TERMINOLOGY RELATED TO GROWTH AND DEVELOPMENT:

GROWTH FIELDS: The outside and inside surfaces of bone are blanketed by soft tissues, cartilage or osteogenic membranes. Within this, blanket areas known as growth fields, which are spread all along the bone in a mosaic pattern, are responsible for producing an alteration in the growing bone.

GROWTH SITES: Are growth fields that have a special significance in the growth of a particular bone, e.g. mandibular condyle in the mandible, maxillary tuberosity in the maxilla. The growth sites may possess some intrinsic potential to grow (debatable).

GROWTH CENTERS: Are special growth sites, which control the overall growth of the bone, e.g. epiphyseal plates of long bones. These are supposed to have an intrinsic growth potential (unlike growth sites).

REMODELING: It is the differential growth activity involving deposition and resorption on the inner and outer surfaces of the bone, e.g. ramus moves posteriorly by a combination of resorption and deposition.

GROWTH MOVEMENTS

Growth movements are primarily of 2 types:

Cortical Drift: is a type of growth movement occurring towards the depository surface by a combination of resorption and deposition on the opposing surfaces simultaneously.

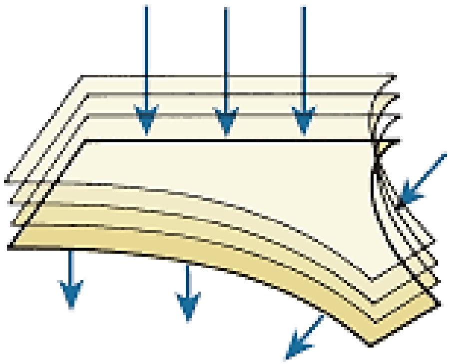


FIG.1. Downward drift of palate

Displacement: is the movement of the whole bone as a unit, two types are seen (FIG.2)**:**

• Primary displacement**:** Displacement of bone in conjunction with its own growth. It produces space within which the bones continue to grow.

• Secondary displacement**:** Displacement of bone as a result of growth and enlargement of adjacent bone/ bones.

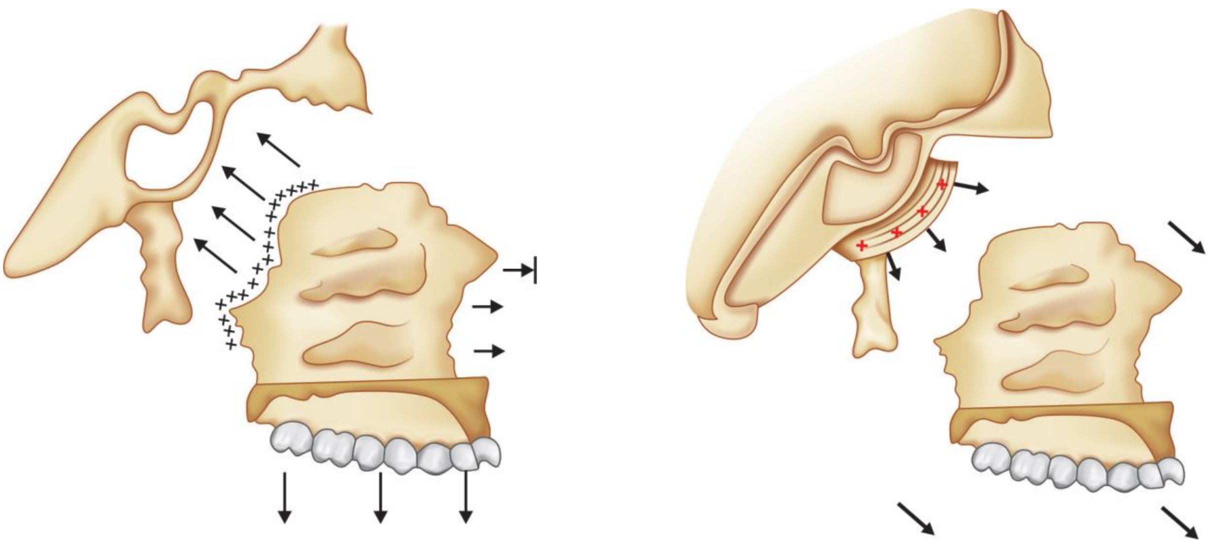
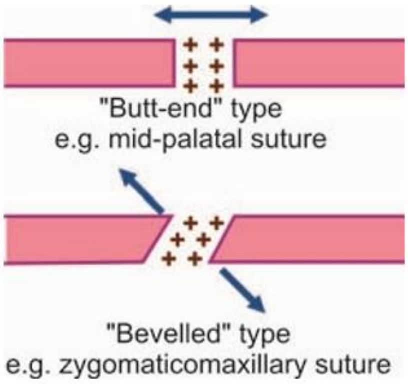


