THE PRE.AND POSTNATAL GROWTH AND DEVELOPMENT OF THE MANDIBLE

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Index

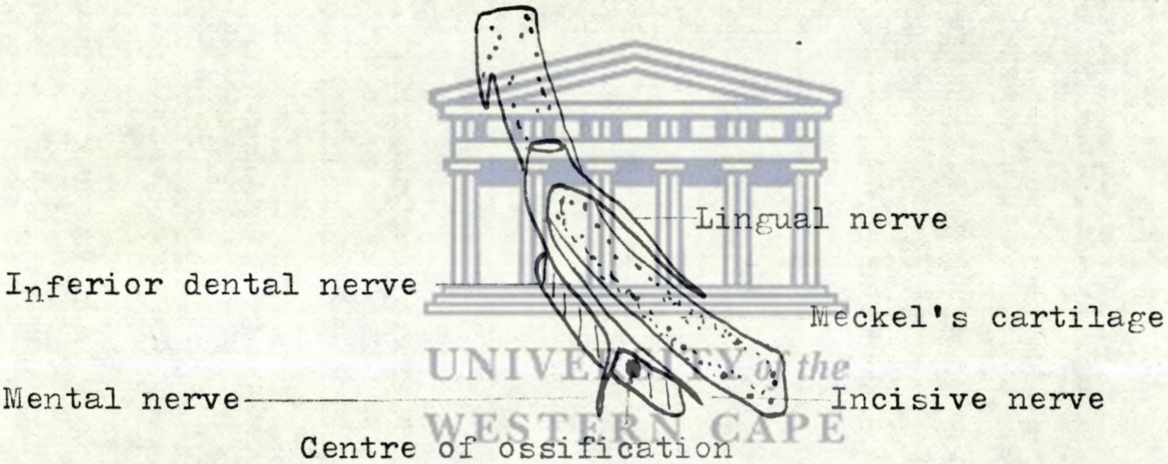
Introduction

The development of the mandible has been a subject of considerable controversy for many years now.At one time, the condyle was considered to be the all important factor for mandibular growth and development and became almost a traditional concept.Then the surrounding soft tissue was given an important role which provided an opposite theory. These two major theories in the literature serve to show how diverse the work has been in this field.

The aim of this paper is to review all the current literature pertaining to mandibular growth and development in an attempt to show how the various theories evolved and perhaps to throw some light onto the subject in this still highly controversial area.

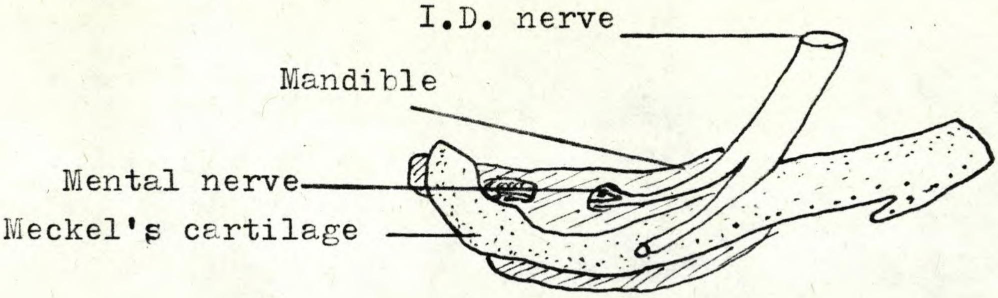
PRENATAL DEVELOPMENT

The mandible develops from the cartilage of the first branchial arch.This cartilage is known as Meckel's cartilage and begins to form in the human embryo at about thirty eight days I.U. By forty two days the bilateral cartilages have met in the midline but not fused.The inferior alveolar nerve runs laterally parallel to the upper margin of the cartilage and ends by dividing into its mental and incisive branches. Ossification occurs in the seventh week (Scott & Dixon I966) in the angle formed by the incisive nerve and the mental nerve i.e. the region of the future mental foramen



Ossification passes posteriorly beneath the mental nerve and in the space of one day (Moore £Lavelle (I974) the bone formation reaches from the symphysis in front to the region of the ramus behind. At this stage the mental nerve lies in a trough of bone, however, ossification has already begun to spread medially below the inferior dental nerve and incisive nerve and upwards between these nerves and Meckel's cartilage so that they are contained in a trough of bone. At the same stage the notch containing the mental nerve is converted into a foramen by ossification extending antero-posteriorly superior to the nerve.

A similair growth of bone over the incisive nerve from the lateral and medial plates converts the trough into the incisive canal.



Somewhat later,a similair process of ossification produces first a plate of bone in relation to the whole of the lateral aspect of the inferior dental nerve,then a bony trough for the nerve to lie in,and very much later bone surrounds the nerve and blood vessels to form the mandibular canal.

Thus,at this stage of development we have the body of the mandible as far back as the mandibular foramen and as far forward as the symphysis.

During the eighth week the deciduous tooth germs begin to differentiate within the tissues superficial to the mandible. As this happens,the bone of the mandible comes into close relationship with them by upward growth of medial and lateral plates of bone above the level of the roof of the inferior dental cand incisive nerve canals forming the medial and lateral plates of alveolar bone.A trough of bone thus forms around the developing teeth which is later subdivided into separate alveoli by bony septa being formed between the medial and lateral plates.

Just as the body of the mandible was first indicated by a fibrocellular condensation so is its backward extension the ramus.The formation of bone in this region occurs rapidly so that the coronoid and condylar processes and the gonial angle are largely ossified by the tenth week.

Further growth of the condylar and coronoid processes is modified by secondary cartilage.These cartilages appear at sites of membrane bone formation and are called secondary because they have no connection with the primary cartilaginous skeleton.The first of these to appear is the condylar cartilage.

The condylar cartilage is the largest of these secondary cartilages and is first seen as a fringe on the superior aspect of the bone in the condylar process during the twelfth week of intrauterine life.It merges into this bone on one side and into the fibrocellular layer limiting the condyle region on the other.

Through additions from the cells of this covering layer of fibro cellular tissue the cartilage soon forms a cone or carrot shaped mass which occupies the whole of the condylar process and reaches down into the ramus as far as the mandibular foramen.

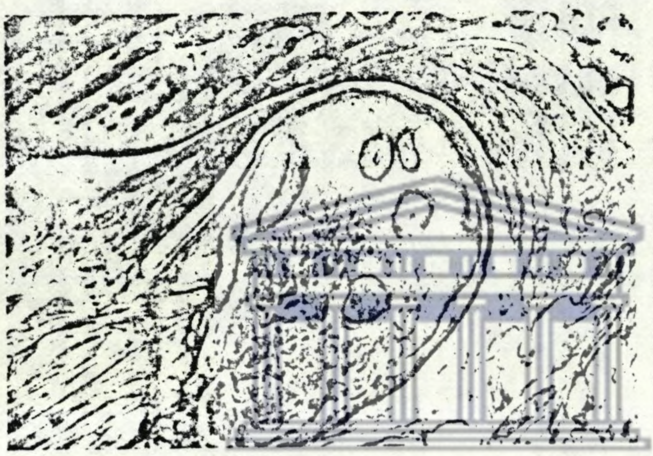


FIG. 73.

Sagittal section through the mandibular joint of human foetus of 210 mm. C.R. length (seventh month). The condylar cartilage is reduced to a zone beneath the articular surface. A number of vascular canals are present in the cartilage. Note the already dense fibrous structure of the articular disc apart from its most posterior part. × 12.

FIG. 74.

Radiographs of the mandible. (A) Five months foetal life. (B) At birth. In both jaws the bone which has replaced the condylar cartilage is seen as a cone-shaped area in the ramus.
(*By courtesy of Dental Record.*)

This ossifies by the fifth month of foetal life leaving the condylar cartilage sitting on a wedge shaped cone of bone. This is well seen in cleared sections (Moore & Lavelle I974) contrasting with the membrane bone of the ramus.

Charles (I925) stated that the area occupied by this cartilage is more extensive in the young foetus than in the full term foetus, and that the full term foetus shows a more extensive area of cartilage than the seven to eight year old child. He concluded that the chondroblast stage is a sign of rapid growth.

The zone of cartilage left behind the articular surface of the condyle persists until twenty years of age. (Symons I967). During this time the zone of cartilage diminishes in thickness until it disappears, the replacing bone now forming the condyle. By the fifth foetal month large vascular canals are visible in the condylar cartilage and are probably for the nutritive requirements of the rapidly growing cartilage. These canals are still present at birth (Symons I952).

Another secondary cartilage, the coronoid cartilage, forms a strip along the anterior border and crest of the coronoid process. It is covered by a thick fibrocellular layer and rests on the membrane bone. There is no trace of this cartilage at birth.

Another secondary cartilage appears a little later than the coronoid cartilage at the symphyseal end of each half of the bony mandible. These two cartilages are separated by the connective tissue of the symphysis. The cells of the connective tissue add to the cartilage. While these cartilages persist, the mandible can grow in width. The two halves of the mandible unite shortly after birth thus they take no further part in the growth of the mandible.

At birth, the mandible is perfectly recognizable as such although the ramus is very small in comparison to the body.

POSTNATAL GROWTH OF THE MANDIBLE

Postnatal Changes in the Morphology of the Mandible

This section will deal with the changes seen in the shape of the mandible so that an idea of the development of the bone may be gained before the various theories of how these changes come about are examined.

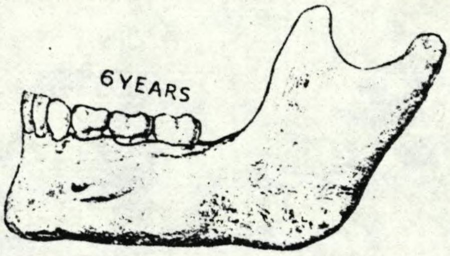
At birth the mandible is in two halves and the body is merely a shell of bone enclosing the developing teeth.At this stage the teeth are not completely separated from each other by the bony septa.The mandibular canal and the mental foramina are near the lower border.

It can be seen that the ramus is very short and the gonial angle is so obtuse that the coronoid process is almost in a line with the body.

The two halves begin to unite shortly after birth and fusion is usually complete by the end of the first year (Scott & Dixon 1966)

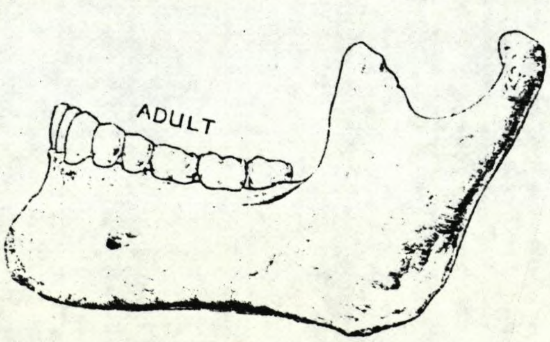
During this time the gonial angle reduces and the deciduous teeth erupt.The deciduous dentition is complete by about two and a half years.

As the teeth erupt the body becomes stronger and deeper, the rami enlarge and the gonial angle reduces, being about 140° in the fourth year.
By the sixth year the first permanent teeth are beginning to erupt



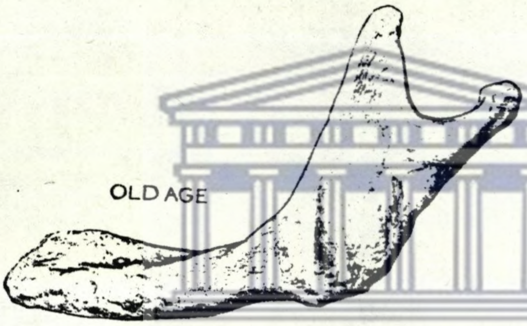
The rami continue to thicken and the body increase in size and by the twelfth year when the second permanent molar erupts the condylar and coronoid processes are well defined and the chin is beginning to show itself

The adult mandible shows a well formed chin, a certain ruggedness at the points of muscle attachment , a deep body which carries the entire permanent dentition and due to an increase in the size of the condylar and coronoid processes. a well defined sigmoid notch.



The gonial angle in the adult mandible becomes reduced to about II0°.

