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SUTURAL GROWTH OF THE UPPER FACE STUDIED BY THE IMPLANT METHOD

by

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INTRODUCTION

The object of this paper is to describe the implant method as applied to the maxilla, to examine the general pattern of maxillary growth in lateral view, to report the results of an analysis of the sutural growth of the upper face in the sagittal plane in a sample of boys, and to illustrate the graphical method employed.

In the technique described small metal pins inserted in the jaws serve as fixed reference points in radiographic study of growth. By this means it is possible to make an objective comparison of the importance of sutural growth with the periosteal remodelling process of apposition and resorption. Studies on the growth of the face using the implant method were started in 1951 on a small group of children, and as a result of the first years of experience (*Björk,* 1955) the sample was increased until it now comprises some 130 children of both sexes. It was divided into groups representing both normal craniofacial growth (*Björk,* 1963) and selected cases of pathologic growth (*Björk,* 1962 a), and analysis of some forms of orthodontic treatment (*Lager,* 1958; *Krebs,* 1959 and 1964; *Skieller,* 1964; *Thørs,* 1964). The

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radiographic analysis of growth covered both lateral and postero-anterior views of the head and was compared with the dental development and body growth.

MATERIALS AND METHODS

The present sample consisted of 45 normal, healthy boys with different types of malocclusions, from slight rotation of individual teeth to severe occlusal disharmony. They were children attending the Department of Orthodontics for various reasons who expressed their willingness to participate in this special type of growth examination. All were called for annual checks on their date of enrolment.

The general technique for inserting the implants in the jaws and the special technique for the mandible has been described in detail in connection with an account of the growth of the mandible (*Björk,* 1963); it will suffice here to mention that the implants, which are tantalum pins 1.5 mm long and 0.5 mm in diameter, are inserted under local analgesia, using a special instrument*; no exposure of the bones is necessary. Before inserting the implants the structure of the maxilla and the position of the dental germs and roots are examined on a profile radiograph.

RESULTS

Maxillary implant technique

Experience gained over a number of years has shown that there are a limited number of sites in the maxilla where the implants can be placed without risk of shifting their position through eruption of the teeth, orthodontic treatment or the resorptive remodelling process.

There are four regions in the maxilla in which implants are unlikely to be disturbed in this way:

(1) At early juvenile ages, before the permanent incisors have erupted, implants near the median plane of the face can be inserted in the hard palate behind the deciduous canines (Fig. 1).

* Manufactured and supplied by O. Dich Ltd., Holmevej 18, Hvidovre, Denmark.

To ensure that the implants are not too near the germs of the permanent canines their position should be checked on occlusal radiographs. The stability of these implants is dependent on the extent to which the nasal floor has been lowered by the resorptive process, and where this is marked it is not certain that they will remain undisturbed until adult age. After the eruption of the permanent central incisors, implants are therefore always placed below the anterior nasal spine.

(2) After the central permanent incisors have erupted, an implant is inserted below the anterior nasal spine on each side of the median suture, and on a level with the root apices, but not in contact with them. The position of these implants almost invariably remains unchanged up to adult age, but in some cases where the resorptive lowering of the anterior nasal spine is particularly great, it may be necessary to insert new ones under the spine towards the end of the growth period.

The implants in region (1) and, especially, in region (2) being situated near the median plane of the face, are especially useful for analysing sutural growth of the upper face in the sagittal plane. The inevitable positional discrepancy incurred in setting the head in the cephalostat from year to year is then of minor importance, and these measurements in the sagittal plane can therefore be performed with accuracy.

Since the implants in regions (1) and (2) are placed on both sides of the median suture they are also suitable for examining the growth in width of the maxilla in the anterior part of this suture, which can likewise be done with accuracy.

(3) and (4) Even at early juvenile age implants can be placed in the zygomatic process of the maxilla on both sides of the head. If they are not to be disturbed by erupting teeth or orthodontic treatment these implants must be placed laterally to the alveolar process. On each side two implants are placed as checks that one is not disturbed. Occasionally, when the bone wall is thin and the maxillary sinus increases greatly in size during growth, one implant may be lost through the nose. In such cases, and when an implant has changed its position a new one is inserted at the next annual check.