FIG.2. Displacement of nasomaxillary complex.

Sutural growth: The bone of the face and skull articulate together mostly at sutures, and growth at sutures can be regarded as a special kind of periosteal remodeling —an infilling of bone in response to tensional growth forces separating the bones of either side of the suture (FIG.3.).



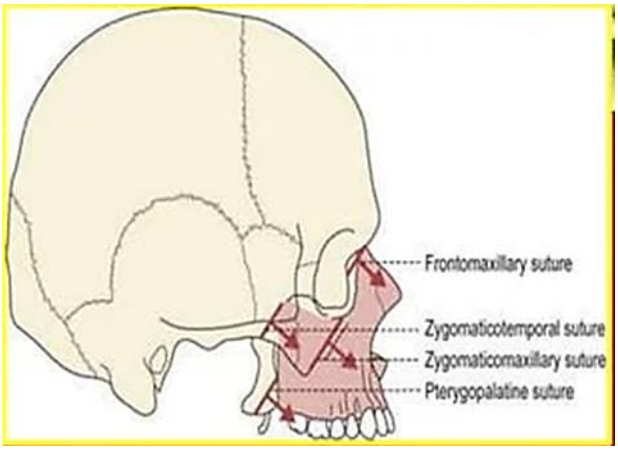


FIG.3. Displacement of nasomaxillary complex.

Mechanism of bone growth:

Bone does not grow interstitially (i.e. it does not expand by cell division within its mass) rather, it grows by activity at the margins of the bone tissue.

Bone is laid down in two ways:

Endochondral ossification: At cartilaginous growth center, chondroblasts lay down a matrix of cartilage within which ossification occurs. At primary growth centers. there are zones of cell division, cell hypertrophy and calcification aligned in columns along the direction of the growth. This process is seen in both the epiphyseal plate of long bones and the synchondroses of the cranial bone. Near the outer end of each epiphyseal plate is a zone of actively dividing cartilage cells. Some of these, pushed toward the diaphysis by proliferative activity beneath, undergo hypertrophy, secrete an extracellular matrix, and eventually degenerate as the matrix begins to mineralize and then is rapidly replaced by bone (see Figure 5). As long as the rate at which cartilage cells proliferate is equal to or greater than the rate at which they mature, growth will continue. Eventually, however, toward the end of the normal growth period, the rate of maturation exceeds the rate of proliferation, the last of the cartilage is replaced by bone, and the epiphyseal plate disappears. At that point, the growth of the