In old age ,a very marked change occurs in the morphology of the mandible should the teeth be lost.The alveolar bone is resorbed thus reducing the depth of the body and making the chin appear more prominent.The mental foramen is approached by the upper border and may cause problems in the wearing of artificial teeth.Remodelling opens out the gonial angle once again and the condylar process may be bent backwards so that the sigmoid notch is widened.



Sexual Dimorphism

The male and female mandibles ,although possessing the same basic morphology have certain differences which are useful in forensic medicine.

The male mandible is larger and thicker with a greater body height especially at the symphysis.The ascending ramus is generally broader in the male and the gonial angle is less obtuse (less than I25°)

The male condyles are larger and the chin is found to be more square with a better developed chin 'button'.

The areas of muscle attachment are more rugged in the male and may cause the angle of the mandible ,where the masseter attaches,to turn out laterally due to the stronger muscle pull.

Theories of Mandibular Growth

Extensive research into the mode of growth of the mandible has produced a number of theories and has been the stimulus for the application of many new techniques.

The condylar cartilage was given prominence as the major growth centre of the mandible from histological studies (Symons, Weinmann & Sicher).

The method of implants was applied by Björk which made it possible to locate the probable areas of growth when combined with serial cephalometry.His studies revealed the size of the mandible as well as the areas of apposition and resorption of bone.

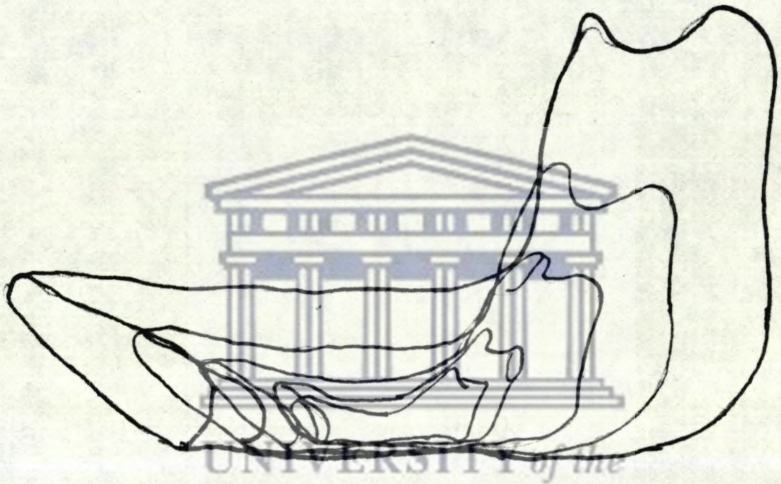
Enlow studied the growth of the mandible using histological evidence of its surface characteristics.This work stressed the remodelling effect and the drifting effect on the morphogenesis of the bone.

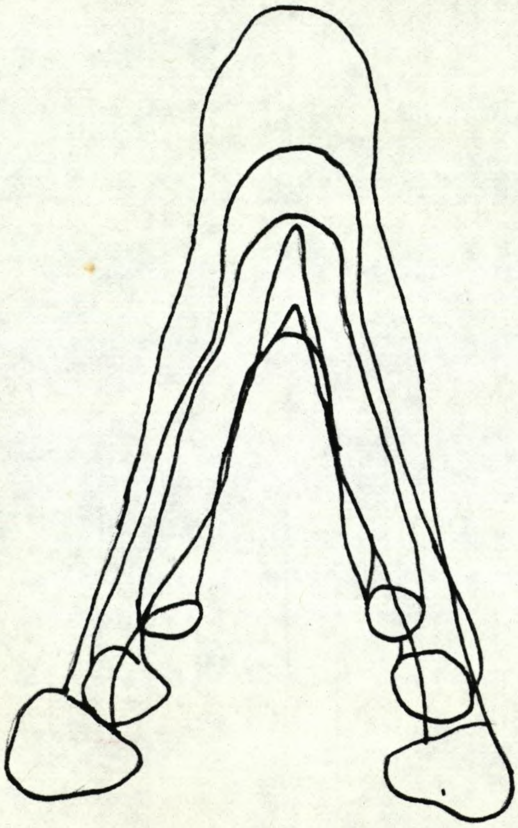
Moss turned to the soft tissue to explain mandibular morphogenesis and developed the theory of the functional matrix as a prime factor.

Ricketts demonstrated that the mandible must grow on an arc, a theory which converges on the concept of Thompson and Hildyard et al.,that of the logarithmic spiral of mandibular development.

Baume and Becks,amongst others investigated the influence of hormones on the development of the growing mandible.

Brash (I934) used pig mandibles to observe the sites of bone deposition by the indirect madder technique.He confirmed the older beliefs that this mainly occurs on the lateral aspect and extends the posterior border backwards and the condyle up and back.He also observed that the principal site of increase in the height of the body of the bone was the alveolar border. He took a series of half mandibles and measured the amounts of new bone deposited and calculated the rates of growth in vertical and anteroposterior directions .This enabled him to superimpose drawings of five mandibles at different stages of growth.





This study showed that the mandible grows both forwards and backwards.The forward growth is due to deposition on the anterior surface of the symphyseal region,and the backward growth is due to deposition on the posterior surface of the ramus extending from the condyle to the angle.Since the condyle is also growing in an upwards and backwards direction it also contributes to the total length of the bone.

The depth of the body is increased by upward growth of the alveolar bone.The space for the erupting molars in front of the ramus is provided by their upward movement during eruption and the upward growth of the alveolar bone in which they are held in relation to the backward sloping anterior border of the ramus,and also by some resorption of bone from this anterior border.The ramus and coronoid process grow upwards and backwards

Growth in width of the mandibleis due to bone deposition on its lateral surfacesand also due to the oblique and outward and backward direction of its growing posterior borders.

The growth processes and directions explained above from a study of mandibular growth of the pig by Brash may nearly all be found in the mandibular growth in humans.

Humans show resorption to occur along the anterior border of the ramus with simultaneous deposition along the posterior border.The resorption seems to provide room for the erupting molars since it occurs most rapidly just before the eruption of these teeth.

The body grows largely posteriorly which not only lengthens the mandible it also increases its width since the halves of the mandible diverge.As in the pig there is very little deposition on the inferior surface of the bone but a small amount of resorption and deposition occur on the lingual and buccal aspects.

The alveolar bone, which is dependent on the **presence** of teeth, serves to increase the height of the body .Its activity is most pronounced in the early years when the tooth germs are developing at a rapid rate.

The Mandibular Condyle as the Primary Growth Centre

This is the so called 'classical theory' of mandible formation.

The importance of the condylar cartilage in the growth of the mandible was first demonstrated by Charles (I925).He used foetal skulls from three and a half months to full term in his study.He commented on the wedge shaped piece of cartilage first described by Fawcett(I924) by saying that this tissue is in fact bone with the exception of the cartilage at the growing end,and that the growth taking place at the top of the cartilaginous cap was the controlling factor in the forward growth of the mandible.He further concluded that mandibular growth is solely controlled by the growth occurring at the top of the condyle.

This view has been echoed by many workers including Symons(I952) and Weinmann (I955).

Sicher (I947) explained how cartilage could grow by apposition and expansion as opposed to bone which can only grow by apposition, and he applied this to the condylar cartilage explaining that as this cartilage proliferates the mandible grows longer, higher and wider.Thus he suggests that growth of the condylar cartilage makes the mandible grow in three dimensions at the same time.He carried the idea a little further to conclude that growth of the mandible and primarily the growth of the condylar cartilage determines the growth of the whole face.

Symons in his studies on growth and formof the mandible (I95I) agreed with the important role ascribed to the condylar cartilage during the growth of the mandible and pointed out that this cartilage is formed not only in man but occurs throughout the whole class of mammals where it also plays an important role in mandibular growth.

A large number of studies have been presented in an attempt to elucidate the nature of the condylar growth mechanism. Blackwood (I966) used tritiated thymidene to investigate this problem.He used rats as his experimental animals and noted a three layered condyle as in humans.The articular surface had a thin layer of flattened cells covering it underneath which was an intermediate zone of tightly packed cells. Beneath this intermediate layer of cells was a layer of cartilage. Blackwood found numerous mitotic figures in the intermediate zone.Cells produced in this zone pass as chondrocytes through the cartilage to be released five days later in the marrow cavity of the bone.These cells showed no evidence of further division during their passage.

The condylar cartilage is a secondary cartilage and not part of Meckel's cartilage which is present in the very early development of the mandible.Weinmann and Sicher (I955) and Symons (I965) described the growth of the cartilage as being appositional growth from the deepest layer of the connective tissue cover of the condyle.This layer responsible for the growth of the cartilage is called the intermediate layer or zone and is located between the surface of the condyle and the cartilaginous portion of it.The cells of this layer are not cartilage cells but resemble undifferentiated mesenchymal cells.

The Condyle as a Growth Centre

In the past the term 'growth centre' has been used rather loosely to cover many kinds of skeletal growth site.(Koski I968). Baume (I96I) proposed the term 'skeletal growth centre' be used to describe 'places of endochondral ossification with tissue separating force'.This definition implies that a growth centre includes only the territory where endochondral ossification is taking place.The time element may also be important,since some sites of endochondral ossification are only temporary and do not contribute to the growth of the skeleton appreciably e.g.secondary ossification centres of the epiphyses.Because of these shortcomings in Baume's definition Koski (I968) suggested a modified definition of a growth centre,'a site of endrochondral ossification with tissue separating force,contributing to the increase of skeletal mass!

Most orthodontic texts include the classical view that growth at the condyle moves the mandibular body forwards and downwards thus opening a space into which the maxillary and mandibular teeth erupt.It has also been claimed that the growth of the condylar cartilage is 'resposible for the anteroposterior growth of the mandible' (Salzmann I966).Thus the condyle was considered the most important growth centre of the lower jaw. A few workers have published theories disagreeing with this view.Scott (I954) suggested that growth at the condylar cartilage enables the condyle to grow'upwards and backwards so as to maintain the contact at the temporomandibular joint as the mandible is carried downwards and forwards by the growth of the upper facial skeleton.'

Moss has also published work which disagrees with the classical view of mandibular growth,in fact,he agreed with Scott as far as the role of condylar growth was concerned,but he believes that the governing factor is the functional matrix.
(Moss I960,I962)

Investigations have been carried out to clarify the controversy of whether the condyle has an independent growth potential or whether it grows as a compensatory movement.
Rönning (I966) transplanted condylar cartilage into subcutaneous tissue and found that it did not retain its structure.When the cartilage was transplanted along with its bony ramus,or a part thereof,it will grow but not maintain its structure in the

same way as a condyle in situ does.These experiments seem to indicate that there is no growth potential in the condylar cartilage,and rather show that its role is that of a site of growth than a growth centre.

Koski (Conference on Genetics,Bone Biology and Analysis of Growth Data,held in I967 at Ann Arbor)studied some characteristics of craniofacial growth cartilages.He said that cartilaginous growth is important in the craniofacial skeleton in both foetal and postnatal life.One of the main growth cartilages in the postnatal skull is the condylar cartilage of the mandible.
Baume (I96I) and Sicher (I965) claimed that the condylar cartilage resembles an epiphyseal growth plate, functionally if not structurally.Koski (I967) examined the condylar cartilage from both a structural and functional viewpoint,and compared it to the epiphyseal cartilage of the long bones.
In the long bone of a 5 day old rat the epiphysis is not yet formed but the cartilage appears to function as a growth apparatus for the bone.At this stage the columns of row cells are 20 or more cells high,and there are 4 to 8 cells in the columns of hypertrophic and degenerative cells.
The condylar cartilage at this age differs markedly from the epiphyseal cartilage.Beneath the articular zone is a zone of cells resembling the small round cells of the former,but of more ovoid shape and not so densely packed as the articular zone cells.The second,or intermediate zone blends without a clear boundary with the next zone of chondroid and true cartilage cells,which is only a few cells high.Then follows a zone of hypertrophied cells which forms about three fifths of the whole height of the cartilage.The hypertrophic cells are smaller than in the epiphyseal cartilage.The matrix is scanty in the condylar cartilage,the primary spongiosa seems to be sparse orlacking and there is no clear organization in the condylar cartilage as there is in the epiphyseal cartilage.Thus,it would appear that the two cartilages are not structurally similair at this stage of development.

