COURSE ID: ODO. 12-1
CRANIOFACIAL GROWTH AND DEVELOPMENT

FOCUS ON BASIC ROLE OF GROWTH AND DEVELOPMENT IN DIAGNOSIS,
TIMING AND TYPE OF TREATMENT IN GROWING INDIVIDUALS
Series includes lectures, seminars, review of key articles,
And presentations by residents of selected assignments

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Goals: This series of lectures and seminars, as well as the following review of articles should enable the resident to:
1. Define and understand the basic growth concepts (area relocation, appositional growth, displacement, remodeling, resorption, deposition, fusion).
2. Understand the growth and development of the main craniofacial components: cranial base, maxilla, and mandible, and their interrelationships at different stages of growth.
3. Understand the tissues involved in facial growth: bone, cartilage and muscle.
4. Understand the differences in facial form and patterns.
5. Understand major deformities of growth.
6. Understand why and how knowledge of facial and somatic growth and development is critical to early treatment of malocclusion through prevention, interception, or early correction of interferences with normal development that lead to malocclusion.

Objectives: The resident should:
Know the basic tissues involved in craniofacial growth, particularly bone and cartilage (muscles are addressed in a specific course).
Know the different locations of cartilage in the head.
Differentiate and identify the endochondral and intramembranous modes of bone formation, and the facial bones involved in each modality.
Know the basic craniofacial growth concepts including area relocation, bone displacement, processes of appositional growth and depositional resorption, and issues of modeling, remodeling, and the V principle.
Know sites and mechanisms of growth of the cranial base, the influence of this growth on the position of the growing maxilla and mandible, and the factors that lead to anomalies of cranial growth.
Know the patterns and mechanisms of maxillary growth in all 3 planes of space, and the influence of sutural growth on maxillary development.
Know the patterns and mechanisms of mandibular growth in all 3 planes of space and the role of condylar growth in mandibular development.
Know the various theories of growth, including Moss’s functional matrix and related control processes of facial growth (the relationship between somatic and facial growth addressed in a separate course).

Evaluate the evidence behind the existing theories on facial growth.

Know how craniofacial development translates at the level of the dentition and occlusion.

Know the basic growth events that may represent opportunities for growth modification through dentofacial orthopedics.

Know deviations from normal development that represent or may lead to facial deformities, including genetic components (details object of specific other courses).

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**COURSE DURATION AND SCOPE:** This course is scheduled in the Fall and Spring of the first year of residency. It is given every Friday in a 2-hour session between 9:30 and 11:00 a.m. It imparts fundamental knowledge about growth concepts and focuses on the development of different craniofacial structures, their interrelationships, and theories of growth.

**POLICY ON EXAMINATIONS:** One final examination is given for this course, usually in July. During the course, a number of progress tests or assignments may be given. Their cumulative weight in proportion to the final grade may not exceed 50%.
CRANIOFACIAL GROWTH AND DEVELOPMENT

**SUMMARY OUTLINE**

- SECTION 1: INTRODUCTION
- SECTION 2: TISSUES OF THE INFRASTRUCTURE: BONE AND CARTILAGE
- SECTION 3: BASIC GROWTH MECHANISMS
- SECTION 4: NEUROCRANIUM- CRANIAL BASE
- SECTION 5: GROWTH OF THE MAXILLA
- SECTION 6: GROWTH OF THE MANDIBLE
- SECTION 7: CONTROL PROCESSES OF FACIAL GROWTH

**COURSE OUTLINE**

### SECTION 1: INTRODUCTION

**KEY CONCEPTS**

Facial growth is dynamic.
The face is “built on the brain”.

1. FACIAL GROWTH

   Facial growth characterized by continuous and time-dependent rates of changes (i.e. skull sizes are different at different ages).
   - Facial growth continues throughout life. Rate of change decreases over time.
   - Teeth are unique: no change or growth after eruption.

   Key concepts
   
   a. The face grows out from underneath the brain.
   b. Brain formed first. At birth: face is very small compared to the brain.
   c. In baby's face: eyes big and low in relation to rest of skull.
   d. Faces of younger vs. adult people: rounder, smoother, and less angulated.
   e. Correspondence between faces and head forms
   f. No part of face is developmentally independent
   g. Mandible is facial bone that grows for longest period of time. Its position is a direct reflection of the glenoid fossa configuration.