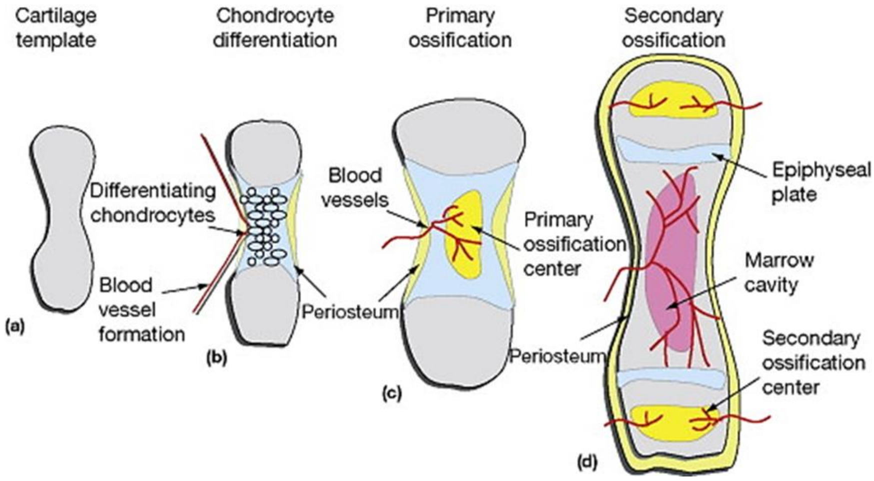


FIG.5. Endochondral ossification

<u>Intramembranous ossification</u>: it is the direct formation of bone within highly vascular sheets of membranes of condensed primitive mesenchyme. There is no precursor cartilage model here. At centers of ossification, ectomesenchymal stem cells differentiate into osteoblasts. The newly formed osteoblasts proliferate around the branches and capillary network and produce a fibrous bone matrix (osteoid). As osteoid deposition continues, osteoblast cells get encased in matrix and become osteocytes. Blood vessels are retained within the spaces and become surrounded by bone. A haversian system starts to form which nourishes the bone. Fibrous bone matrix (osteoid) eventually becomes mineralized. Entrapped blood vessels supply nutrients to osteocytes and bone tissue (fig. 6).

Peripheral mesenchyme condenses on the outer surface to form fibrocellular periosteum. Further bone deposition occurs from new osteoblasts differentiating from osteoprogenitor cells in the deeper layers of periostium. Membrane bones in craniofacial skeleton are cranial bones, mandible, etc. (most of the bones of craniofacial skeleton are of intramembranous origin). However, in certain membranous bones, secondary cartilages (not part of cartilaginous primordium of the embryo) develop and after initiation of intramembranous ossification contribute significantly to their growth, e.g. condylar cartilage in mandible.