Another interesting difference between the cartilages is shown when they are stained with Sudan black.In the long bones only the matrix around the degenerative cells is stained,whereas in the condyles the matrix is stained around the hypertrophic cells also.Thus in the condyle more than half of the cartilage appears to be mineralizing.

Koski used transplants of the cartilages to show how great the independent,growth promoting potential of the different growth cartilages is.

Koski and Ronning (I966) transplanted the distal cartilaginous ends of the radius either subcutaneously or intracerebrally. These transplants had a well differentiated epiphyseal growth plate,an ossifying epiphysis and a diaphysis of varying length after I5 days.

Three types of condylar transplants were used by Koski,

I)condylar cartilage proper

2)condylar cartilage plus the adjacent spongiosa

3)condylar cartilage plus adjacent ramus down to the well ossified part of the latter.

These were recovered after 30, 60, and 90 days.

The recovered transplants of type I)maintained their original shape,and increase in size in some of them had occurred in a lateral direction.They consisted of cartilage,calcified cartilage,chondroid and young immature bone.Many presented a picture of mineralizing cartilage or of cartilage being transformed directly into bone.No typical structure of the condylar cartilage was seen in any of these transplants.

The transplants of type 2) behaved differently.After 30 days cartilage was present in about half of the specimens examined. The cartilage was never of the same structure as in the condyle. After 60 days osteoid,young bundle bone and lamellar bone were seen in the specimens in varying proportions.Some of the transplants had increased in size apparently in the direction corresponding to the vertical dimension of the ramus.

Transplants of type 3) resembled those of type 2).

Fig. 7. A schematic picture of the posterior part of the mandible in a 5-day-old rat illustrating the three types of condylar transplants: 1 = cartilage only, 2 = cartilage with the adjacent spongiosa, 3 = cartilage with the adjacent ramus down to the well ossified part.

Koski summed up his work by stating that with regard to structure the two types of cartilages used were not similair. The most interesting differing features seem to be the cell type of the proliferating layer and the rapid transformation in the condylar cartilage of the cartilage cells into hypertrophied cells between which there is very little matrix.
Generally speaking this work indicates that the condylar cartilage is not comparable to the epiphyseal cartilage as growth centres in early postnatal rats.

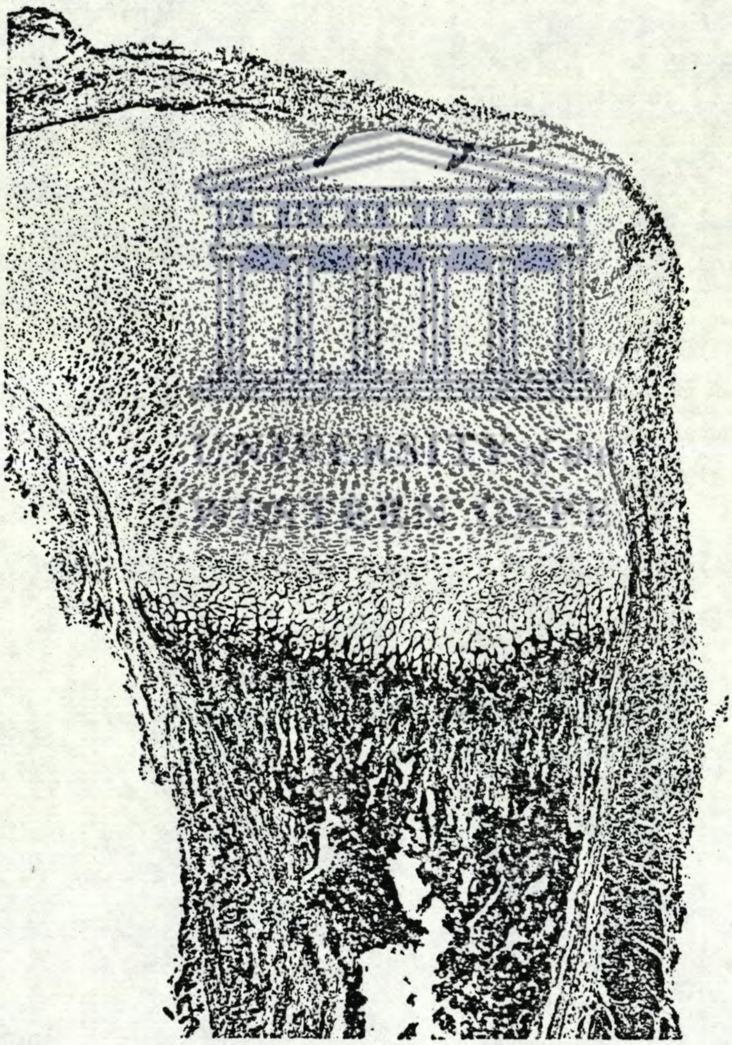


FIG. 1. The proximal end of the tibia of a 5-day-old rat. The zones of row cells, hypertrophic cells, and degenerative cells are distinguishable. Note that the Sudan black stain does not reach up to the hypertrophic cell zone. (Courtesy of Dr. O. Rönning.)

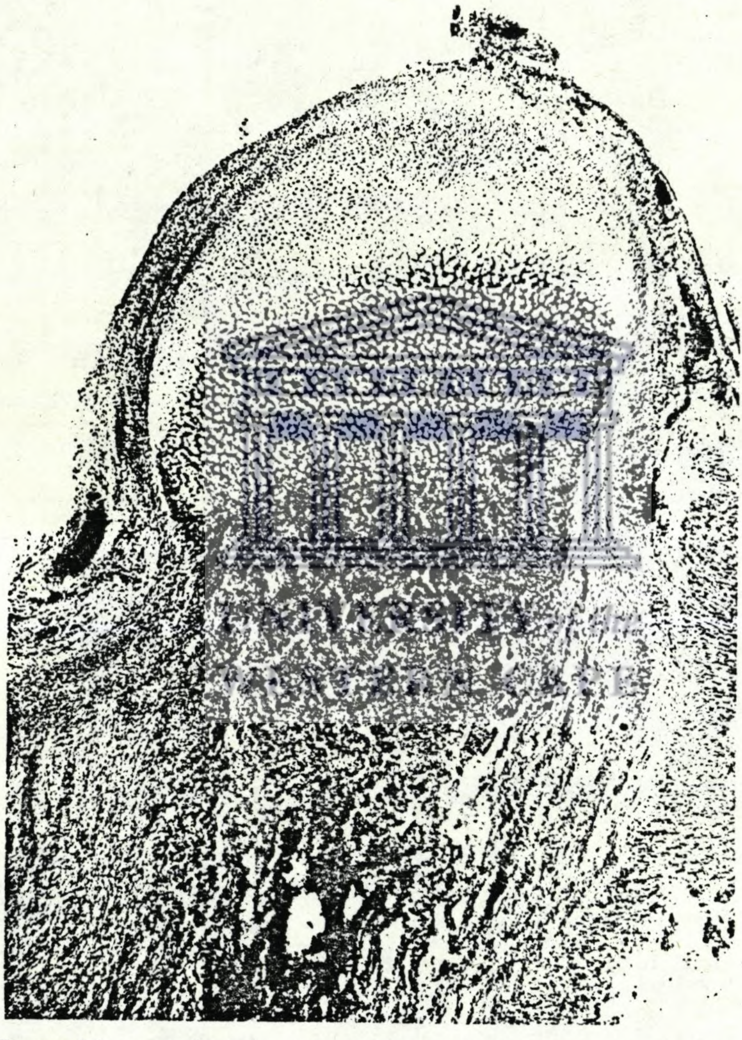


FIG. 3. The condylar area of a 5-day-old rat. The structural pattern is clearly different from that seen in the tibial end and in the synchondrosis. Note that the Sudan black stain covers the matrix throughout the hypertrophic cell area. (Courtesy of Dr. O. Rönning.)

Another technique used widely in the study of condylar cartilage is the so called extirpation technique,i.e. condylectomy and resection.

Sarnat (I957) carried out unilateral and bilateral resection of the condyle in 8 month old monkeys.Two years postoperatively the mandible had a shorter and wider ramus than the controls whereas the length of the body of the mandible was unaffected. Sarnat also noticed that the maxilla was shorter and narrower in the subnasal portion and suggested that the lack of condylar cartilage was responsible for these changes by reducing the forward and downward growth of the mandible.He concluded that the growth of condylar cartilage,and thus the mandible,is indispensible for the normal vertical growth of the face.

Sarnat changed his opinion later (Sarnat and Muchnic I97I) after a study on squirrel monkeys gave similair results,but as there was no histological evidence of osteogenesis in the condyle at the time of removal it was considered unlikely that changes in facial skeleton could be attributed to interference with normal condylar growth processes.It was suggested that they were secondary to the disturbance of the temporomandibular joint and its associated musculature.

Bilateral condylectomy,carried out by Jarabak and Thompson (I953) and Gianelly and Moorrees (I965) in growing rats showed little change in the facial skeleton.Gianelly and Moorrees found the distance from the base of the skull to the cut end of the ramus to be maintainedand the reduction in growth of mandibular depth to be 2mm.From their findings Gianelly and Moorrees concluded that condylar growth is adaptive not primary.

Pimendis and Gianelly (I972) repeated the above studies using bilateral condylectomy on newborn rats since the anteroposterior dimension of the mandible may have already received a contribution from the condylar cartilage.They found that the incisor relationship was normal,and although the length of the condylectomized mandibles was I5% less than the control they were in fact double their original length at the start of the experiment.

They concluded that the condyle is not critical for overall lengthening of the rat lower jaw,thus the role of condylar growth is secondary and compensatory.Their results support the functional matrix theory that condylar growth is adaptive.

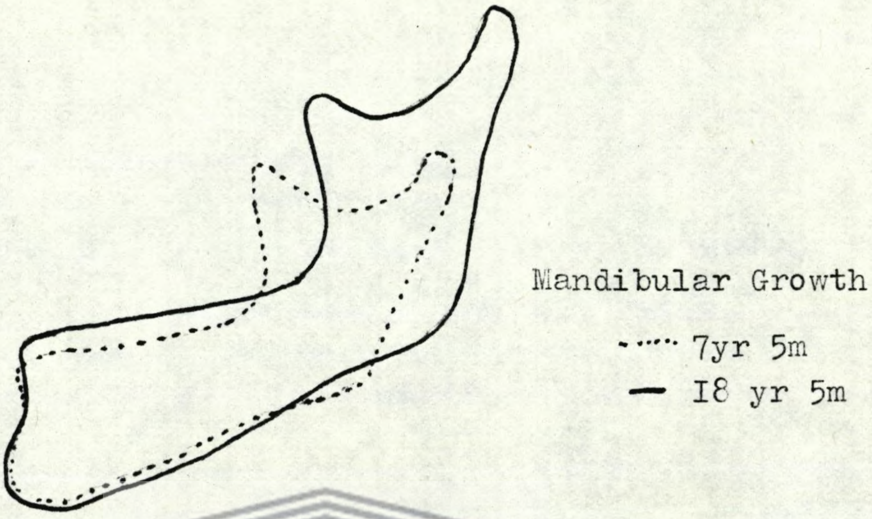
Moss and Rankow (I968) presented a case report concerning a seven year old white female who had trouble opening her jaws and could only manage Icm. of actual opening on forced excursion.On investigation of the temporomandibular joints fibrous adhesions were found between the condyles (both of which were deformed) and their glenoid fossae.The decision was made to excise these deformed condyles.Following the operation the mandible could be opened widely and function freely without limitation.During five years of post operative follow up,this mandible has lowered in space,increased in body length, has moved horizontally and continued normal dental maturation.In summary, this non condylar mandible has produced relatively small changes in facial growth compared to a normal mandible.