Implants in the zygomatic processes of the maxilla are suitable for measuring the growth in width of the maxilla in the central

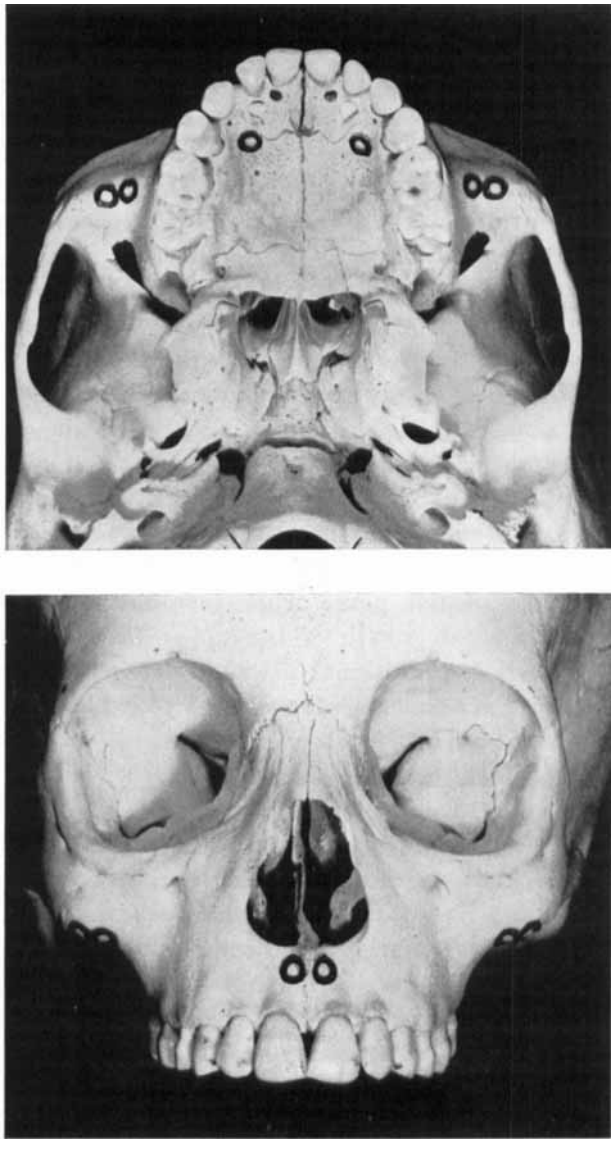

Fig. 1. For radiographic analysis of the growth of the maxilla and the sutural growth of the upper face metallic implants are inserted in three zones in the maxilla. (*i*) Before eruption of the permanent incisors, one on each side in the hard palate, behind the deciduous canines; (*ii*) after eruption of the permanent incisors, one on each side of the median suture, under the anterior nasal spine; (*iii*) two on each side in the zygomatic process of the maxilla.

part of the median suture and this determination is performed with great accuracy. Since such implants are situated remote from the median plane of the face, they are not so suitable for examining the sutural growth of the upper face in the sagittal plane. For the same reason a determination of the rotation of the maxilla in the sagittal plane during growth using these implants may incur a substantial error.

Besides the regions mentioned implants have also been placed, with good results, at the border of the hard palate and the alveolar process, medially to the first molar (*Krebs*, 1964).

Implants inserted in the maxilla in other regions than those mentioned — for instance in the part of the alveolar process where the teeth are situated — have proved to be unstable.

The positioning of the head in the cephalostat must be done with accuracy if the structures of the right and left sides of the face are to correspond on the lateral radiograph, and at each annual check the radiographs are compared with earlier ones in the series before they are accepted.

Maxillary growth pattern

The pattern of maxillary growth in profile is illustrated in Fig. 2. The growth in length is sutural towards the palatine bone, and it is accompanied by periosteal apposition at the maxillary tuberosity. In no case has growth in length by periosteal apposition been found on the anterior surface of the maxilla, apart from the alveolar process. The growth in height takes place at the sutural articulations of the frontal and zygomatic processes, and by periosteal apposition on the lower border of the alveolar process. The nasal floor is lowered through resorption together with periosteal apposition on the hard palate, and the anterior nasal spine is likewise lowered through resorptive remodelling. In the floor of the orbits resorptive remodelling occurs in the opposite direction, with apposition on the upper surface and resorption on the lower. As a rule the direction of eruption of the teeth is predominantly vertical, but if there is a large forward component the alveolar prognathism will be increased and the alveolar arch elongated forwards; if eruption involves a backward component the alveolar prognathism will be reduced and the alveolar arch