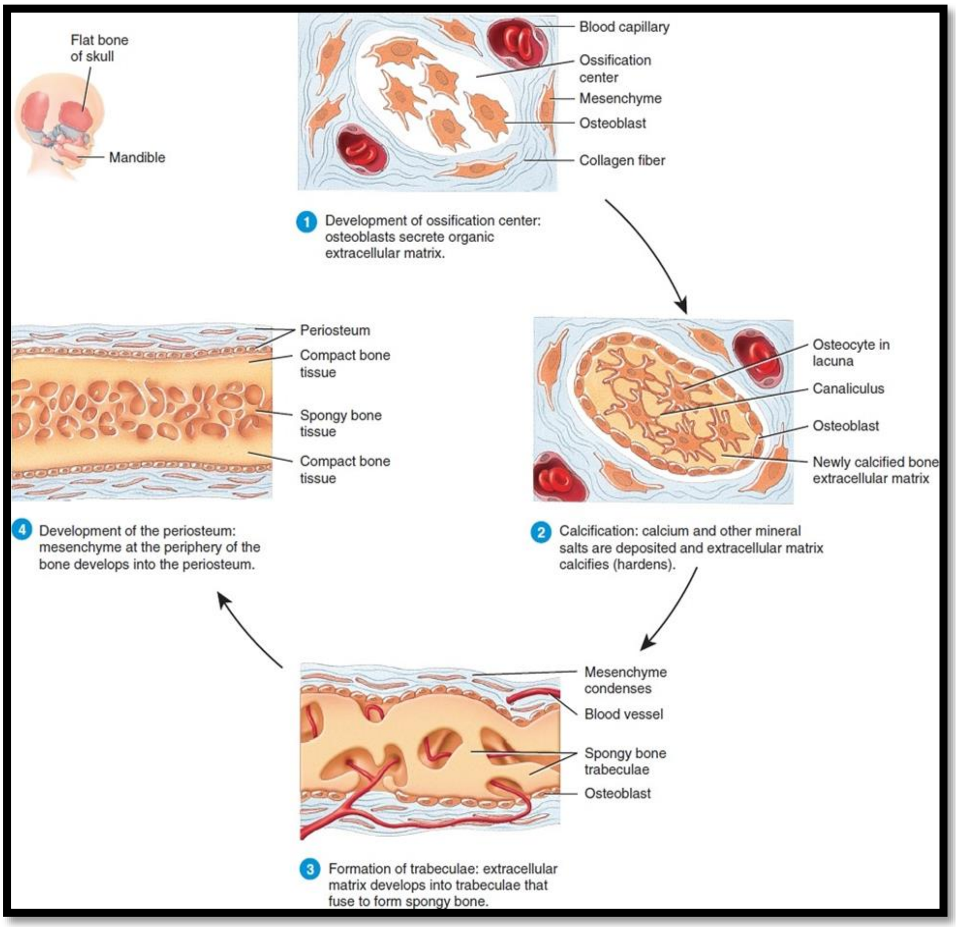


FIG.6. Intramembranous ossification

<u>The post natal growth of the craniofacial complex:</u>

Can be divided into four areas that grow rather differently:

a. The cranial vault the bone that covers the upper and outer surface of the brain.

b. The cranial base the bony floor under the brain, which is also a dividing line between the cranium and the face.

c. The nasomaxillary complex made up of the nose, maxilla, and the associated structures.

d. The mandible.

A-THE CRANIAL VAULT

Is the part of the skull which develops from the membranous bones surrounding the brain and the therefore it follows the neural growth pattern (the growth in the cranial vault is because of the enlarging brain).

It comprises:

1- Parietal bones (2)
2- Fontal bone
3- Squamous part of temporal bones (2)
4- Occipital bone.

As the brain expands, the separate bones of the cranial vault are displaced in outward direction. This intramembranous sutural growth replaces the fontanels that are present at birth. Apart from growth at sutures, growth also occurs by periosteal and endosteal remodeling. Resorption at the endosteal lining and apposition at the periosteum leads to an increase in the overall thickness of the medullary space between the inner and the outer tables. Cranial vault following the neural growth curve achieves most of its growth during first few years of life, with over 90% of growth by 5 years and 98% by 15 years of age. At birth, the flat bones of the skull are rather widely separated by relatively loose connective tissues. These open spaces, the fontanelles (Fig. 3), allow a considerable amount of transient deformation of the skull at birth-a fact which is important in allowing the relatively large head to pass through the birth canal (fig.7).

After birth, apposition of bone along the edges of the fontanelles eliminates these open spaces fairly quickly, then closes by 18 months.

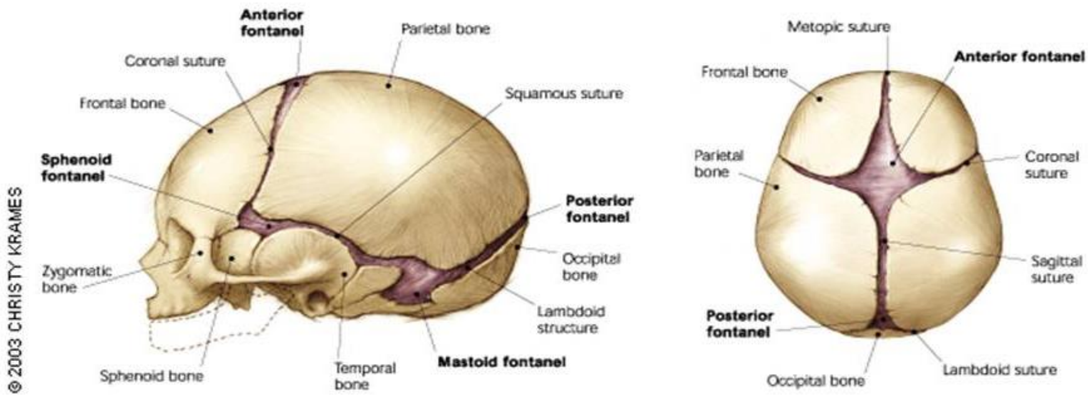


Fig 7. Fontanelles in cranium

<u>Growth of cranial vault consists of:</u>

1- **Drift:** Internal cranial aspects of the bones are resorbed while bone is laid down on the external surface.
2- **Displacement:** The bones are separated by growing brain, with fill-in bone growth occurring at the sutures to maintain continuously of the cranial vault.