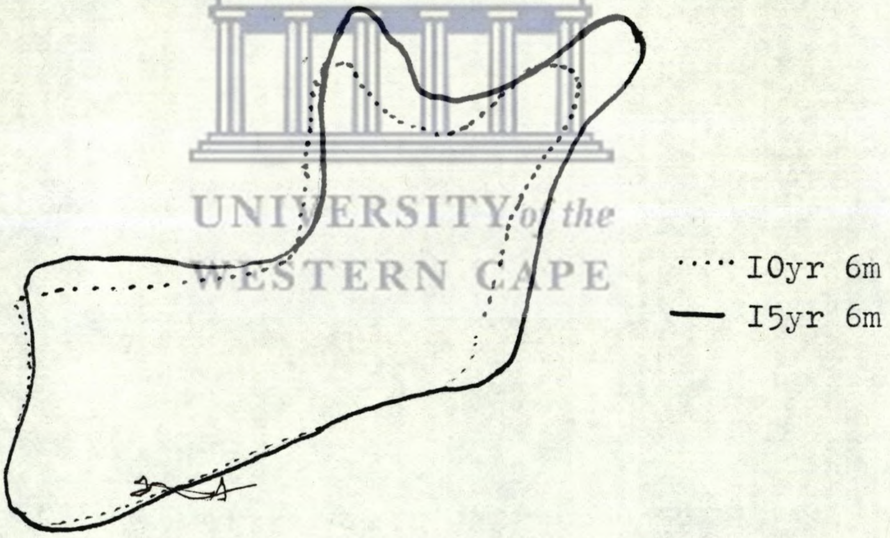
Meikle (I974) states that the effect of the surgical procedure cannot be disregarded,and that the only conclusion that can be made concerning the relevance of condylectomy experiments to an understanding of mandibular growth,is that within the age limitations of the animals at operation,such experiments can give,at most,a very rough indication of the quantitative contribution of the condyle to postnatal growth of the mandible.

Bearing in mind the problems associated with the extirpation technique,it would appear that the condyle plays a less prominent part in the determination of mandibular growth than previously thought.

This theory is supported by the results of condyle transplantation experiments. Murray (I925) in his experimental grafting of chick limb buds onto chorioallantoic membrane showed that although the general shape of the cartilaginous skeleton develops solely due to intrinsic factors,extrinsic factors such as function are necessary for the preservation of skeletal form.

Bjork in I963 and I964 used the implant method to show the directions and amount of growth in the various directions which then allowed him to superimpose old and young mandibles as an illustration of this.





Bjork in 1963 gave a detailed account of a longitudinal study of mandibular growth in children extending over approximately twelve years.This investigation used cephalometric radiographs after the placement of metallic markers.The method used for the placement of these markers has been described in an earlier work of Bjork's (I955)
Using the dorsal surface of the condyle to indicate the direction of its growth Bjork found that this direction in relation to the posterior tangent to the ramus on the first radiograph was on average 6 degrees.Related to the tangent to the lower border of the mandible,also on the first radiograph,the mean direction of growth was I23 degrees which was less than the mean gonial angle on the first radiograph (I29 degrees).From this Bjork suggests that the mandibular base was curved with growth which was accompanied by a reduction in the gonial angle.This reduction in the gonial angle was generally not pronounced since it was compensated for by resorptive remodelling below the angle of the mandible and by periosteal growth below the symphysis. The direction of growth of the condyle showed a distinct curvature in many cases.The direction of condylar growth was subject to great individual variation.In some cases it was in a vertical direction and then increased the curvature of the mandibular base,whereas in other cases it took place in a sagittal direction ,where the mandibular base was flattened.The gonial angle was found to increase with growth in the sagittal direction ,and to decrease when growth was in a vertical direction.The compensatory resorption beneath the angle region was great in the case of vertical condylar growth,whereas in the case of saggital growth it was moderate or even apposition could occur.Apposition beneath the symphysis was greatest in the vertical growers (see figure)

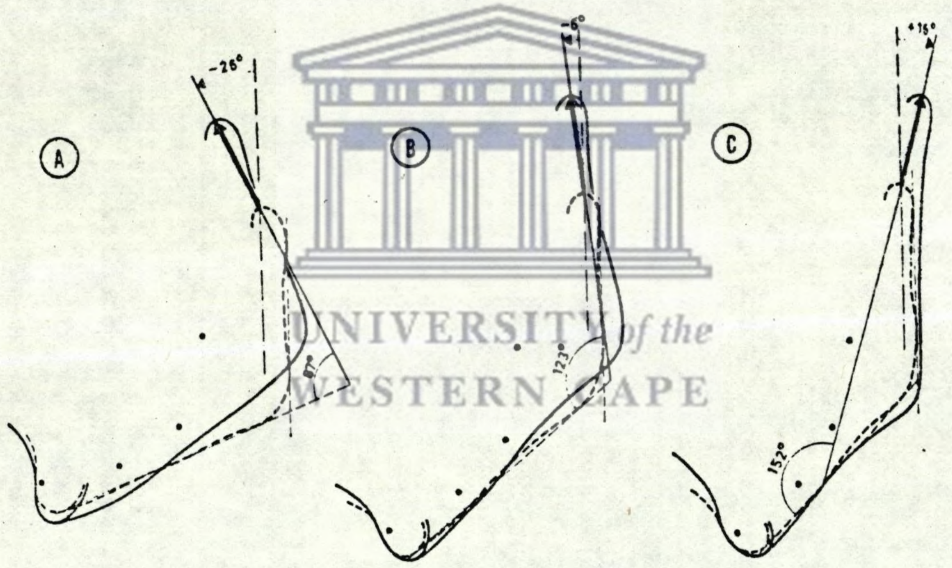


FIG. 5.—Diagram illustrating mean direction of growth at the condyles and extreme vertical and sagittal directions for 45 subjects of the male sample. The direction of growth is measured with respect to the tangent to the ramus and to the lower border of the mandible on the first radiograph in each age series. The direction of growth is determined from the first to the last film of each series. *A* = extreme vertical; *B* = mean; *C* = extreme saggital.

The following figures show how the different directions of growth at the condyle affect the development of the mandible. The first shows mean growth direction at the condyle allows the eruption of the teeth to remain in a constant position.

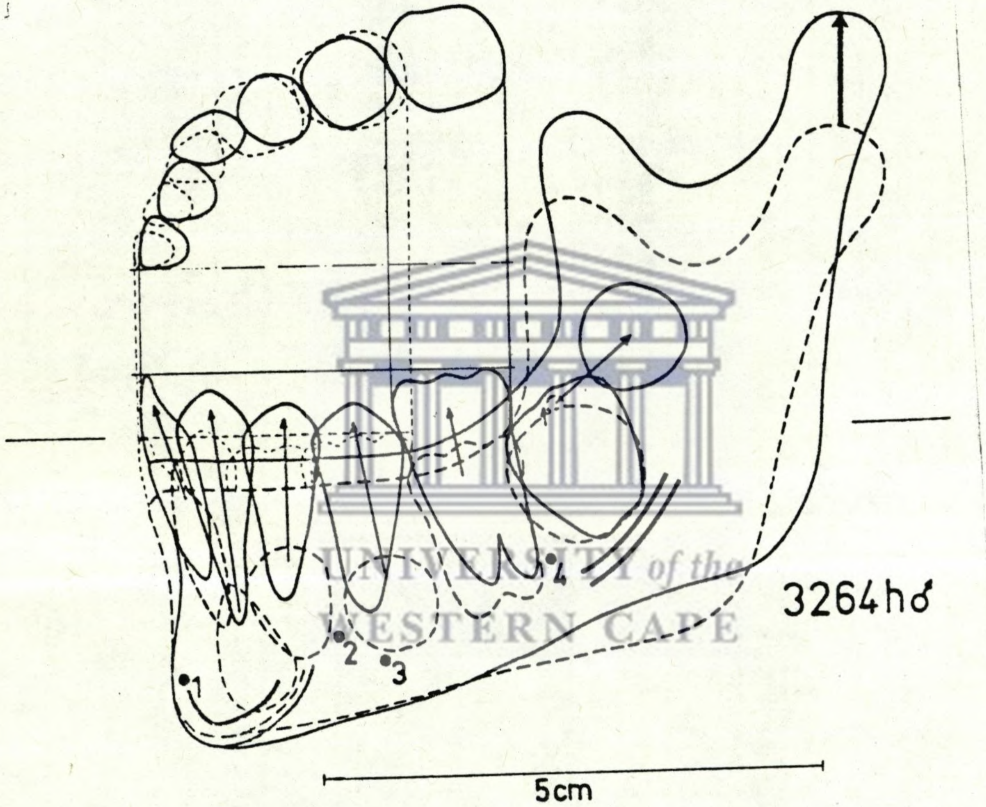


FIG. 6.—A case from the boy sample representing mean direction of growth at the condyles. *Broken line* = age 5 years 8 months; *solid line* = age 10 years 8 months.

The next shows vertical growth at the condyle and the teeth are seen to erupt in a forward direction.

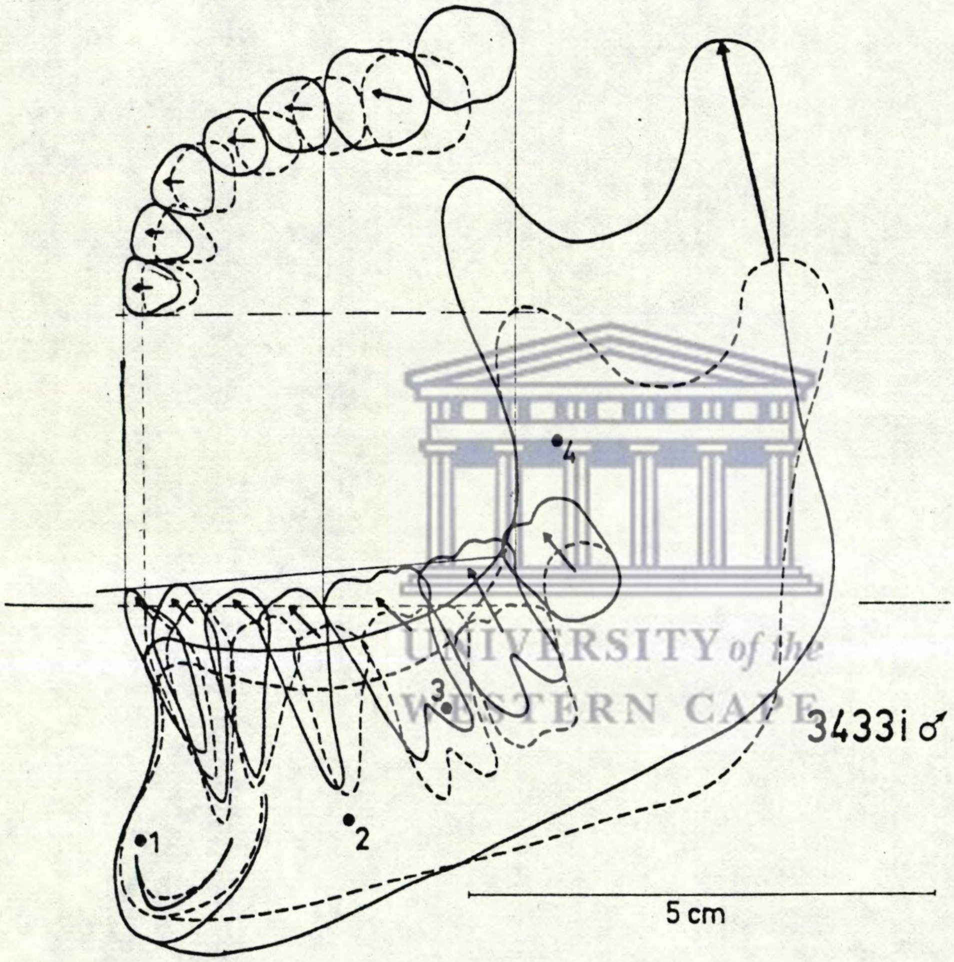


Fig. 7.—Case illustrating extreme direction of vertical growth at the condyles in the boy sample. *Broken line* = age 11 years 7 months; *solid line* = age 17 years 7 months.