2. FACIAL TYPES

   A. General differences in people's faces: long, thin vs. short, fat.
   
   a. Brachycephalic
- Wide head that is shorter front to back.
- Compatible with smaller, wider noses (pug nose)
b. Dolichocephalic: long, thin, tapered head
c. Mesocephalic: Intermediate between brachycephalic and dolichocephalic

B. Regional variations in head forms (i.e. north vs. south India).

SECTION 2: TISSUES OF THE INFRASTRUCTURE-
BONE AND CARTILAGE

KEY CONCEPTS
Bone can only change by appositional growth.
Cartilage changes by appositional and interstitial growth.
Bone cells stay encased in their mineral matrix.

1. BONE

A. Bone is a calcified tissue thus providing rigid support.

B. Bone histology overview
Bone is a structural tissue consisting of:

a. Cells
Osteoblasts (responsible for synthesis of organic components of bone matrix). Derive from osteoprogenitor cells. Do not divide: give rise to osteocytes, remain as osteoblasts or return to state of osteoprogenitor cells.
Osteocytes: mature osteoblasts (encased in calcified matrix or lacunae). Have reduced synthetic activity and are not capable of mitotic division.
Osteoclasts: multinucleated cells derived from monocytic-macrophage system; responsible for bone resorption.

b. Bone matrix
Organic components: type I collagen (95%) and amorphous material, including glycosaminoglycans and proteins
Inorganic components: about 50% of dry bone weight (calcium, phosphorus, bicarbonate, citrate, magnesium, potassium and sodium.)

C. Bone internal architecture

a. Osteons
Basic unit of structure of compact or lamellar bone
They are the product of repair or biochemical remodeling.
May not be seen in young bone or developing cells because they are a product of breakdown.

b. Cutting and filling cones
Responsible for internal remodeling of bone
Has a head of osteoclasts and a tail of osteoblasts
Responsible for secondary osteon formation
This mechanism allows replacement of previously formed bone and used to maintain constant calcium levels in blood.
D. Bone soft tissue covering
   a. Bone has a soft tissue covering over all hard surfaces.
      Endosteum covers inside surface of bone (marrow space).
      Periosteum covers outside surface of bone.
   b. Both membranes contain abundant supplies of blood vessels and nerves.
   c. Endosteum and periosteum contain osteoprogenitor cells.
   d. Resorption and deposition take place on both endosteal and periosteal surfaces of a bone.

E. Types of bone
   Endochondral bone: first formed as cartilage then converted to bone (i.e. humerus, ulna, radius).
   Intramembranous bone - bone develops from direct transformation of condensed mesenchyme (i.e. facial bones, kneecap).

F. Bone growth
   a. Bone is a living tissue that adapts to environmental conditions such as gravity, tension and pressure.
   b. An individual bone grows by 2 means: modeling and remodeling.
      Modeling is a process in which bone achieves its final shape during growth.
      Remodeling is the combination of apposition and resorption which can simultaneously occur on both endosteal and periosteal surfaces. It maintains the form of a bone and provides for its enlargement.

G. The V principle
   a. Many facial and cranial bones, or parts of bones, have a V-shaped configuration.
   b. Bone deposition occurs on inner side of the V.
   c. Bone resorption occurs on outer side of the V.
   d. The V will move towards its wider end and will increase in size.

2. CARTILAGE

A. Cartilage properties
   A structural tissue like bone.
   Semi-rigid tissue.
   Unique because pressure-tolerant, unlike bone.
   Can be found on the ends of bone (e.g. hyaline cartilage).

B. Cartilage histology
   Has an amorphous cellular structure that allows for diffusion of nutrients to the cartilage cells (chondrocytes).

C. Cartilage growth
   Cartilage undergoes both interstitial (growth within tissue) and appositional (growth at surfaces) growth.
   Cartilage made up partially of chondrocytes.
As cartilage cells divide and grow, they get replaced by bone resulting in lengthening of bone.

Four regions in epiphyseal plate responsible for formation of cartilage then conversion to bone:
- Resting zone
- Proliferation zone
- Hypertrophic zone
- Calcification zone

SECTION 3: BASIC GROWTH MECHANISMS

KEY CONCEPTS
Area relocation is where specific areas of bone are relocated to near areas through bone growth.
Bone displacement occurs when an entire bone is moved to a new location.
Processes of appositional growth and depositional resorption.