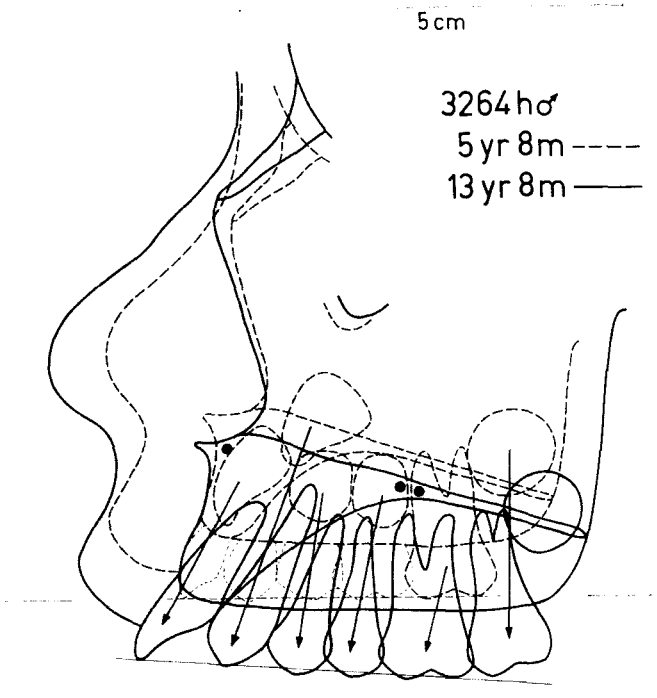

Fig. 2. Growth of the maxilla in an untreated case, analysed by the implant technique, representing the average growth pattern.

shortened. This pattern of growth of the maxilla has been described in an earlier report (*Björk,* 1955). It is obvious that the nasal line (*NL*) through the floor of the nose cannot serve as a reference for analysis of the maxillary growth pattern or of the eruption of the teeth. Nor is it a reliable guide for determing the change in position of the maxilla in relation to the cranial base during growth. An accurate evaluation calls for fixed reference points, such as are provided by metal implants.

Direction of sutural growth

To obtain a general picture of the direction of sutural growth of the upper face in the sagittal plane in relation to the anterior cranial fossa the following method was employed. The first and last radiographs of each series were compared by superimposing

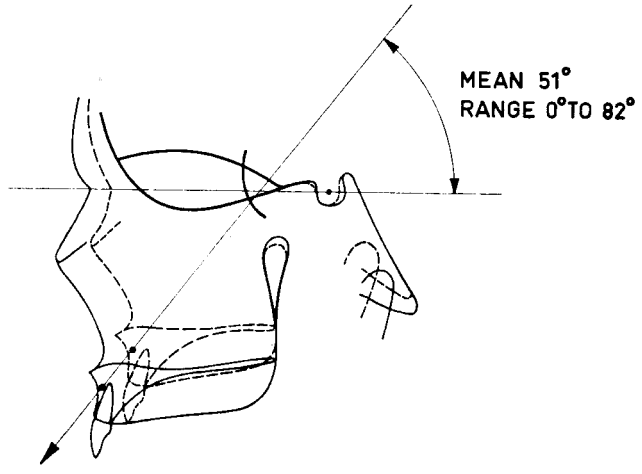

Fig. 3. Mean direction of sutural growth in the upper face measured in the sagittal plane by the implant method; 32 Danish boys. The range of variation is given. The first and last radiograph of each series were oriented with respect to coincident structures in the anterior cranial fossa and the pterygopalatine fossa.

them so that the maximum number of structures in the anterior cranial fossa and the pterygopalatine fossa coincided. The method has been described earlier in detail (*Björk,* 1960). The measurements were performed directly on the superimposed radiographs with the aid of a sheet of cellophane with printed lines (*Björk & Solow,* 1962). One line was placed through the nasion and sella points on the first radiographs, another through an implant in region (1), or possibly region (2), on the first and second radiographs (Fig. 3). The angle between these lines has been taken as a general expression of the direction of sutural growth of the upper face in the sagittal plane. The error of the method is comparatively large; on the basis of repeated measurements it has been put at ± 5°. The mean angle for 37 of the boys in which it could be studied was 51°, but it varied individually from almost purely sagittal to purely vertical. It must be stressed, however, that as the direction is apparently not linear it should, in an accurate study, be measured from year to year, as shown in Fig. 9. This picture from a sample of girls shows a direction of growth that follows a steady curvelinear course. The growth of