The third figure illustrates sagittal growth accompanied by backward eruption of the anterior teeth.

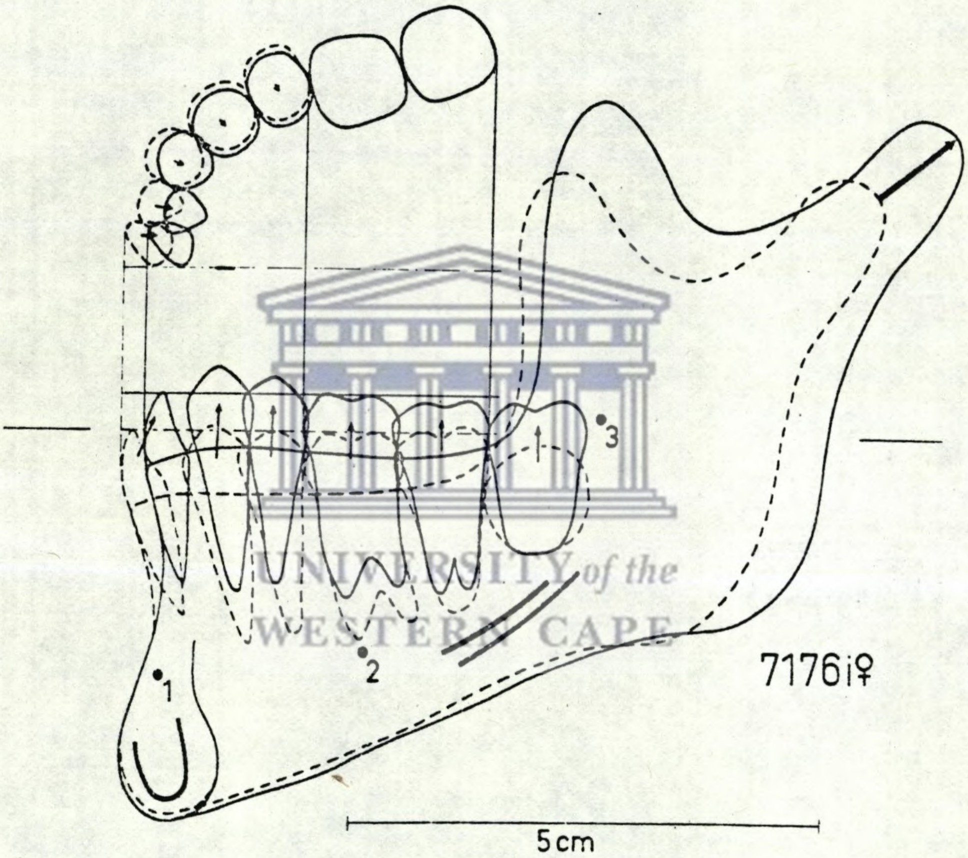


FIG. 8.—Case illustrating extreme direction of sagittal growth at the condyles in the female sample. *Broken line* = age 10 years 6 months; *solid line* = age 15 years 6 months.

According to Enlow (1968)

The growth of any facial bone cannot take place simply by uniform,overall,surface accretion as the surface contours would become disproportionate and the configuration of the bone would be lost.In fact two distinct but,closely coordinated processes are at work.One is the addition of bone at the various growth sites,the other is a process of remodelling which maintains a constant configuration of the bone during its growth.
The mandible grows in a posterior direction predominantly and the forward projection of the jaw is due to the displacement caused by this mode of growth.

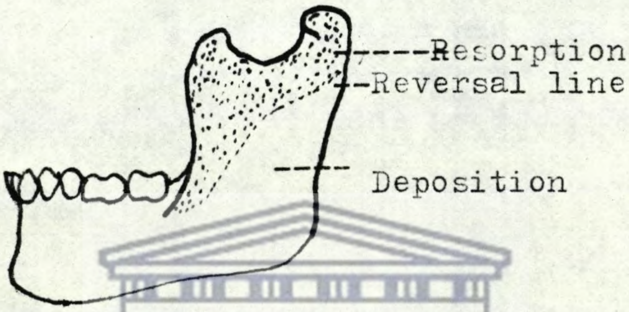
The cartilage of the condyle has a dual function,
I)Articular cartilage
2)Growth cartilage
Growth at the condyle moves it in an upward and backward direction towards the temporal bone.As it grows,the deeper part of the cartilage is continually replaced by endochondral bone ,thus the cartilaginous plate moves by growth on one side and bone replacement on the other.This endochondral bone formation produces a medullary core of cancellous bone
The cortical bone is produced by the activity of the periosteum.
The entire head of the condyle moves up and backwards forming a completely new condyle behind the moving cartilage.This process is continuous and as the condyle migrates its former levels become simultaneously converted into the condylar neck.

The broad head is remodelled into the narrower neck (a process called'area relocation' (Enlow)
The neck moves in the same directionas the head of the condyle by a process of endosteal apposition and periosteal resorption.
Area relocation continues as the neck becomes incorporated in the ramus.

As the condyle (head and neck)moves obliquely,the posterior border of the ramus recieves proportionate deposits of bone to allow it to keep pace with the posteriorly moving condyle.
At the same time the ramus becomes elongated vertically.
This bone deposition is rapid and produces one of the dominant growth movements of the mandible.

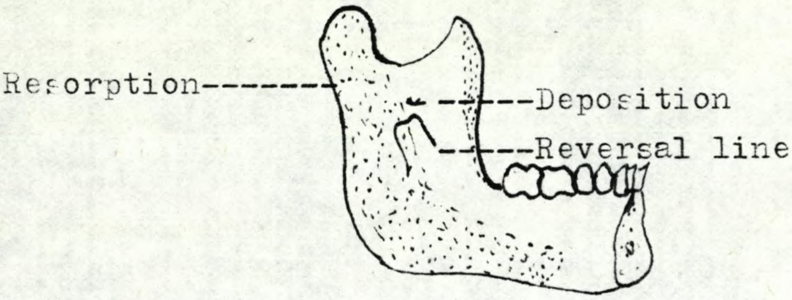
The buccal surface of the ramus may for growth purposes,be divided into two parts separated by a reversal line of bone activity .This line represents the approximate line along which the growing and relocating neck has passed during previous growth stages.

The area above this line(which may be seen as a bony ridge in a dried specimen)has a resorptive surface which continues down from the neck onto the upper part of the ramus and includes the area of the sigmoid notch on its buccal side and the coronoid process .



Below this line the remainder of the ramus is depository in nature.

There is a similair reversal seen on the lingual surface of the mandibular ramus.The reversal line coincides with the ridge running obliquely down and forwards from the condyle. Above this line bone is deposited and functions to produce growth in a superior and posterior direction.



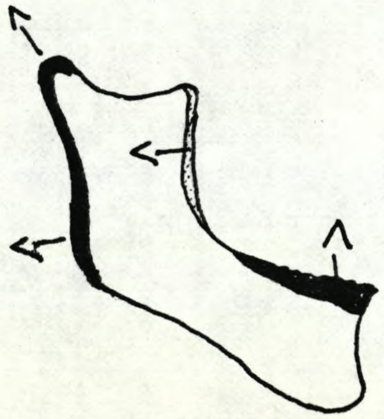
Below the line ,the surface is resorptive.This area is succeeded posteriorly by the depository zone along the posterior border of the ramus.

This pattern of bone remodelling results in a progressive drift of the entire buccal and lingual cortical plates in a buccaland posterior direction.

Thus the two rami move apart.

During postnatal life,the body of the mandible increases in anteroposterior length,vertical height and buccolingual width. The separation of left and right sides also increases. The increase in anteroposterior length occurs by removal of bone from the anterior border of the coronoid process and the relocation of regions of bone which were originally part of the ramus,into parts of the body.This elongation of the body is secondary to the posterior growth of the ramus. This simplified explanation is not ~~the whole story~~. complete The posterior teeth are supported in alveolar bone overhanging the sublingual fossa and mylohyoid line.The anteroposterior axis of these teeth,if projected distally runs lingual to the ramus.Therefore,the process of relocation of ramus into body involves a lingual shift.This is brought about by addition of bone to the lingual aspect of the ramus immediately below the coronoid process.Posterior and inferior to this is a band of resorption which extends down and forward into the sublingual fossa as far forward as the canine region. Thus the fossa is deepened relative to the overhanging arch and the basal region of the body is shifted buccally.This lingual resorption and buccal deposition on the body of the mandible results in the basal part of the body moving buccally and the separation between right and left halves of the mandible increasing,thus the mandibular arch is widened.

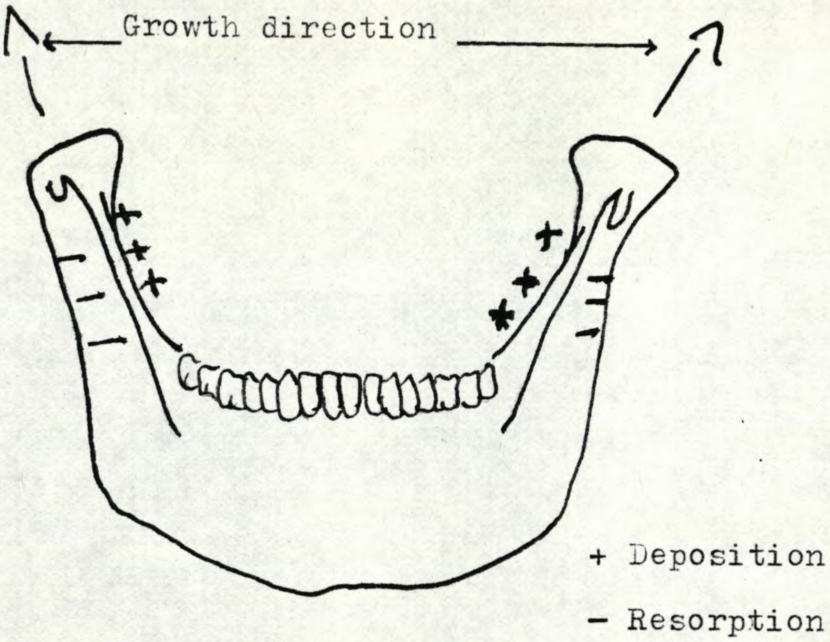
The increase in height of the mandibular body is brought about by the addition of bone on the alveolar processes and perhaps to a very small degree by the apposition of bone on the inferior surface.



Growth directions

■ Deposition.

▨ Resorption



Remodelling changes

The chin in Man increases in prominence with age but there is no muzzle formation as occurs in other species.The mandibular arch is reduced in conjunction with the correspondingly short,flattened maxilla.It has been suggested that the chin is a structural adaptation to this reduction (Enlow& Harris) Modelling processes in the chin region appear to be rather subject to individual variation.

The mental protruberance is marked by large deposits of bone of bone.These deposits continue onto the lingual side where they extend the full height of the lingual cortex in the genial region.The maturation of the chin in shape and size is a slow process and continues throughout the postnatal period of facial growth.

As the mental protruberance grades into alveolar region above a reversal occurs where the external surface becomes resorptive. The position of the reversal line varies and is associated with individual expression of this area.

This reversal serves to increase the prominence of the mental protruberance and change its contour

The resorption of the bone superior to the mental protruberance is a primary remodelling factor contributing to the flattened anterior part of the mandibular arch which is characteristic of man as indeed is the prescence of a chin.

Functional Matrix

Moss has revitalised a functional concept of cranial growth which was first conceived by van der Klaauw (I948) This concept suggests that the organs surrounding the bone are responsible, through their function, for the form, growth and position of all skeletal units.

Considering the mandible, Moss states that the forward and downward relocation during growth occurs as a response to the primary volumetric increase of oral, nasal and pharyngeal cavities. Since the mandible is completely embedded in this so termed 'oro facial capsule' it is carried in the direction of the resultant growth vectors. He suggests that this translative growth carries the condyle away from the articular eminence and that the growth which undoubtedly occurs at the condylar cartilage is compensatory in nature. Koski (I968) supports this theory which is further backed up by the results of various condylectomy studies (Gianelly I965, Sarnat et al I97I, Jarabak et al I953).