1. MODES OF GROWTH

A. Basic concept of bone growth: bone can only change at its surface.
B. Two modes of growth
   1. Remodeling
      a. It is the combination of apposition and resorption, which can simultaneously occur on both endosteal and periosteal surfaces. It maintains the form of a bone and provides for its enlargement.
      b. Function: Area relocation.
      In the face, areas that are part of one structure sometimes get relocated and become part of another structure. Example: Growth of mandible:
         b1. A part that was once a part of the ramus is now a part of the corpus.
         b2. Deposition: bone deposited at posterior surface of ramus.
         b3. Resorption: bone resorbed at anterior border of ramus
         b4. Processes of area relocation permit eruption of 2nd molars at age 12 and 3rd molars at age 18-25.
         More room is created for the developing dentition as areas of the mandible become relocated to new areas.
   c. Growth fields
      c1. Difference between growth centers and growth fields.
      c2. Distribution: mosaic-like pattern on inner and outer surfaces of a bone.
      c3. Specific placement of the boundaries between growth fields.
      c4. Differential rates and amounts of deposition and resorption towards each field.
      c5. Timing of the growth activities among the different fields.

2. Displacement
   a. Involves movement of the whole bone.
   b. Occurs at suture lines. Amount of enlargement equals extent of displacement.
c. Primary displacement: process of physical movement related to a bone’s own enlargement.
d. Secondary displacement: one bone displaces another bone as the first bone is moved; the visible effect is result of a growth event that happened in another place

C. The face is continually remodeled and displaced. It changes as it grows out from under the brain.

D. Displacement must occur first and then remodeling will take place as bone grows.

2. WAYS TO STUDY GROWTH

A. Implants (Bjork’s studies)
B. Vital dye markers
C. Superimposition of headfilm tracings

SECTION 4: THE NEUROCRANIUM
CRANIAL BASE GROWTH AND DEVELOPMENT

KEY CONCEPTS
The cranial base (CB) is very important in determining a functional occlusion:
- oldest component of the vertebrate skull.
- floor the cranium and provides the platform upon which the brain grows and around which the face grows.
- connects the cranium to the rest of the body (vertebral column and mandible).
- provides vital neural and circulatory connections between the brain and the face.

1. ANATOMY

A. Exocranial view:
   a. Anterior Cranial Fossa
      - Frontal
      - Ethmoid
      - Sphenoid

   b. Posterior Cranial Fossa
      - Temporal
      - Occipital

B. Endocranial view:
   a. Anterior Cranial Fossa
      - Borders
         Anteriorly: - posterior wall of the frontal sinus
         Posteriorly: - anterior margins of the chiasmatic groove.
                       - posterior borders of the small wings of the sphenoid.
         - Structures
Foramen caecum
Crista galli
Cribiform plate of the ethmoid
Jugum sphenoidal
Chiasmatic groove

- **Sutures**
  - Fronto-ethmoidal
  - Spheno-ethmoidal
  - Spheno-frontal

b. Middle cranial base

- **Borders**
  - Anteriorly: - anterior clinoid process
    - anterior margins of the chiasmatic groove
  - Posteriorly: dorsum sella

- **Structures**
  - Optic foramen: transmits optic nerve and ophthalmic artery to the orbital cavity
  - Anterior clinoid process
  - Sella turcica

- **Foramina**
  - Rotundum: Maxillary nerve
  - Oval: Mandibular nerve
  - Spinosum: Middle meningeal vessel
  - Lacerum: Internal carotid artery

- **Sutures**
  - Spheno-parietal
  - Spheno-squamosal
  - Spheno-petrosal

c. Posterior cranial base

- **Borders**
  - Anteriorly: Dorsum sella
  - Posteriorly: Inferior occipital fossa

- **Structures**
  - Dorsum sella
  - Clivus of the occipital
  - Occipital
  - Petrous and mastoid portions of the temporal bone
  - Mastoid angle of parietal bone

- **Foramina**
  - Magnum
  - Jugular
  - Internal acoustic meatus

- **Sutures**
  - Occipito-mastoid
  - Parieto-mastoid
2. EMBRYOLOGY AND PRENATAL GROWTH

- The human cranial base first appears during the second month of embryonic life. It is called the chondrocranium.
- By the 7th week, 9 groups of paired cartilagenous precursors are present.
- By the 8th week, 41 ossification centers appear in the chondrocranium. The chondrocranium transfers to basicranium.
- By the middle of the 3rd month, 1 ossification center in the basioccipital.
- By the 4th month, 2-4 ossification center in the post-sphenoid.
- By the 5th month, 2 ossification center in the presphenoid.
- By the 1st year after birth one center in the mesethmoid.