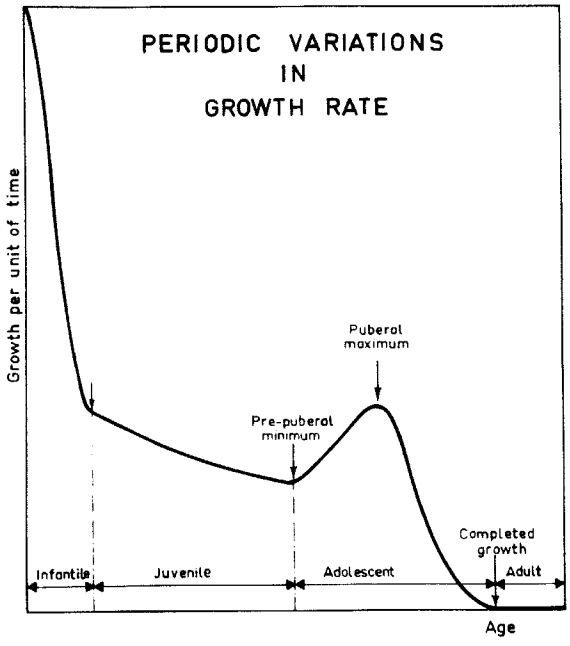

Fig. 4. Periods in the development of the child, divided according to the rate of growth.

the upper face in this case (Fig. 7) is mainly sagittal in direction in the juvenile period, to become predominantly vertical during adolescence; this results in a constant change in the facial proportions. From the available evidence a change in direction of growth generally occurs, but closer investigation is called for.

Sutural growth rate

The velocity curve for the human skeletal growth has a characteristic form with a pronounced periodicity (Fig. 4). During the infantile period, covering approximately the two first years of life, the rate of growth falls off steeply, followed by a flection of the curve to a much slower retardation; this continues during the juvenile period towards a well defined pre-puberal minimum. During adolescence the rate increases towards a puberal maximum, and then decreases until adulthood when growth ends. The times at which these characteristic changes in growth

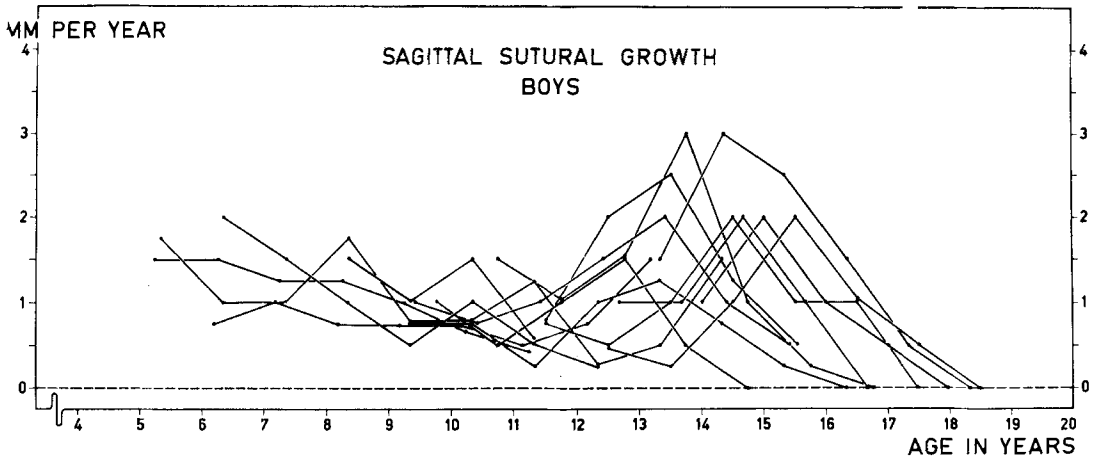

Fig. 5. Individual curves for the rate of growth in the sutures of the upper face measured by means of metallic implants; 25 Danish boys. The rate is measured as the annual growth in its direction in the sagittal plane.