Frankel (I967) referred to the same concept when he wrote of 'developmental mechanical' and 'functional mechanical' influences on facial growth. Moss (I968) considers these equivalent to the capsular and periosteal matrices respectively. These are described as follows, periosteal functional matrices act directly and actively upon their related skeletal units. Alteration in their functional demands produces a secondary, compensatory transformation in size or shape of their skeletal units. These transformations are brought about by deposition and resorption of bone.

The capsular functional matrices differ completely in their action. They act indirectly and passively on their related skeletal units.

Moss distinguishes six skeletal units in the mandible. These are, with their associated functional matrices, basal (inferior alveolar neurovascular bundle), condyloid (temporomandibular joint and lateral pterygoid muscle), coronoid (temporal muscle), angular(masseter and medial pterygoid muscle), alveolar (dentition) and symphyseal (facial and genial muscles attached to the chin region) (Moss I960 & Moss and Rankow I968)

The capsular functional matrices produce a secondary, compensatory translation in space.These alterations in spatial position of the skeletal units are brought about by expansion of the orofacial capsule within which the facial bones arise and grow.The facial skeletal units are passively moved in space as their enveloping capsule is expanded.

Considering mandibular growth Moss (1968) suggested that the downward and forward repositioning of the skeletal units as a whole occurs as a response to the primary volumetric increase of the oral,nasal and pharyngeal cavities.It is noted that an identical passive translatory movement occurs in patients with congenitally missing ramal units bilaterally.

Moss (1962) investigated the relative roles of genetic and environmental influences on skeletal form.He stated that intrinsic (genetic) factors are primarily responsible for the initiation of bone form.That is,a bone,when removed from its normal soft tissue or environmental matrix has the ability to express itself ontogenetically up to a point.The further morphological differentiation as well as the maintenance of the bone,which is already formed,comes under the influence of the soft tissue environment,and skeletal elements grown together with their soft tissue show normal growth and maintenance of skeletal form.

Moss (1962) stressed that the growth of the mandible is a response to the matrix of the oral cavity and that the growth at the condylar cartilages is not the primary force.Growth at the condyles he considered to be a secondary response to the growth of the viscera which make up the functional matrices.

The growth force of the soft tissues constantly relocates the condyle and the growth at the condyle is just enough to counteract this separative movement.Again,this is supported by the bilateral condylectomy studies in which no disturbance of mandibular body position or form is seen and the only portion of the bone to suffer deformation is the ramus.

Further evidence for the functional matrix concept is given by Moss and Rankow from a study of young patients with bilateral temporomandibular joint ankylosis.This condition shows a progressive facial deformation due to the uninterrupted growth of the oral viscera.The magnitude of growth vectors is never altered,only the direction of the vector changes.Thus when the mandible is unable to move in responseto the vectors of the oral visceral growth the direction of these vectors is altered and the mandible forced into an increasing deformity. Moss and Rankow performed bilateral condylectomies on these patients which allowed the body of the mandible to move in space within the orofacial matrix thus allowing the patient to open and close the jaws once more.Moreover,the mandible being free again could move more normally in space when subjected to visceral growth forces.

Arcial Development

Ricketts (I972) recognized that a bending was occurring in the mandible with growth and in an orderly manner,such that the greater the magnitude of growth the greater the bending.He tried various points to see if this bending could be reduced to the segment of a circle,an ellipse or a spiral curve.After some trial and error he found that the true arc for growth of the mandible passed through points Eva and Pogonion with a further point equidistant from both of these as the centre of the arc.This point was labelled 'Tr'. From this theory Ricketts evolved a method of predicting the growth of the mandible,(Angle Orthodontist 42 368 I972)

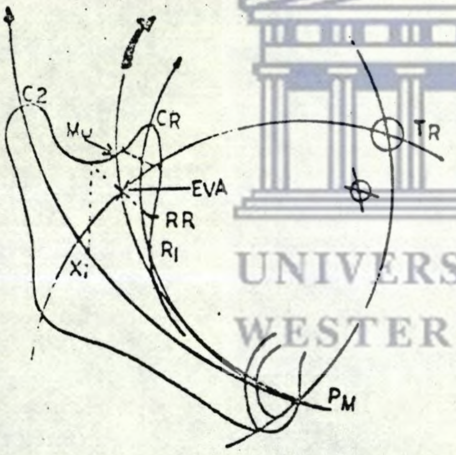


Fig. 11 Should be compared with the experimental studies shown in Figures 6 and 7, representing the search for the true arc of growth of the mandible. A line from Xi point to the sigmoid notch is bisected and a parallel point (RR) is selected on the anterior border of the ramus. (This point is used in growth forecasting as seen below). RR point is connected to point R3 at the lower border of the sigmoid notch. This line is crossed by a second line selected from a point midway of the base of the coronoid process to the Xi point. The crossing of these two lines (called point Eva) approximates the center of the upward and forward quadrant of the ramus. Eva almost exactly coincides with the forking of the stress lines on the internal and outer table of the ramus (Fig. 10). A third point is selected, of equal distance from Eva and PM, which is TR (true radius), the true arc for growth of the mandible. This point is used for the center of the circle which is drawn from pogonion through Eva. The heavy arrow shows the direction of growth of the mandible. At the point of intersection of the arc with the border of the sigmoid notch, a point was selected which was called point Mu.

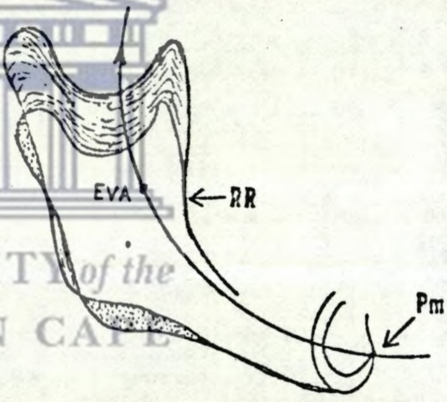


Fig. 12 As the 8-year composite was extended on the arc, with the increments added, the mandible was duplicated almost absolutely, confirming the true arc of growth.

Hildyard et al. (1976) found that the mandible of Man grows along a constant logarithmic spiral by plotting the position relative to the median plane of foramen ovale,mandibular foramenand the mental foramen.They compared the growth of the chimpanzee and the gorilla to that of Man and found that in the chimpanzee growth was along a progressively unfolding spiral. The unfolding,however,was greater in the gorilla than in the chimpanzee.From an evolutionary point of view,they argued that the mode of growth seen in the apes evolved as these forms became more prognathous because less compensatory rotation of the mandible was required,while the form seen in Man is probably closer to that which occurred in the common ancestral form.

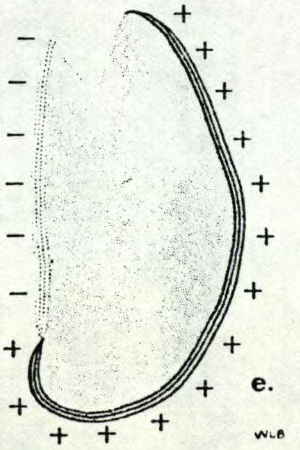
Development of the Human Chin

The mental protruberance or 'chin button' of the human mandible is a characteristic of Man.The small chin of the infant becomes progressively more prominent with increasing age.The growth changes causing this involve a combination of surface deposition and resorption in different parts of the mandibular arch forward of the canine teeth.Growth patterns in the chin area are more variable than in any other part of the mandible. The most typical remodelling changes show the protruberance itself to be marked by massive deposits of periosteal bone,the cortex is thick,dense and composedof typically slow growing types of lamellar bone.These periosteal deposits encircle the base onto the lingual side where they extend for the full height of the lingual cortex in the region of the genial tubercles.

The maturation of the chin in shape and size continues slowly throughout the postnatal period of facial growth.

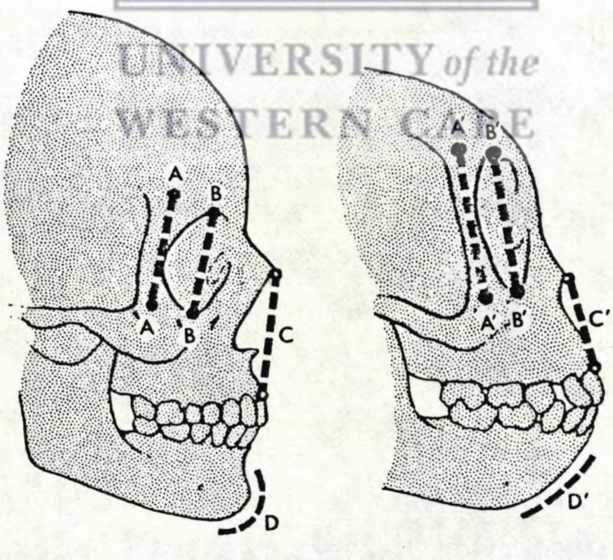
Enlow (I968) suggested that as the mental protruberance grades into the alveolar region above it,a characteristic reversal occurs.The reversal position however,varies and appears to be associated with the variation in morphology and bony adjustments in relation to the maxilla found in different individuals.

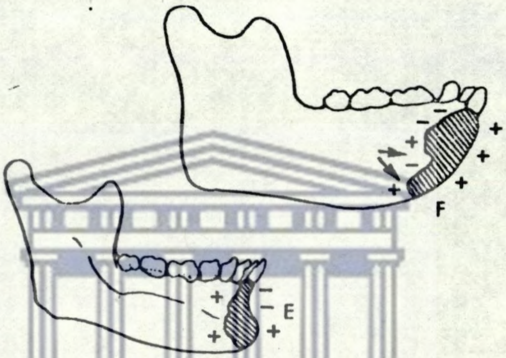
The combination of continued periosteal deposition around the base and apex of the chin along with periosteal resorption and endosteal deposition in the alveolar region above it acts to progressively enlarge the mental protruberance and change its contour.The alveolar region undergoes cortical regression and so moves posteriorly,while at the same time the mental protruberance continues to grow forward.This increases the prominence of the chin.



(*e*) the cortex on both sides grows in a generally lingual direction with some periosteal deposits being added at the apex of the chin itself. (Adapted from Enlow, D. H., and D. B. Harris: *Am. J. Orthodont.*, 1964.)

In comparison to the mandible of the human, the monkey lacks the prominent chin, however it posseses a simian shelf on its lingual side. This difference is caused by the entire labial cortex of the monkey'chin' being formed by periosteal deposition. The endosteal surface is resorptive so that in combination these growth processes produce cortical drift in a forward or labial direction. In the monkey, continued periosteal deposition contributes to the elongated, pointed nature of the mandible in comparison to Man.
On the lingual surface of the mental region where Man shows a marked accumulation of periosteal bone, the monkey has a largely resorptive surface and its endosteal mode of forward growth complements the anterior growth on the opposing labial surface.
Another difference is seen on the lingual surface at the genial crest where a reversal occurs allowing periosteal deposition in a lingual direction resulting in the formation of the simian shelf in monkeys.

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E

Growth Rate

Although the body as a whole, in the normal individual, grows from conception, its rates of grow vary throughout the growth period. The most rapid growth occurs during puberty and so is known as the pubertal growth spurt. In South Africans this occurs between I0½ years and I2½ years in females and between I3 and I5 years in males. This growth spurt can be predicted from the formation of bones in the hand and wrist from a radio graph.

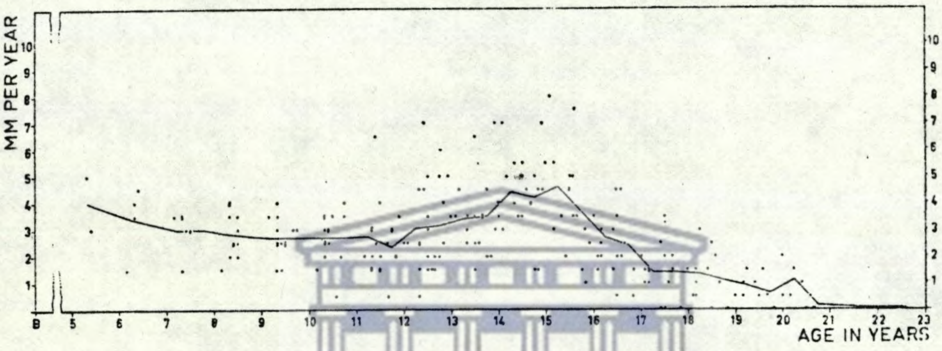

FIG. 9.—Annual rate of growth at the mandibular condyles in the male sample, measured in the direction of growth. The 209 points represent annual observations, marked at the middle of the year of observation. The curve represents the mean annual growth.