Superior view of chondrocranial precursors and ossification centers (After Sperber, 1989).

Anterior precursors: neural crest cells
- Posterior precursors: mesodermal tissue origin

Ossification types:
1. Endochondral
   - Greater wings
   - Lesser wings
   - Ethmoid
2. Intramembranous
   - Pterygoid plate / Greater wing
   - Temporal
   - Occipital
   - The inferior nasal concha undergoes cartilaginous ossification: center detaches from the ethmoid.

3. POSTNATAL GROWTH

A. Antero-posterior growth
- The anterior cranial base elongates in parallel with the frontal lobes of the brain, reaching approximately 95% of its adult size by the end of the neural growth period (6 years).
- The first part of the anterior cranial base to cease growth is the cerebral part of the frontal bone at age of 1 year.
- The lamina cribosa and the jugum sphenoidal start to be stable at the age of 4-5 years.

- The growth at the sites of the sphenoid-ethmoidal and the fronto-ethmoidal ceases at 7 years of age.
- The anterior wall of the sella turcica reaches stability at 5-6 years of age.
- The tuberculum sella and the posterior wall of the sella turcica stop growing at ages of 18 years in males and 16 years in females.
- The Spheno-occipital suture closes at age of 16-20 years, whereas Irwin (1960) found that the first osseous contact between the occipital and the sphenoid bones occurs at age of 10-13 years.
- The occipital part of the clivus is subjected to resorption till ages of 19 years in boys and 17 years in girls.
- Apposition of bone on the anterior margin of the foramen magnum was seen up to age 18 years in males and 16 years in females.
- A direct projection of these findings on our orthodontic cephalometric superimpositions methods is that the superimposition on the cranial base especially on the sella turcica as a stable landmark might be erroneous.

“The method of best fit of the anterior cranial base may be better than the others”.

B. Medio-lateral growth
- The increase in width of the anterior and posterior cranial fossa occurs from growth of the fronto-ethmoidal and occipito-mastoidal sutures.
- The sphenoid does not widen much.

C. Supero-inferior growth
- The endocranial floor is resorptive whereas the inferior side of the skull base is depotory.
- All parts of the cranial base displace superiorly except the cribiform plate, and the posterior cranial fossa which occurs only on humans implying the cranial base flexion.
D. Angulation
- The postchordal (posterior cranial base) plane is most commonly defined using 2 landmarks, usually basion and sella, or using the line created by the dorsal surface of the basioccipital clivus.
- The prechordal plane (anterior cranial base) has been measured in more diverse ways:
  a. Sella to Nasion
  b. Sella to Foramen Caecum
  c. Planum Sphenoideum.
- Changes in cranial base angulation occur within synchondroses. Flexion would result from increased chondrogenic activity in the superior vs inferior aspect of the synchondroses especially the Spheno-occipital synchondrosis (remains active till 12 years of age at least).
- Posterior drift of the foramen magnum, inferior translation of the cribiform plate relative to the anterior cranial base and remodeling of the sella turcica, cause a flexion on the cranial base angle.
- Moss related the flexion of the cranial base angle to the brain growth and indirectly to the remodeling taking place in the cribiform plate. Moss referred to the congenital malformations of the brain such as acrocephaly and cranial dysostosis. He noticed in these cases that the defect in the midbrain affect the cartilaginous tissue in the cranial base angle leading to a downward movement of the cribiform plate and closing of the cranial base angle.
- Similar situation was observed in CI III malocclusion patients where the pre-sella portion has a greater downward inclination relative to the clivus. These findings were supported later by Bjork.

4. CRANIAL BASE AND FACIAL GROWTH

A. Anterior cranial base and upper facial growth
- The upper face incorporates elements of the anterior cranial base:
  a. Ethmoid
  b. Parts of the sphenoid
  c. Significant portion of the frontal bone
- As the eyes expand, the orbital cavity expands anteriorly, inferiorly and laterally through translation and rotation. Thus, the upper face grows away from the rest of the cranial base.
- Since the roof of the orbit contributes to the floor of the anterior cranial fossa, the position, orientation and shape of the orbital roof must unavoidably be affected by growth of the frontal lobes and anterior cranial fossa.