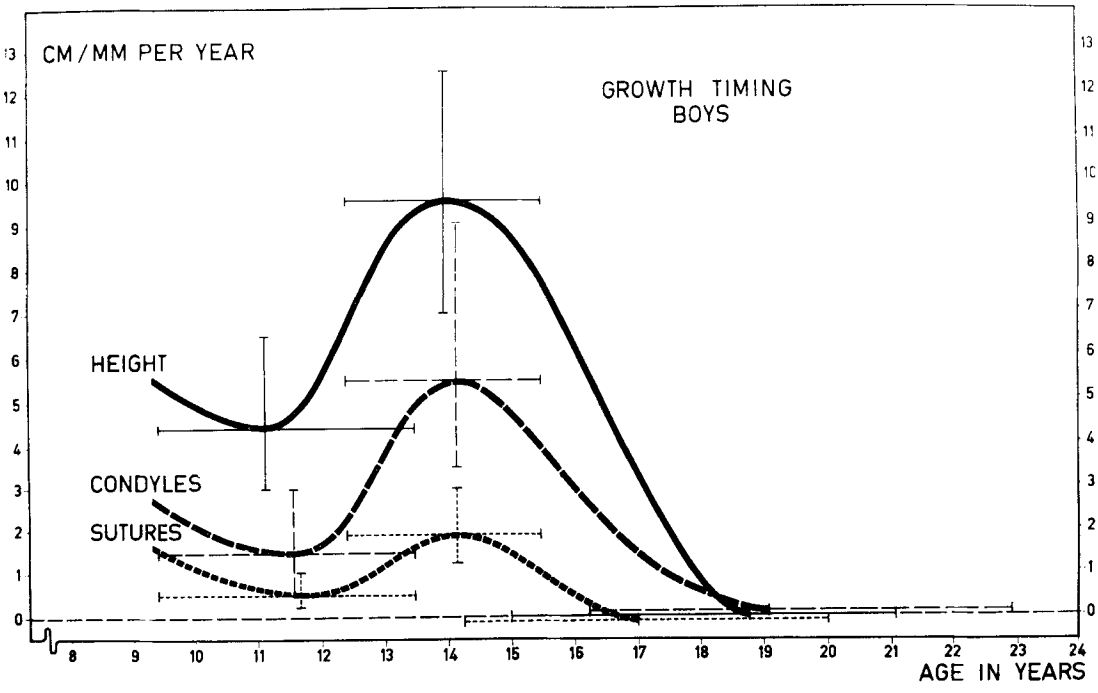

Fig. 6. Mean times and individual variations for pre-puberal growth minimum, puberal growth maximum and completed growth in body height, the growth at the mandibular condyles and the sutural growth of the upper face in the sagittal plane. For the pre-puberal minimum and puberal maximum the mean growth and individual variations are given. Each value is based on observations relating to about 25 Danish boys.

occur constitute a measure of the physical maturity of the individual. The stages are associated with hormonal development, and consistency within families indicates that in one way or another they are associated with the genes (*Tanner,* 1962). The times for these periodic variations are interrelated, an early pre-puberal minimum being followed by an early puberal maximum, and by early adulthood (*Stolz & Stolz,* 1951). Puberty and completion of growth occur about 1½ years earlier in Danish girls than boys.

The annual fluctuations in the sutural growth of the upper face in relation to the anterior cranial fossa were measured in the sagittal plane with guidance of implants in region (1) or (2). Fig. 5 shows individual velocity curves for 25 Danish boys; the puberal growth spurt is clearly seen. The annual growth in the juvenile period is on an average about 1 mm. At the time for the pre-puberal minimum the growth slows down to about 0.25 mm and increases to about 1.5 mm during puberty, to cease on an average at 17 years.

The times for the pre-puberal minimum, puberal maximum and completion of growth are shown in Fig. 6 for the sutural growth, compared with growth at the mandibular condyles and with the body height. The various times are expressed in terms of means and individual ranges of variation; the growth rate at these times is given in the same way. The values for each time are based on observations from about 25 subjects. In this group of boys the pre-puberal minimum occurred at 11½ years and the puberal maximum at around 14 years for both sutural and condylar growth. For the body height these times occurred a few months earlier. The puberal growth of the face therefore took place slightly later than the growth in height (cf. *Nanda,* 1955). The ranges of variation for the different times overlap, and at around 13 years of age a particular boy is just as likely to be at his minimum as his maximum growth. It would seem that an annual record of the growth rate in height might be of practical value in the orthodontic clinic as a guide in determining the individual stage of development and hence in the choice of the time and method for treatment.

The growth at the sutures ceased on an average at 17, which was 2 years before the body height. Condylar growth was com-

plete a little later. The individual variations were great — especially for condylar growth, which was recorded up to 23 years of age.

The cephalometric radiographs were obtained in a cephalostat with the tube focus 180 cm from the median plane of the head, and 10 cm between this plane and the films. This gives an enlargement of 5.5 per cent in the median plane. The values in the graphs are direct measurements, with no correction for enlargement.