Bjork (I964) and Grave and Brown (I976) have studied the timing of the growth spurt and discussed its importance in relation to orthodontics. It is only during this growth spurt that any appreciable orthopedic change can be accomplished, thus the prognosis of a case with a skeletal discrepancy between upper and lower jaws will depend on the timing between treatment and this period of accelerated growth if surgery is to be avoided.

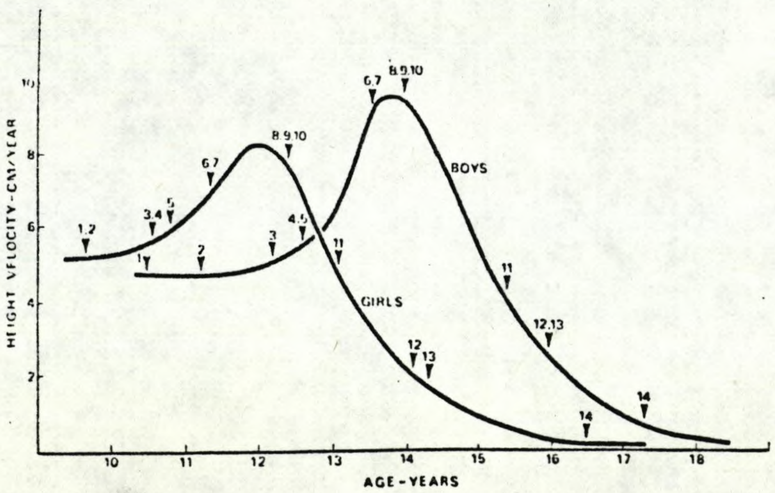

Fig. 3. Ossification times relative to peak growth velocity. The numbers refer to the events listed in Table I.

The growth of the mandible is especially important in orthodontics and has been shown to increase in rate from a juvenile rate of 3mm.per year to a puberal maximum of 5mm. per year (Bjork 1963). This may go as high as 8mm. per year. The mandible grows for a longer period of time in males thanfemales. In males it grows until 22 or 23 years of age finishing with the development of the chin 'button' which is more marked in males than females. (Walker 1977).

Age Changes

Hellman (I927) described a cross sectional study of growth of the ancient Amerindian skull.He divided his sample into seven groups depending on their dental age . these groups ranged from,I)Before completion of the deciduous dentition to group 7)where severe attrition was apparent. The lower face height,measured from intradentale to menton showed a pattern of accelerations and decelerations.He found the greatest increments to occur up to the completion of the deciduous dentition and from the eruption of the first permanent molars to the eruption of the second permanent molars. (I7 % and 24% respectively)He found the growth rate a little retarded between the completion of the deciduous dentition and the eruption of the first permanent molar (I4%) After the eruption of the second permanent molars and the premolars the growthrate fell considerably.

The lower face height was found to increase proportionately more than the upper face height over the total growth period. Hellman also studied the changes in positionof the face during growth by measurement from porion .He found that while the whole face moves away from the external auditory meatus,the chin does so most rapidly.

Todd (I930) studied the growth of the negro skull and noted spurts in forward growth of the lower jaw during the first six months postnatally,between four and seven years and between sixteen and nineteen years.He associated these spurts with the eruption of the dentitions.

Brodies studies on human facial growth (I94I,I949 and I953) investigated the mandibular growth by superimposing the inferior borders of the mandible at different ages on gonion. The shape of the angular region altered little with age,up to seventeen years although the mandibular angle decreased , showing that as the ramus increases in height the condyle projects posteriorly at successively higher levels from the posterior border of the ramus.The angle made between occlusal plane and a line from gonion to gnathion remained constant. The chin was found to advance faster than the incisal edge of the lower incisors until the age of four years after which they tended to grow together.

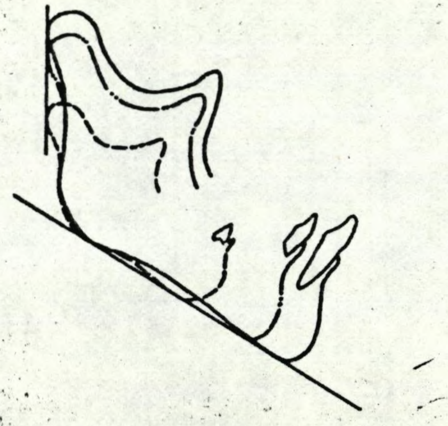

Fig. 9 Method of superposing used by the writer in examining growth stages of the mandible.

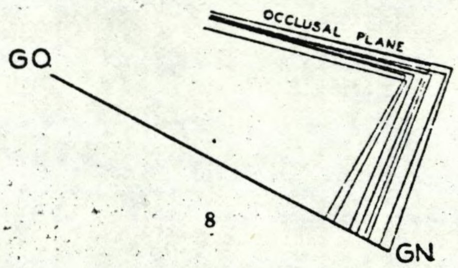

Fig. 8 Composite pattern of growth of mandible from 2½ years to 7 years of life.

The Role of Function

The importance of function to normal development has been stressed by Baker (1922) and Landsberger (1924) and it is reported that Walkoff in I904 removed part of one temporalis muscle in dogs to produce assymetry of the jaws.

Wolff (I885) stated that if a normal bone is used in a new way its structure and form will change to meet the new function ; if a deformed bone is rectified and its normal function restored then that bone will reassume its normal shape and structure and retain it.

Many experiments have been carried out to show the role of muscle action in the production of bones of adaptive shapes.

Washburn (I947)removed the temporal muscle newborn rats and after a few months found that the coronoid process had completely disappeared.Watts and Williams (I95I)fed rats on a diet that requird extra mastication and produced heavier and thicker mandibles.

Horowitz and Shapiro (I95I) repeated Washburn's experiments on 30 days old rats .At the time of operation they noted that the coronoid and temporal crests were both well developed ,however at two months post operative time the crests had both completely disappearedon the operated side.

Avis (I959) performed a similar study when he removed the superior portion of the temporal muscle only, leaving the coronoid process unexposed,for this study he used six week old cats, Sixteen months later the coronoid process on the operated side was smaller& of different shape ,it projected directly upwards instead of upwards and backwards.

Horowitz and shapiro (I955) performed unilateral and bilateral masseterectomies on thirty days old rats.In the unilateral subjects the mandible became deviated towards the operated side Moore and Lavelle (I974) suggested that these results are attributable to the muscular imbalance caused by the removal of the large masseter muscle on one side only.

In the bilaterally operated animals Horowitz and Shapiro reported no gross alterations of the jaws.

Avis (I96I) studying 2 to 4 week old rats removed the superficial masseter in one group,in a second group the internal pterygoid muscle was removed and in a third group both of these muscles were removed.The first group showed distortion and reduction in size of the angular process,the second group showed some reduction in the angular process but this was not as marked as in the first group.Th third group in which both muscles were removed showed a complete loss of the angular process.

Petrovic and Stutzmann (I972) resected the lateral pterygoid muscle in young rats and found that this led to a decrease in the rate of multiplication of the prechondroblasts of the intermediate zone on the operated side,also some of the prechondroblasts showed a tendency to differentiate into osteo blasts rather than chondroblasts.

Petrovic (I972) treated young rats with a chin cup and treated a second group with a hyperpropulsive device.He found that growth of the condylar cartilage was inhibited in those rats wearing the chin cup and stimulated by the wearing of the hyperpropulsive device.He also found that wearing a chin cup causes a significant lengthening of the lateral pterygoid muscle resulting in an increase in the number ofsarcomeres,whereas hyperpropulsion causes a shortening of the lateral pterygoid muscle resulting in a decrease in the number of sarcomeres. Petrovic suggested that although this finding requires more research,it appears that intervention of the lateral pterygoid muscle may be an essential factor of condylar growth.

Moss and Meehan (I970) removed the middle and posterior fibres of the temporal muscle in rats,down to the level of the zygomatic arch.The animals were killed at intervals from two days to forty three days postoperatively.They found that a progressive decrease in the size and number of trabeculae of the coronoid process resulted.

Moss and Simon (I968) compared human mandibles at the stage of the deciduous dentition with those of the adult.The angular process was found to change from a medial inclination in the infant to a lateral inclination in the adult.They suggested that this change was due to an alteration in the line of action of the masseter and medial pterygoids during growth.

From all the evidence cited above it would appear that the morphology of a bone is related to its functional mechanics, but Manson (I968) interpreted this in a different way,saying that these experiments only demonstrate that an abnormal environment including abnormal functional stresses produces abnormal forms,but little light is shed on the role of normal functional stresses in normal development.Manson described the changes in surface contour that take place in the growth of the mandible and stated that there is no indication that these changes are related to the force or direction of muscle pull.For instance in the remodelling of the mandibular ramus in the cat,the masseter and medial pterygoids are inserted into approximately equal areas of bone surface and act at approximately the same angle to the ramus with a similair moment of force, yet the surface changes are consistently different on medial and lateral surfaces of the ramus.

Sissons (I956) stated that under normal circumstances intrinsic factors are of overwhelming importance in determining the form of bones.

Normal function and thus muscle activity must be regarded as part of the overall environment in which normal growth can take place without playing a more active role in determination of the form of the bone.Abnormal function may not allow this to take place.

Epker and Frost (I966) stated that modelling and remodelling of the periosteal bone surface during growth determines the cross sectional size and geometry of the adult bone.Since these processes are the result of two basic cellular processes, osteoblastic and osteoclastic,the problem they studied was the reason for the deposition of bone in some areas and removal of it in others.They suggested two possible mechanisms,

I)Genetic control

2)External influences directing these activities in such a way as to produce the changes in size and shape that occur during growth

Earlier work of Epker and Frost (I965) supports the second theory tested in this study

Ribs taken from individuals who had received tetracycline therapy on one or more occasions before death or surgery were studied in this I966 investigation.

The observation of three possible states of bone remodelling was based on histological evidence,

a)New lamellar bone formation is indicated by the prescence of an osteoid seam.

b)Bone resorption was indicated by the prescence of surfaces showing Howship's lacunae.

c)The prescence of a smooth,normally mineralized surface indicated that there was neither form of cellular activity.

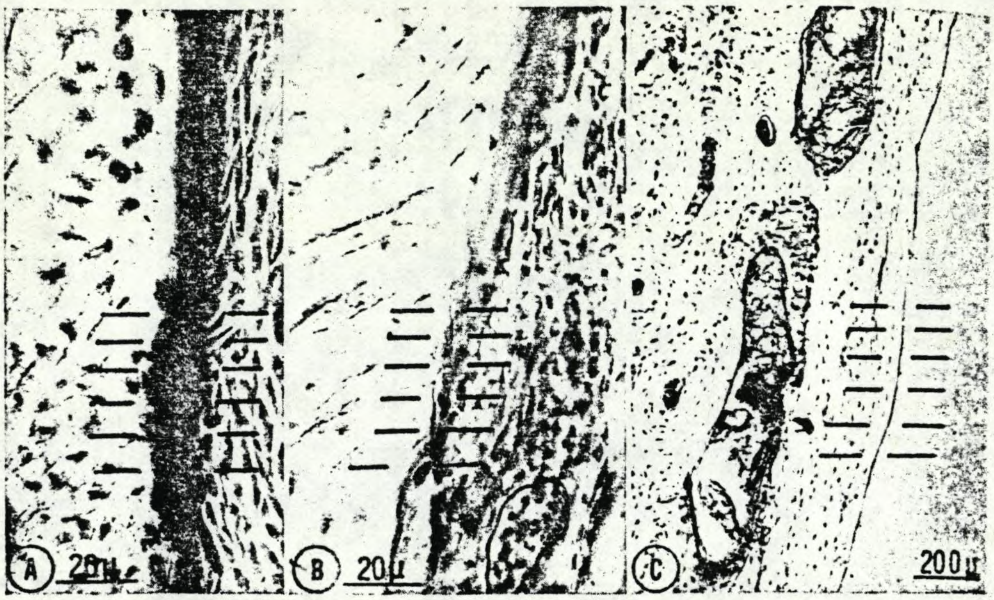

FIG. 2.—These three photomicrographs are made of mineralized human bone sections. A: An osteoid seam in longitudinal section, shown between the India ink brackets. Already mineralized bone lies to the left, and a layer of osteoblasts to the right. A seam indicates that lamellar bone formation is going on. B: A surface scalloped by Howship's lacunas lies between the brackets. An osteoclast is outlined below. This is a longitudinal view through a resorption front. Mineralized bone lies to the left; on the right is the cavity and its mass of cells. C: A smooth periosteal surface is bracketed, with bone to the left and extraperiosteal space to the right. This is a cross section that shows two osteons (haversian systems) in various stages of formation.