B. Middle cranial base and midfacial growth
- The ethmomaxillary complex grows anteriorly, laterally, and inferiorly away from the middle cranial fossa. Consequently, the shape of the middle cranial fossa, especially the greater wings of the sphenoid must also play some role in influencing the
orientation of the posterior margin of the ethmomaxillary complex and its position relative to the rest of the cranial base.

- Lieberman defined the Posterior Maxillary plane (PM) as the plane relating:
  a. Ptm the average midline point on the most inferior and posterior points on the maxillary tuberosity; and
  b. PMp the average midline point of the anterior-most points of the lamina of the greater wings of the sphenoids.
- The relationship between the back of the face (as measured for example by the PM plane) to the anterior cranial base also influences nasopharynx shape.
- As the anterior cranial base flexes relative to the posterior cranial base, the PM plane also must flex relative to the posterior cranial base, rotating the posterior and upper portions of the face underneath the anterior cranial fossa.

5. SUMMARY AND CONCLUSIONS ON CRANIAL BASE DEVELOPMENT

A. Ossification of the cranial base is mostly completed by endochondral osteogenesis whereas the intramembranous type takes place at the level of limited portions such as sphenoidal wings and part of the sella turcica.
B. The anterior cranial base ceases growth progressively till age of 7 years while the posterior cranial base continues growing till late adolescence.
C. The growth of the cranial base has an important effect on craniofacial development. For instance, the upper facial skeleton is closely related to the anterior cranial fossa and the posterior cranial fossa articulates with the mandible through the temporomandibular joint.
D. Two major theories were brought up when debating in the growth motor. The first one relates the shape to the function as in the functional matrix theory where the brain shape and the pharyngeal airway play the major role in giving the cranial base its shape (in parallel to the predetermined genetic influence). The second one establishes the origin of growth in the cranial base itself at the level of the sutures.

6. FOCUS: INFLUENCE OF CRANIAL BASE ON FACIAL FORM AND PATTERN

1. The cranial base forms the template for the face.

A. The angle between the anterior cranial base and the posterior cranial base varies from person to person.
B. Three points define the cranial base:
   a. Nasion.
   b. Spheno-ethmoidal junction.
   c. Base of the occipital bone.
C. The anterior cranial base is more closely related to the maxilla because the nasomaxillary complex is suspended from the anterior cranial base.
D. The articulation of the mandible (glenoid fossa) is located in posterior cranial base.

2. The cranial base angle
A. The Cranial Base Angle is the angle formed where the anterior and posterior cranial base come together.
B. As the cranial base angle becomes more acute, the mandibular posterior teeth are more anteriorly positioned and the maxillary posterior teeth are more posteriorly positioned.
C. As the cranial base angle becomes more obtuse, the mandibular posterior teeth are more posteriorly positioned and the maxillary posterior teeth are more anteriorly positioned.
D. Dolichocephalic people have more obtuse cranial base angles and brachycephalic people have more acute cranial base angles.
E. Maxillary and mandibular structures can compensate for variations in cranial base angles up to some limits.

SECTION 5: GROWTH OF THE MAXILLA

KEY CONCEPTS
- Displaced downward and forward during development
- Remodeled upwards and backwards
- Teeth can move independently of bone

1. PRENATAL GROWTH
A. Days 28 to 38 IU: formation of the primary palate.
B. Day 42 to 55: Closure of the secondary palate:
   - Lateral differentiation of palatal shelves
   - Elevation of palatal shelves
   - Lateral growth of the shelves
   - Creation of epithelial wall
   - Fusion of the shelves (anterior 2/3, anterior to posterior)
C. 8th Weeks I.U.: Intramembranous ossification of the palate
   Ossification does not occur in the most posterior part of the palate, giving rise to the soft palate region.
D. 10 1/2th Weeks: Midpalatal sutural structure is evident.
E. 7-18 weeks: The fetal palate increases in length more rapidly than in width after which the width increases faster than the length.
F. Clefts result from the delay in elevation of the palatal shelves from the vertical to the horizontal, defective shelf fusion, possible post-fusion rupture, failure of mesenchymal consolidation.