Case analysis

To illustrate the graphical method employed in analysis of the sutural growth in the sagittal plane of the face in relation to the facial growth as a whole, a case of bicondylar hyperplasia with development of extreme mandibular overjet was selected for description from a sample of girls. The patient was followed from the age of 7 years until the cranial growth ceased at 18 years. The eruption of the third molars, all of which were present, was not complete until one year later.

The direction of growth at the mandibular condyles gradually assumed a vertical direction. This is illustrated on Fig. 9 by an arrow on which the annual growth is indicated.

The development of the face as a whole is illustrated in Fig. 7. The positional change of the two jaws in relation to the anterior cranial fossa is shown by the arrows through the implants, and the annual change is marked with transverse lines. As a consequence of the change in the direction of condylar growth the direction in which the mandible moves in the face is altered, in this case from a predominantly forward direction at juvenile age to a predominantly downward direction during adolescence.

From the tracing of the facial growth (Fig. 7) it is also seen that there was a similar positional change of the maxilla, the sagittal sutural growth gradually turning in a vertical direction. The proportions of the face therefore changed markedly with age during growth. Changes in proportions apparently seem to be common and the facial form is therefore not constant in the individual during growth. The facial development at 7, 11 and 18 years of age for the case in question is illustrated also by a logetronic radiographic growth picture in Fig. 8, and photographs at

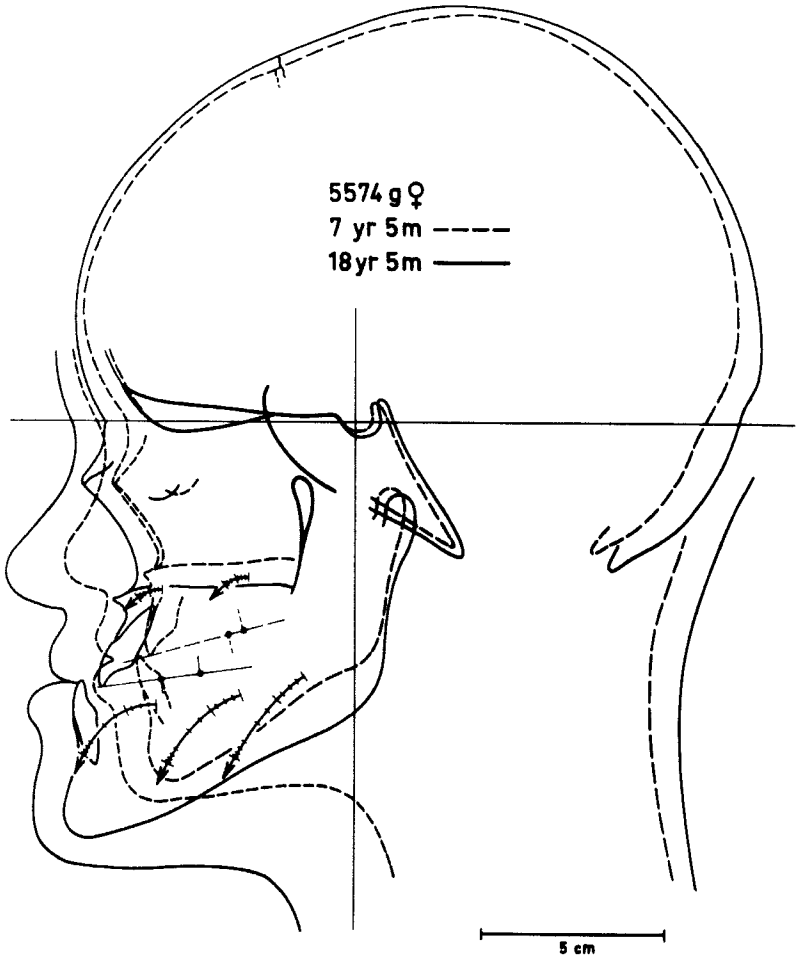

Fig. 7. Facial growth in an untreated girl with bi-condylar hyperplasia, analysed by the implant method.