It should be realized that there is actual translation as well as remodeling of the individual bones, with the structures being moved outward by the growing brain. Despite early accomplishment of the pattern, the parietal bones do not close until the middle of third decade of life.

<u>B-THE CRANIAL BASE</u>:

The cranial base, unlike cranial vault, is not completely dependent on brain growth and may have some intrinsic genetic guidance and a pattern that is, similar in some dimensions, to that of the facial skeleton. In contrast to the cranial vault, the bones of the cranial base are formed initially in the cartilage and are later transformed by endochondral ossification into bone. This is particularly true of the midline structures. As one moves laterally, growth at sutures becomes more important, but the cranial base is essentially a midline structure. Centers of ossification appear early in embryonic life in the chondrocranium, indicating the eventual location of the basioccipital, sphenoid and ethmoid bones that form the cranial base (Fig. 8).

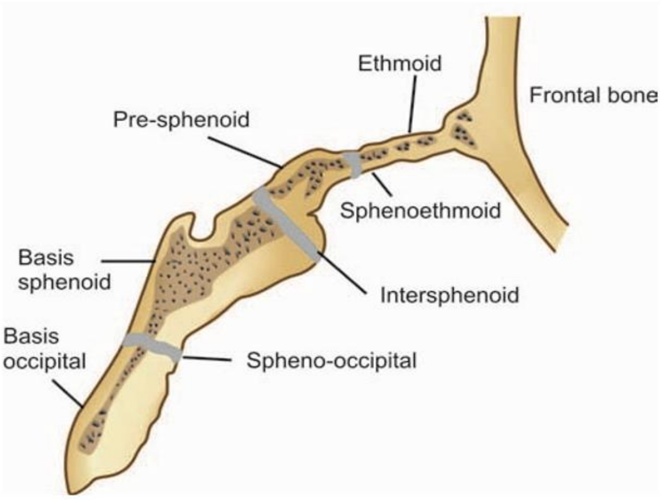


Fig. 8: The bones that form the base of the skull

The cranial base grows primarily by cartilage growth in the sphenoethmoidal, intersphenoidal, spheno-occipital and intraoccipital synchondroses, mostly following the neural growth curve (Fig. 4.4). Activity at the intersphenoidal synchondrosis disappears at birth. The intraoccipital synchondrosis closes in the 3rd to 5th years of life. The sphenooccipital synchondrosis is a major contributor as the ossification here extends till the 20th year of life (Fig.9).

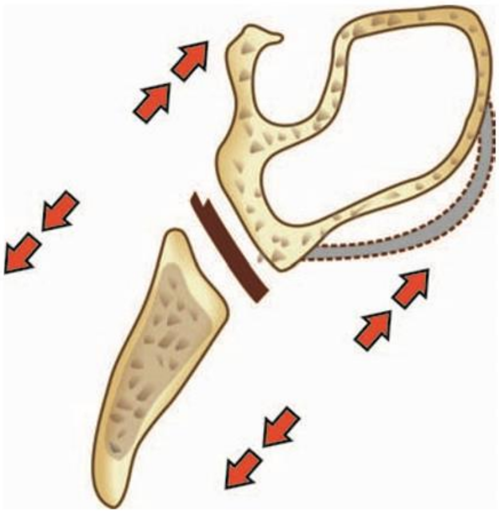


Fig. 9: Growth at the inter-sphenoidal synchondrosis

The cranial base plays an important part in determining how the mandible and maxilla relate to each other, For example, Class Il skeletal facial pattern is often associated with the presence of a long cranial base which causes the mandible to be set back relative to the maxilla.

In the same way, the overall shape of the cranial base affects the jaw relationship, with a smaller cranial base angle tending to cause a Class Ill skeletal pattern, and a larger cranial base angle being more likely to be associated with a Class Il skeletal pattern (Fig. 10).