2. POSTNATAL GROWTH
A. Vertical growth of the maxilla
   a. The downward growth of the maxillary arch is produced by two mechanisms:
      - Downward displacement of the entire nasomaxillary complex due to bone apposition on the sutures sites; this displacement-sutural growth mechanism
accounts for half of the total downward movement of the maxillary arch and palate
- Remodeling by combination of resorption/deposition processes causing a direct inferior relocation of the palate and maxillary arch.
b. The downward movement of teeth is similarly a two part process
- Remodeling growth of alveolar bone (paced by periodontal membrane).
- Displacement of maxilla as a whole, with alveolar bone not participating.

B. Horizontal growth of the maxilla
a. Anterior bone deposition till age 5-6 years.
b. Posterior bone deposition at the tuberosity region which will cause anterior displacement of the maxillary complex.
c. The extent of forward displacement is matched by the amount of backward bone growth.

C. Transversal growth of the maxilla
a. The maxilla increases in width till the end of growth in the site of the midpalatal suture.
b. In addition, the remodeling of the vault of the palate will contribute to the widening of the maxilla.
c. Laterally, width is increased by remodeling.
d. The adult maxilla is normally large enough to accommodate all the permanent teeth in a harmonious arch.

3. THEORIES ON MAXILLARY GROWTH

A. Functional matrix theory (Moss)
Any given bone grows in response to functional relationships established by the sum of all the soft tissues operating in association with that bone, i.e., the functional soft tissue matrix is the actual governing determinant of the skeletal growth process.
In the Maxilla:
The major determinant of growth in the maxilla is the enlargement of the nasal and oral cavities, including the sinuses which grow in response to functional needs. This is called the orofacial capsular matrix.
B. Cartilage growth (Scott)
The cartilage as a determinant of maxillary growth. Although there is no cartilage in the maxilla itself, there is cartilage in the nasal septum which provides a thrusting force which carries the maxilla forward and downward during growth.
C. Sutural growth theory (Enlow)
The sutures of the maxilla are sites not centers of growth; they allow downward and forward positioning of the maxilla
As growth of surrounding soft tissues translates the maxilla downward and forward, new bone is added on both sides of the superior and posterior sutures.
4. SUMMARY ON MAXILLARY GROWTH

A. The maxilla is displaced downward and forward, but is remodeled upward and backward.
B. Growth of the maxilla and its associated structures occurs from a combination of growth at sutures and direct remodeling of the bone.
C. The maxilla is translated downward and forward as the face grows and new bone fills in at the sutures.
D. The surrounding soft tissues playing a role of a functional matrix contribute to the growth of the maxilla.
E. Growth of the cartilage of the nasal septum plays a role in the translation of the maxilla.

SECTION 6: GROWTH OF THE MANDIBLE

KEY CONCEPTS:
The mandible is made up of the alveolar process, the condyle, the ramus and the corpus.
The gonial angle of the mandible plays an important part in the position of the lower incisor teeth.
Variations in the size or shape of different component parts often sums to produce the same overall result.

1. PRENATAL GROWTH

A. Embryology and prenatal growth of the mandible
   - 4th week: Meckel’s Cartilage
   - 5th – 6th week: membranous ossification sites
   - 10th week: secondary cartilaginous sites
     a. condyle
     b. coronoid
     c. angle and symphisis (controversial: Delaire)
   - 14th week: start of endochondral ossification.

B. Comparison with the size of the maxilla
   - Initially during fetal life: the mandible is bigger than maxilla
   - 8th week (i.u): maxilla overlaps the mandible.
   - 11th week: equal size of upper & lower jaws.
   - Between 13th & 20th week: mandible growth lacks behind maxilla.
   - At birth, the mandible tends to be retrognatic relative to the maxilla.

2. POSTNATAL GROWTH

A. Mandiular components: at birth:
   - 2 small hemi mandibles unified at the symphysal suture
   - Immature TMJ
   - Short ramus (within corpus extension)
- Wide gonial angle

B. Mandible and cranial base
- Mandibular position and displacement during growth depend on the cranial base.
- Mandibular position is a direct reflection of the glenoid fossa situation

C. Mandibular growth:

1. In the vertical and sagittal plane
- The whole mandible is displaced away from its articulation in each glenoid fossa by the growth enlargement of the composite of soft tissues in the growing face.
- The condyle and ramus grow upward and backward into the “space” created by the displacement process.
- The ramus remolds as it relocates postero-superiorly.
- The forward shift of the growing mandibular body changes the direction of the mental foramen during infancy and childhood.