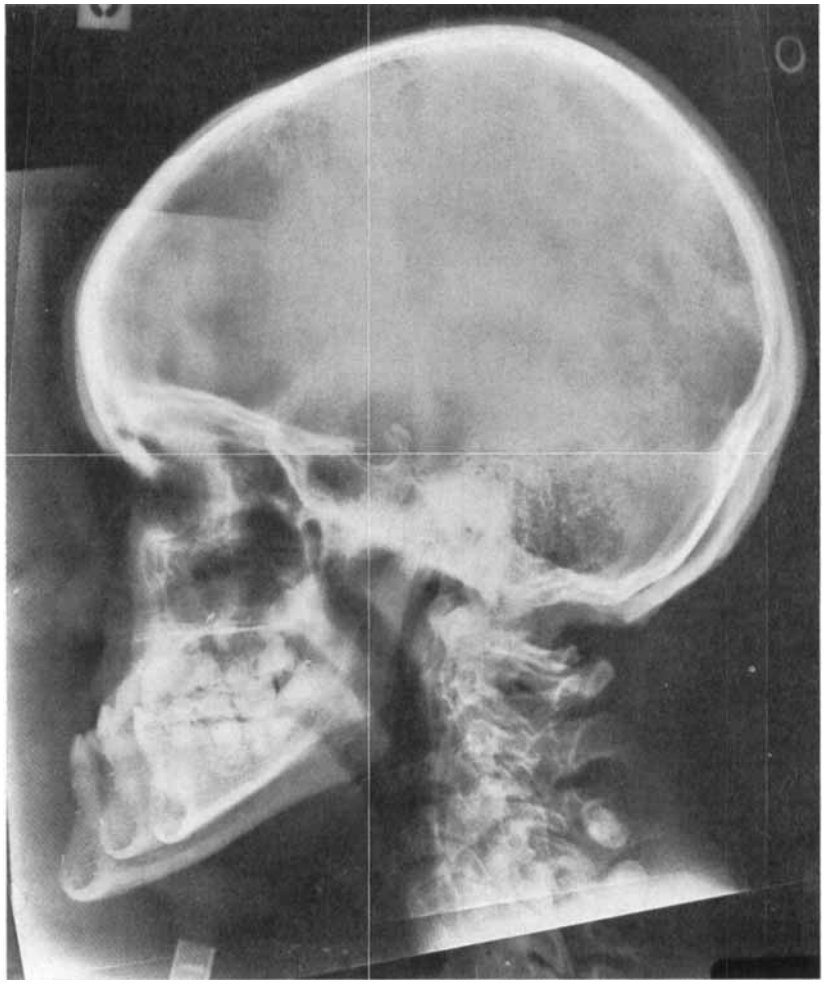

Fig. 8. Logetronic growth picture at the ages 7, 11 and 18 years.
The picture is produced by the following technique. A negative film of each of the three radiographs to be compared is made in a logetronic contact printer, model CP-45, with about 50 per cent dodging. These negative films are superimposed and oriented with respect to the anterior cranial fossa and the pterygopalatine fossa; a positive logetronic film is then made of the three superimposed films, also with 50 per cent dodging. The film used was Gevaert N 32 P and the developer, Johnson Azol. Diapositives can be obtained by photographing the superimposed logetronic radiographs on two-tone film, such as Adox R. 14.