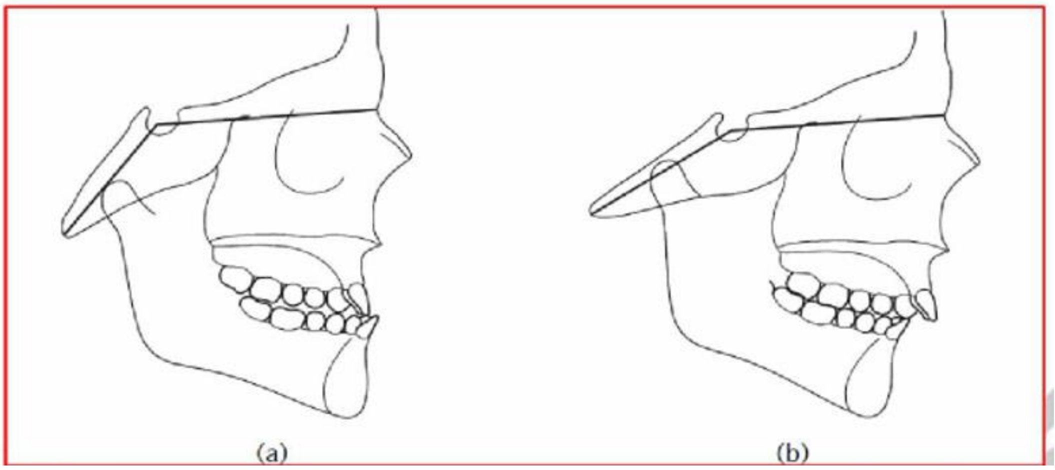
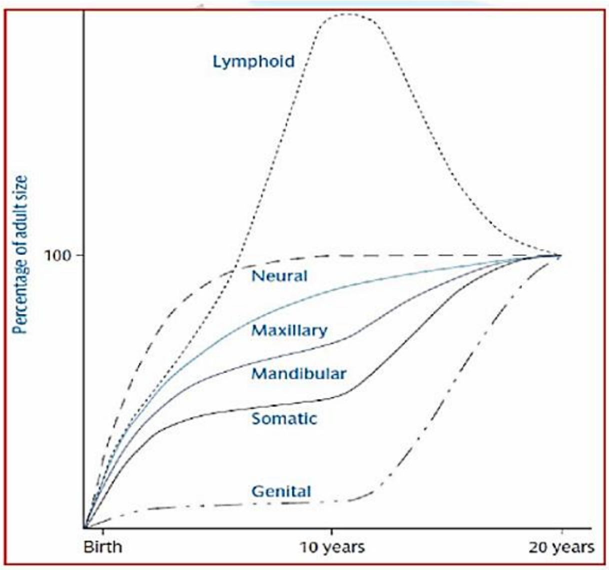


Fig.10 a: low cranial base angle associated with Class Ill, b: High cranial base angle associated with Class Il

The cranial base angle usually remains constant during the postnatal period, but can increase or decrease due to surface remodelling and differential growth at the spheno-occipital synchondrosis.
C-Naso maxillary complex:

Postnatal growth of the maxilla follows a growth pattern that is thought to be intermediate between a neural and a somatic growth pattern (see Fig. 11).



(Fig. 11): Post natal growth pattern

Clinical orthodontic practice is primarily concerned with the dentition and it's supporting alveolar bone which is part of the maxilla and premaxilla. However, the middle third of the facial skeleton is a complex structure and also includes, among others, the palatal, zygomatic, ethmoid, vomer, and nasal bones. These articulate with each other and with the anterior cranial base at sutures.

Growth of the maxillary complex occurs in part by displacement with fill-in growth at sutures and in part by drift and periosteal remodelling. Passive forward displacement is important up to the age of 7 years, due to the effects of growth of the cranial base.

When neural growth is completed, maxillary growth slows and subsequently, approximately one-third of growth is due to displacement (0.2-1 mm per year) with the remainder due to sutural growth (1-2 mm per year). In total, up to 10 mm of bone is added by growth at the sutures.

Much of the antero-posterior growth of the maxilla is in a backward direction at the tuberosities which also lengthens the dental arch, allowing the permanent molar teeth to erupt. A forwards displacement of the maxilla gives room for the deposition of bone at the tuberosities.

Downward growth of the mid face occurs by:

1-Vertical development of the alveolar process

2-Eruption of the teeth

3-Inferior drift of the hard palate, i.e. the palate remodels downwards by deposition of bone on its inferior surface (the palatal vault) and resorption on its superior surface (the floor of the nose and maxillary sinuses) (see Fig. 1).