2. Corpus growth:
   a. in length
   - As the ramus is relocated posteriorly, the corpus becomes lengthened by a remodeling conversion from what was at one time the ramus during a former growth period.
   - While the mandible is displaced forward the ramus is repositioned backward and it becomes thicker.
   - The resorption of anterior border of the ramus is less important than the posterior apposition.
   - Resorption of 1.5 mm/year of anterior border is observed to manage the space for the 3rd molars in the future.
   b. in height
   - Growth in height of corpus depends mostly on alveolar growth and results also from remodeling process of basilar border.
     - This remodeling process keeps the dental canal away of the inferior bony surface.
   c. in width
   - Synostosis of the symphysal suture occurs at the end of 1st year (postnatal).
   - Transversal growth then caused by periosteal growth: apposition on lingual surface (basilar border) and resorption on external alveolar surface.
   - Evidence found for opening hinge movement of mandibular halves around a vertical axis located in the region of the mandibular symphysis (unilateral implant markers).

3. GROWTH MECHANISMS AND THEORIES

A. Growth mechanisms of the mandible
   b. Periosteal contribution
   - Exists which is subordinated both to orders affecting the whole organism and to local control factors represented chiefly by muscular contraction
a. **Cartilaginous contribution** (condylar, coronoid and angular)
Exits which is more easily modulable and more subject to local control systems

B. Skeletal subunits of the mandible
The basal bone of the body forms one unit, to which are attached the alveolar, coronoid, angular and condylar processes and the chin.

Functional matrix theory (Moss):
- Teeth act as a functional matrix for alveolar unit.
- Action of temporalis muscle influences the coronoid process.
- Masseter and medial pterygoid muscles act upon mandibular angle and ramus.
- Lateral pterygoid has some influence on condylar process.
- Functioning of related tongue and perioral muscles and expansion of the oral and pharyngeal cavities provide stimuli for mandibular growth to reach its full potential.

C. Condylar cartilage
- Periosteal growth processes involved in ramal, corpal and alveolar growth were viewed as secondary to the condylar changes.
- With time, the periosteal contributions were further diminished conceptually.
- The proliferative zone of the mandibular condyle in a non-functional environment.
- The influence of extrinsic factors upon the mandibular condyle is on cellular differentiation rather than on the proliferative activity that is linked to some intrinsic programmer of a genetic nature.
- Differentiation between primary cartilages (such as epiphyseal plate) and secondary cartilages (do not develop ontogenetically and phylogenetically from the primary cartilaginous skeleton).

4. ANOMALIES OF DEVELOPMENT

1- Agnathia
- Mandible may be grossly deficient or absent.
- Reflects a deficiency of neural crest tissue in the lower part of the face.
- Aplasia of the mandible and hyoid bone (1st and 2nd- arch syndrome) is a rare lethal condition with multiple defects of the orbit and maxilla.

2- Micrognathia:
   Diminutive mandible is characteristic of several syndromes, including Pierre Robin's and the cat-cry (cri du chat) syndromes, mandibulofacial dysostosis (Treacher Collins' syndrome), Down's syndrome (trisomy 21) and turner's syndrome (XO sex-chromosome complement).

3- Macrognathia
   - Usually an inherited condition
   - Abnormal growth phenomena such as hyperpituitarism may produce mandibular overgrowth of increasing severity with age.
4- Congenital hemifacial hypertrophy
   - Evident at birth
   - Tends to accentuate at puberty.
   - Unilateral enlargement of the mandible, the mandibular fossa, and the teeth.
   - It is of obscure etiology.
   - More common is isolated unilateral condylar hyperplasia.

5- Bifid or double condyle
   - Rare variations in condylar form may occur.
   - It result from the persistence of septa dividing the fetal condylar cartilage.

6- Ankylosis
   - Defective development of the joint results in ankylosis.
   - Results in impaired mandibular formation.
   - Absence of all elements of the joint is exceedingly rare.
   - The hyaline cartilage of the condylar head had an important role in the development
   of the mandible and traumas targeting this site may cause ankylosis, growth
   retardation, and resultant facial malformations.
   - Hence, mechanical damage to the articular surface and resection of the condylar
   head almost always resulted in ankylosis.
   - Intra-articular hematoma alone was established not be a causative factor for
   ankylosis formation.

SECTION 7: CONTROL PROCESSES OF FACIAL GROWTH

KEY CONCEPTS
Moss’s functional matrix theory: primary influence of capsular and periosteal matrices on skeletal form.
Intracranial brain growth causes suture separation and bone growth.
Radiographs only a compromised method to monitor changes in bone.

