation of the temporomandibular articulation, the condyles, and indeed the entire mandible can vary according to the length, and the posteroanterior and vertical orientation, of the petrous pyramids.

Thus, individual variation can exist in both the distance separating the frontomaxillary articulation from the temporomandibular articulation and its vertical situation.

One can see, therefore, that mandibular growth adapts to maxillary growth and, inversely, maxillary growth is influenced by mandibular growth.

Normally, a balanced condition results from adaptive compensation of the entirety of the maxilla, mandible, and dentoalveolus. Pathologic equilibrium results when variations exceed the adaptive compensatory reserve, particularly when abnormal *cephalic posture and linguomandibular imbalance* intrude.

CONCLUSIONS

The following conclusions can be drawn:

1. Maxillary growth results from movements of forward translation of the maxilla with the frontal bone, anterior rotation with forward advancement of the lower part of the maxilla, and vertical elongation with descent of the palate.

2. Maxillary growth also results from particular growth of skeletal units, both premaxillary and dentoalveolar, and skeletal structures, particularly the anterior maxillary pillar and the maxillary sinus.

3. Maxillary growth depends on diverse influences that are both constitutional and functional in nature. Constitutional influences include pushing of the growing brain, ocular globes and contents, and certainly the cartilaginous mesethmoid (nasal capsule and nasal septum). Functional influences include those transmitted to the lower part of the maxilla by the muscles of the tongue, the cheeks, the lips, the soft palate, and the dental occlusion during mastication and deglutition.

4. Mandibular growth is the sum of growth of the various skeletal units of which the corpus, condyle, and dentoalveolar units are the most important. The size, situation, and orientation of these units can vary, which explains not only variations in mandibular form but also mandibular adaptation in order to achieve skeletal facial balance.

5. Mandibular growth, and hence the final situation of the corpus and bony menton, is influenced by the orientation of the petrous pyramids of the temporal bone, which determines the situation of the temporomandibular articulation. This situation can vary further according to cranial type and cephalic posture, resulting in large variations in position and orientation of the mandible and, in turn, the entire facial skeleton.

6. The mandible normally adapts to the maxilla, but the maxilla also adapts to the mandible. Normal maxillomandibular equilibrium is objectively demonstrated by the straight line that in most cases joins the following anatomic points: frontomaxillary articulation, entrance of the nasopalatine canal, and inferior point of the bony menton.

7. In both normal and pathologic facial balance, there is an equilibrium of all skeletal elements, not only of the face but also of the cranial base and vault, and the cervical spine. This skeletal equilibrium is

associated with a soft tissue equilibrium, which can also be normal or pathologic.

8. Pathologic soft tissue balance can cause skeletal abnormalities. Skeletal equilibrium that is pathologic can cause soft tissue abnormalities.

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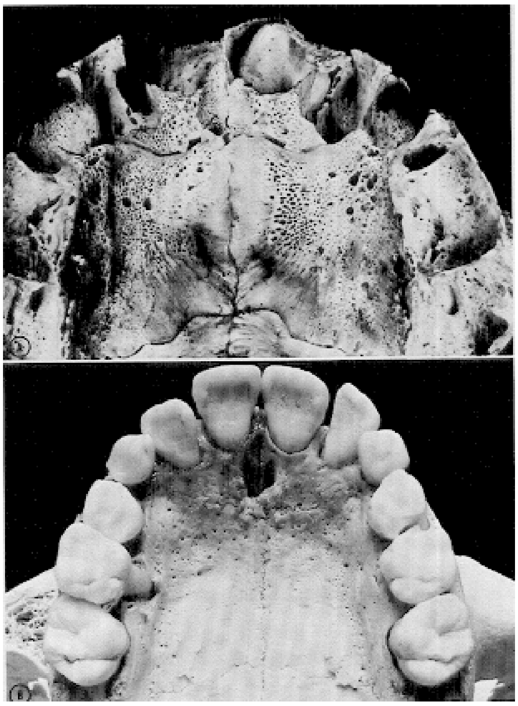

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