4-These changes are also associated with some downward displacement of the bones as they enlarge, again necessitating infilling at sutures.

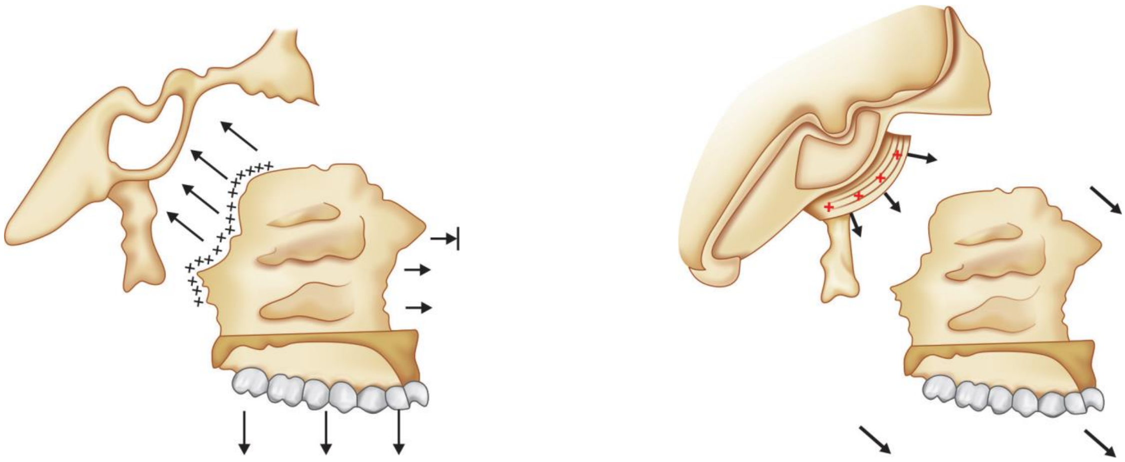


Fig. 12: Naso maxillary complex growth

Lateral growth in the mid-face occurs by displacement of the two halves of the maxilla, with deposition of bone at the midline suture. Internal remodeling leads to enlargement of the air sinuses and nasal cavity as the bones of the mid-face increase in size.

Therefore, growth is accompanied by complex patterns of surface remodeling on the anterior and lateral surfaces of the maxilla which maintain the overall shape of the bone as it enlarges. Despite being translated anteriorly, in fact much of the anterior surface of the maxilla is resorptive in order to maintain the concave contours beneath the pyriform fossa and zygomatic buttresses.

Growth of the nasal structures is variable but occurs at a more rapid rate than the rest of the maxilla. During the pubertal growth spurt, nasal dimensions increase 25 per cent faster than maxillary dimensions. Maxillary growth ceases on average at about 14 years in girls and rather later at about 16 years in boys.

D-The Mandible:

The mandible is derived from the first pharyngeal arch and it is a membrane bone ossifying laterally to Meckles cartilage (fig. 13). The role of the condylar cartilage in the growth of the mandible is not yet entirely clear. It is not a primary growth centre in its own right, but rather it grows in response to some other controlling factors. However, normal growth at the condylar cartilage is required for normal mandibular growth to take place.

Postnatal growth of the mandible follows a pattern intermediate between a neural and somatic pattern, although it follows the somatic pattern more closely than does the growth of the maxilla (Fig 6).

Most mandibular growth occurs as a result of periosteal activity.