Epker and Frost's histological observations showed that in children (2 to 20 years) the periosteal cutaneous surface is covered almost exclusively by either smooth surface or osteoid seams, indicating that bone is formed almost to the exclusion of resorption.

The periosteal pleural surface showed both smooth surfaces and Howship's lacunae, indicating resorption.

In adults over the age of 20 years, both surfaces show equal amounts of osteoid seams and Howship's lacunae indicating that bone turnover continues into adult life but that reshaping ceases. The tetracycline labels were deposited in the periosteal cutaneous surfaces in people less than 20 years old, whereas in people older than 20 years the deposits were equally distributed over both surfaces.

It is known that the anterior two thirds of the upper eight or ten ribs drift towards the cutaneous side if the thoracic wall which accords with the findings of this study. Epker and Frost suggest that this drift pattern occurs because, in the growing individual, during inspiration the overall curvature of the rib tends to straighten out. This is called paradoxical chest wall motion and is direct evidence of the kind of flexure that intact ribs normally sustain during inspiration.

Epker and Frost (1966) also postulated that surface drift should stop after the muscles stop growing. This implies that in adult life, because muscle growth has stopped, there could be no asymmetrical flexure caused by muscle forces since dynamic forces acting on a bone should be approximately equal in all directions.

These postulates were applied to predict changes in shape of the coronoid process and angle of the mandible as explained in the following figure.

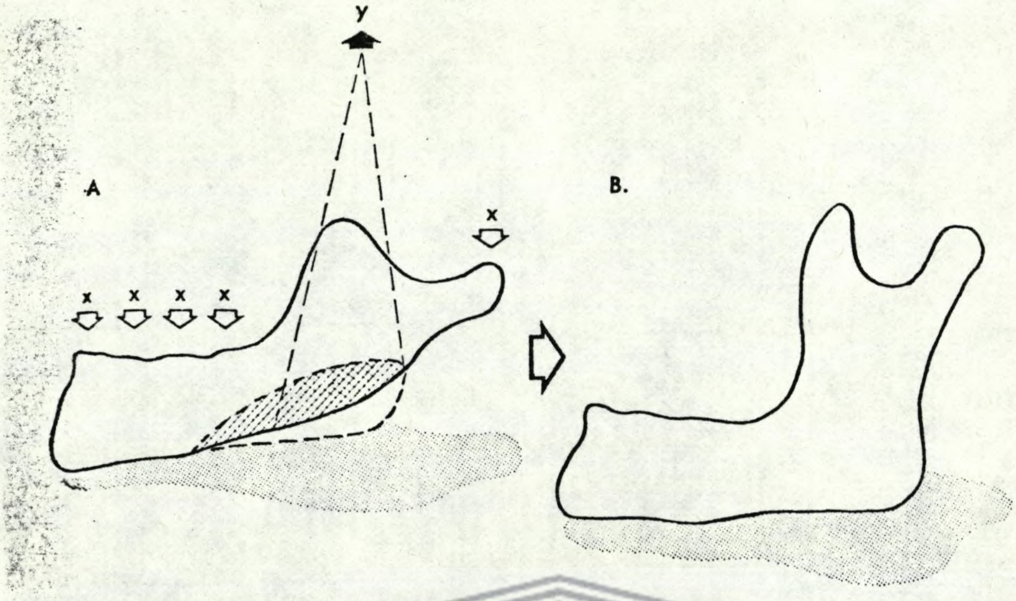

FIG. 4.—A: An infant mandible seen from the left side, where (X) indicates reactions and (Y) indicates the muscle pull of the masseter and internal pterygoid. When these muscles contract, the posterior-inferior angle of the mandible is deformed minutely in the direction indicated by the dotted line at the top of the shaded area. Thus, the surface tends to become less convex (more concave) with respect to its resting shape. This leads to osteoblastic drift, which adds bony material to the angle, tending to produce the modified (adult) shape shown on the right (B) and suggested by the dotted line below the unshaded area in A. (Not to scale.)

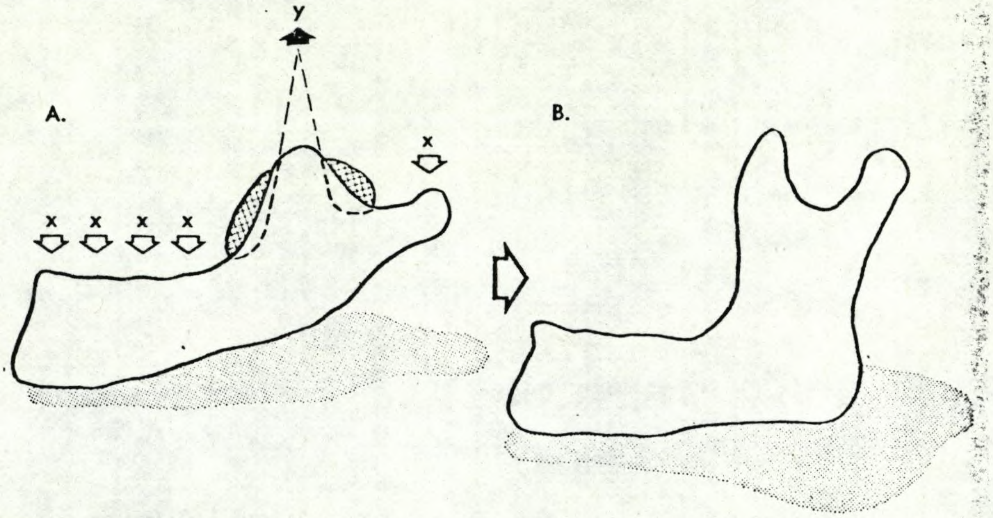

FIG. 5.—Symbols have the same meaning as in Figure 4, except that here the temporalis muscle force is illustrated. The pull of this muscle tends to make the surface adjacent to its attachment bulge upward, as suggested by the shaded region on the left and right of the attachment. This is an increased convexity (decreased concavity) with respect to the resting shape, which causes osteoclastic drift. The surface is reshaped as suggested by the broken lines in A, and as shown in B. The actual changes in contour caused by the muscle forces are minute and are greatly exaggerated in the left drawings in A and B for illustrative purposes. It is important to recognize that the changes in contour are with respect to the resting shape (the shape when no muscle forces act on the bone).

These findings are in agreement with those of Washburn (1947) who removed the insertion of the temporalis in growing animals and found that the coronoid process failed to develop.
The postulates of Epker and Frost (1966) provide a basis for prediction of changes in bone shape following changes in function and suggest that we may be able to control surface drifts in bones and so influence the outcome of their growth.

Growth Prediction

There are three methods for predicting the shape of the mandible in growing subjects.These may be termed longitudinal,metric and structural.

Prediction by the longitudinal method is acheived by following the course of development in annual cephalometric radiographs. This method is useful in orthodontic treatment planning.

The limitation of this approach is that the pattern of growth is not constant and may change with age,(Bjork I969)

The metric method predicts facial development on the basis of facial morphology studied from a single radiograph.However, the prediction of the intensity or direction of development relies on the existence of a positive correlation between dimensions of the face at different stages of development. Bjork and Palling (I954) showed that only a weak correlation exists.

The structural method is based on information concerning mandibular remodelling gained from the implant studies of Bjork (I963).The principle is to recognize specific structural features that develop as a result of remodelling.A prediction of the subsequent course is then made on the assumption that the trend will continue.From this a prediction can be made from a single radiograph.

Bjork suggested seven signs,

I)Inclination of the condylar head
2)Curvature of the mandibular canal
3)Shape of the lower border of the mandible
4)Inclination of the symphysis
5)interincisal angle
6)Intermolar angles
7)Lower anterior face height

Bjork's work was modified and added to by Ricketts who produced the following list of structural features useful in the prediction of mandibular development.

Mandibular characteristics:	Tendency on chin:
1. Thickness of condyle	wide > narrow V
2. Inclination of condyle	forward > backward V
3. Coronoid height	low > high V
4. Width of ramus	wide > narrow V
5. Gonial angle	acute > obtuse V
6. Curvature of mandibular canal	tight > open V
7. Mandibular plane angle	low > high V
8. Ante-gonial notching	normal > notched V
9. Corpus length	long > short V
10. Width of symphysis	wide > narrow V
11. Inclination of symphysis	upright > forward V
12. ANB angle	low > high V
13. Y axis angle	low > high V
14. Interincisal angle	obtuse > acute V
15. Anterior facial height	reduced > increased V

Hormonal Studies

Becks et al.(I946)in an investigation of the effects of thyroxine and growth hormone on the condylar cartilage and epiphyseal cartilage found that in the former cartilage the response to growth hormone was inhibited by thyroxine whereas in the epiphyseal cartilage the effect of growth hormone was augmented by thyroxine.

Baume et al.(I953) investigating 63 days old rats,studied the effects of growth hormone and thyroxine given separately and in combination.The rats were thyroidectomized at birth and showed dwarfed and deformed mandibular joint structures.The prominent histological defects consisted of,stunted chondrogenesis and depressed modelling resorption.

Administration of growth hormone restored the mandibular dimensions by marked activation of chondrogenesis and membranous osteogenesis.Chondroclasia and osteoclasia however remained deficient giving the joint structures a juvenile,immature appearance.

Thyroxine administration promoted maturation of the condyle to the same degree as in the normal age control group,but did not restore normal mandibular dimensions even in the growth hormone treated group.This was attributed to the fact that in the absence of the thyroid gland,growth hormone does not seem able to promote endrochondral ossification,but stimulates chondrogenesis and periosteal bone formation.

Combined growth hormone and thyroxine administration resulted in an increase in size to almost mormal,while maturation was accelerated more than in the growth hormone injected group. These findings were taken as evidence that proper mandibular development is dependent on normal thyroid function.

Summary

This paper has attempted to describe the prenatal development of the mandible in humans and its postnatal growth.
The various theories of how this growth occurs have been described including the historical work by Brash,the 'classical theory', which includes a section on the controversy regarding the term 'growth centre' and its application to the mandibular condyle.
Bjork's investigations using the implant method have been covered.This method allowed him to superimpose the mandibles in a longitudinal growth study with more ease and accuracy than was formerly possible.Note that no mention is made in this paper of the error due to magnification changes in the radiographs resulting from the growth itself.
Enlow's theory ,including his ideas on relocation,cortical drift,reversal etc.based on the morphology of the mandible are covered.
The functional theory of Moss which has many supporters and is perhaps one of the strongest theories is included with a further section on the role function plays
The other main theory described is the theory of arcial growth discovered by Ricketts.
The chin is a characteristic of Man and a short section will be found about its development
Nowadays we are using prediction of the growth of an individual as an intgral part of our treatment plan in orthodontics .I have attempted to describe the structural features of a cephalo metric radiograph which are our guidelines for prediction along with a knowledge of the pattern of growth rates
I have included at the end a short part about investigations using hormones to study their role in development.This only scratches the surface of the many hormonal studies carried out but serves to show another side of research concerning the development of the mandible.

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