1. SUTURAL GROWTH THEORY

A. It is an early theory.
B. Since cell division occurs at sutures; cell division is driving force of bone growth.
C. NOT TRUE, because we already know that bone does not grow under tension.
D. The brain can provide tissue separating force; it is a soft tissue mass that expands
   inside flat bones, leading to skull growth.
   a. Initially, the brain grows very fast, then the younger skeletal tissue catches up.
   b. Since the brain is soft tissue, it can grow interstitially (it is encapsulated).
   c. Brain expansion produces separation at the sutures of the skull and thus permits
      formation of new bone.
   d. These observations led to the development of the next theory of facial growth.

2. FUNCTIONAL MATRIX HYPOTHESIS
FUNCTIONAL CRANIAL ANALYSIS

A-Skeletal units: protect and/or support the functional matrix
   a. microskeletal units: When a bone consists of a number of skeletal units
   b. macroskeletal units: When adjoining portions of a number of neighboring bones are united to function as a single cranial component

B-Functional matrix: carries out the function
   a-Soft tissues: muscles, glands, nerves, vessels, fat, etc..
   b-Teeth
   c-Functioning spaces of the oronasopharyngeal cavities
   d-Basic types of functional matrices (sites of their activity):

1. Periosteal:
   - Deposition and resorption
   - The response of skeletal units to periosteal matrices is to alter their size and/or their shape
   - Muscles, blood vessels, nerves, glands.

2. Capsular:
   - All the functional cranial components are organized in the form of cranial capsules.
   - Contains a series of functional cranial components.
   - Each capsule surrounds and protects a capsular functional matrix.

2.1. Neurocranial capsule:
   - It is the total neural mass volume
   - The response of the capsule as a whole is to expand in a compensatory manner
   - The periosteal matrices and their microskeletal units, are then carried outward within the capsule in a totally passive manner
   - Such translations occur without the necessity of involving the processes of selective periosteal apposition and resorption

2.2. Orofacial matrices
   - Surrounds and protects the oronasopharyngeal functioning spaces
   - The volumetric growth of these spaces is the primary morphogenetic event in facial skull growth
   - The volume of these spaces is related to the general metabolic demands of the body as a whole.

3. In summary:
   - Cranial growth is a combination of the morphogenetically primary activity of both types of matrix
   - Growth is achieved by both spatial translation and changes in form.

3. TECHNIQUES FOR LABELING BONES
A. Vital dye (label cells at the time they are formed)
B. Radioactive labels
C. Implants

4. THE NASAL SEPTUM THEORY

A. Developed by Dr. Scott.
B. The nasal septum is found in the midface.
C. States that there is a critical function of the midface.
D. Breathing through the nose allows the face to grow.

5. CARTILAGINOUS GROWTH

A. Hyaline cartilage is cell-free: not involved in growth. Epiphyseal plates contain cells and are responsible of growth.
B. Most cartilage growth occurs at cranial base.
C. Synchondroses
   a. Gives separating forces well.
   b. Cartilage fills the gap between bones.
   c. There are three main synchondroses in the cranial base. Each one fuses at a different point in time.
      - Intra-sphenoidal: closes at birth.
      - Spheno-occipital: closes around 9-10 years.
      - Spheno-ethmoidal: closes around 3-5 years.

6. CONTROL PROCESSES OF MANDIBULAR GROWTH

A. The processes which control mandibular growth are much less clear.
B. Mandibular condyles have growth cartilage involved in growth.
C. Mandibular condyles are in the site of growth.
D. Mandibular condyles are not the center of growth.

6. TRANSLATION OF CRANIOFACIAL GROWTH AT LEVEL OF OCCLUSION

*Vertical proportion relates to antero-posterior proportion
Gradual movement at the level of the dentition*

A. The level of the occlusal plane only varies by about 6 mm in 90% of the human population.
B. The sum total of facial growth allows the teeth to come together.
C. Most of the compensatory changes in the maxilla take place at the level of the alveolus.
D. In the mandible, there can be variations in the ramus, corpus, and the alveolus.
E. The vertical relationship of component parts impacts the anteroposterior dimension, (i.e. as the face grows vertically, the lower incisors go more posteriorly.)
F. As the face continues to change throughout life, the teeth remain in occlusion.

REFERENCES