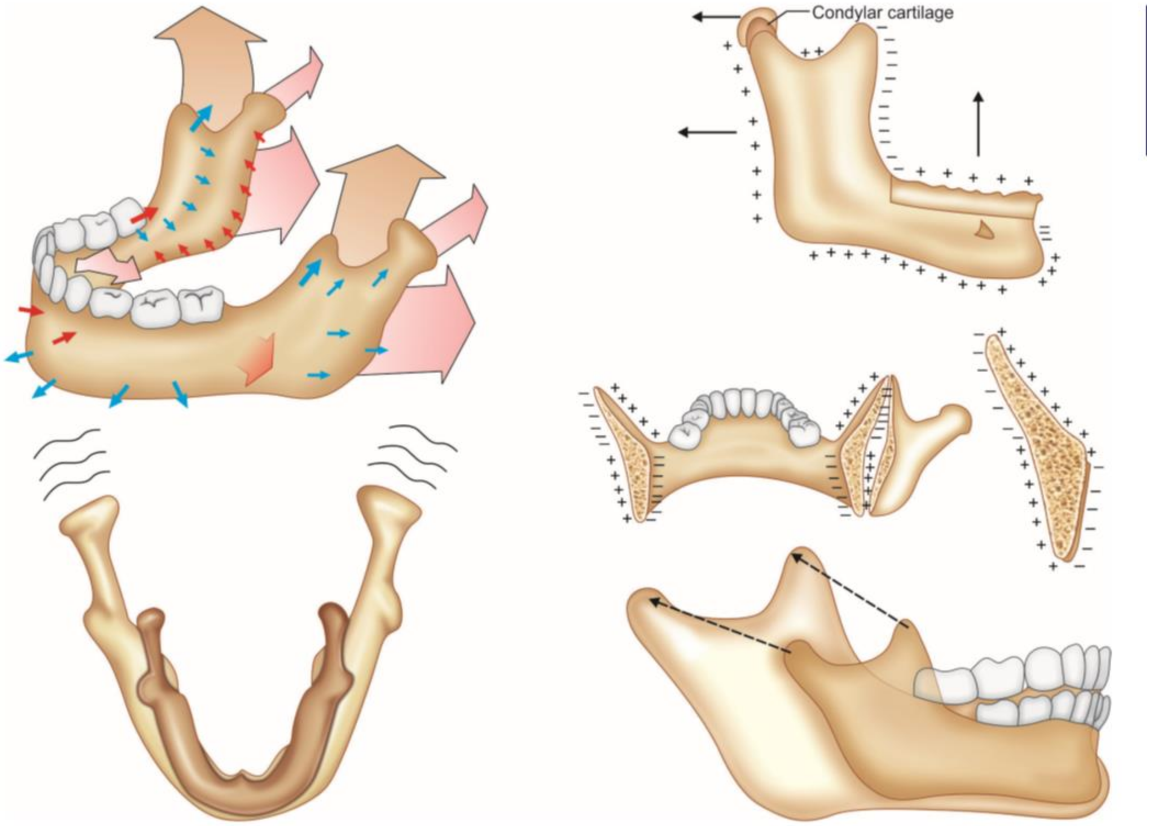
As the mandible is displaced forwards growth at the condylar cartilage fills in posteriorly while at the same time periosteal remodelling maintains its shape.

Bone is laid down on the posterior margin of the vertical ramus and resorbed on the anterior margin, and this posterior drift of the ramus allows lengthening of the dental arch posteriorly. At the same time the vertical ramus becomes taller to accommodate the increase in height of the alveolar processes.

Remodelling also brings about an increase in the width of the mandible, particularly posteriorly. Lengthening of the mandible and anterior remodelling together cause the chin to become more prominent, an obvious feature of facial maturation especially in males. Indeed, just as in the maxilla, the whole surface of the mandible undergoes many complex patterns of remodeling as it grows in order to maintain its proper anatomical form.

Before puberty growth occurs at steady rate with an increase of 1-2 mm per year in ramus height and 2-3 mm per year in body length. However, growth rates can double during puberty and the associated growth spurt.

Mandibular growth slows to adult levels rather later than maxillary growth, on average at about 17 years in girls and 19 years in boys, although it may continue for longer.



Figs. 13 A to E: (A) Overall growth occurring at various areas of mandible. Red arrows bone resorption, blue arrows bone deposition; (B) Downward and forward mandibular growth follows the expanding 'V' principle; (C) Anterior-posterior growth of the ramus and the body of the mandible occurs by bone resorption at the anterior border and deposition at posterior border of the ramus; (D) Vertical section through mandibular ramus and coronoid process showing bone remodeling changes that cause expansion of the bone on a 'V' principle; (E) Increase in the length of mandibular arch, which provides room for erupting permanent molars