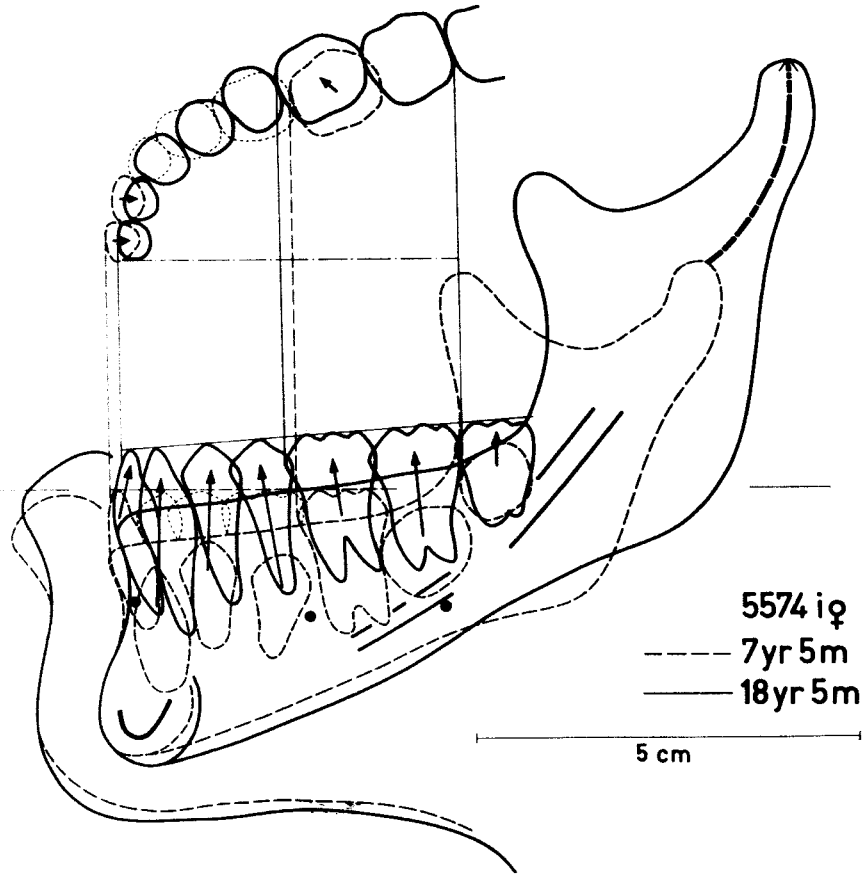

Fig. 9. Growth of the mandible and dento-alveolar development analysed by means of the implants.

the same stages are shown in Fig. 11. On the logetronic picture as well as the photographs the described changes in facial proportions are clearly seen.

The development of the dental arches is shown in the photographs of the dental casts in Fig. 12. By means of a special technique (*Björk*, 1962 b) drawings of dental casts can be transferred to radiographic growth tracings of the lower and upper jaws and oriented so that the movement of the teeth can be defined in three planes in relation to the implants during occlusal development

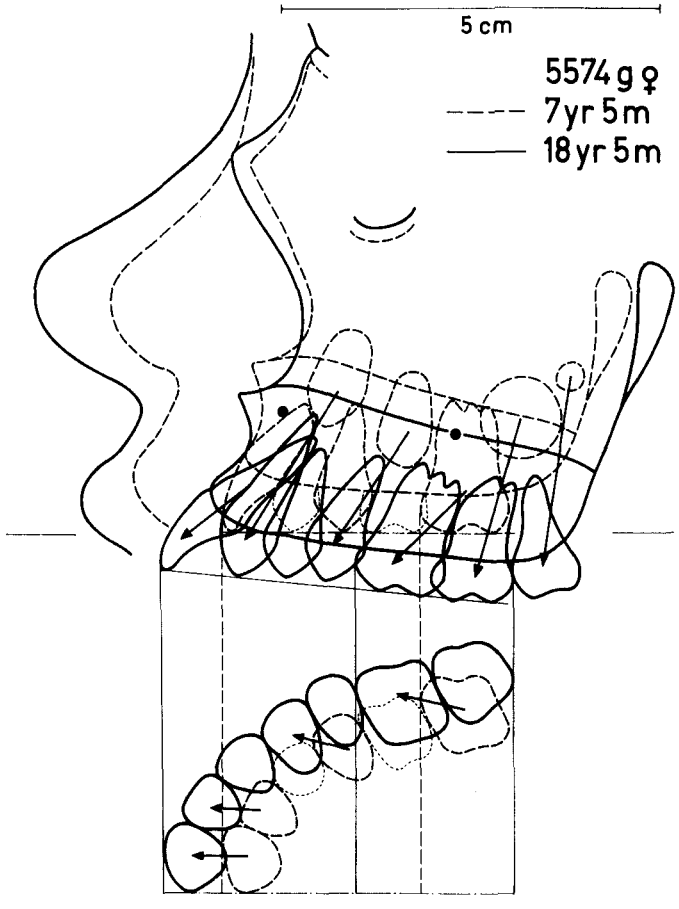

Fig. 10. Growth of the maxilla and dento-alveolar development, analysed by means of the implants.

(Figs. 9 and 10). A notable feature of this case is the pronounced compensatory migration of the teeth of both jaws, especially the maxilla, brought about by intercuspidation. This compensatory dento-alveolar development resulted in a considerably smaller mandibular overjet and mesial occlusion than could be expected from the marked increase of the mandibular prognathism in relation to the maxillary prognathism. Another notable feature is the marked compensatory dento-alveolar increase in width in the maxilla, which took place as a result of intercuspidation.

By virtue of the limited size of the series and the special selec-

Fig. 11. Photographs of the face at 7, 11 and 18 years.

tion, the data for the sutural growth of the upper face and for the periodic variations in face and body development given in this paper must be considered as tentative and will probably be revised in the light of the results of the current investigation.

SUMMARY

An account is given of the technique of inserting metallic implants in the maxilla for radiographic study of growth. The mode of growth of the maxilla as disclosed by this method is outlined.

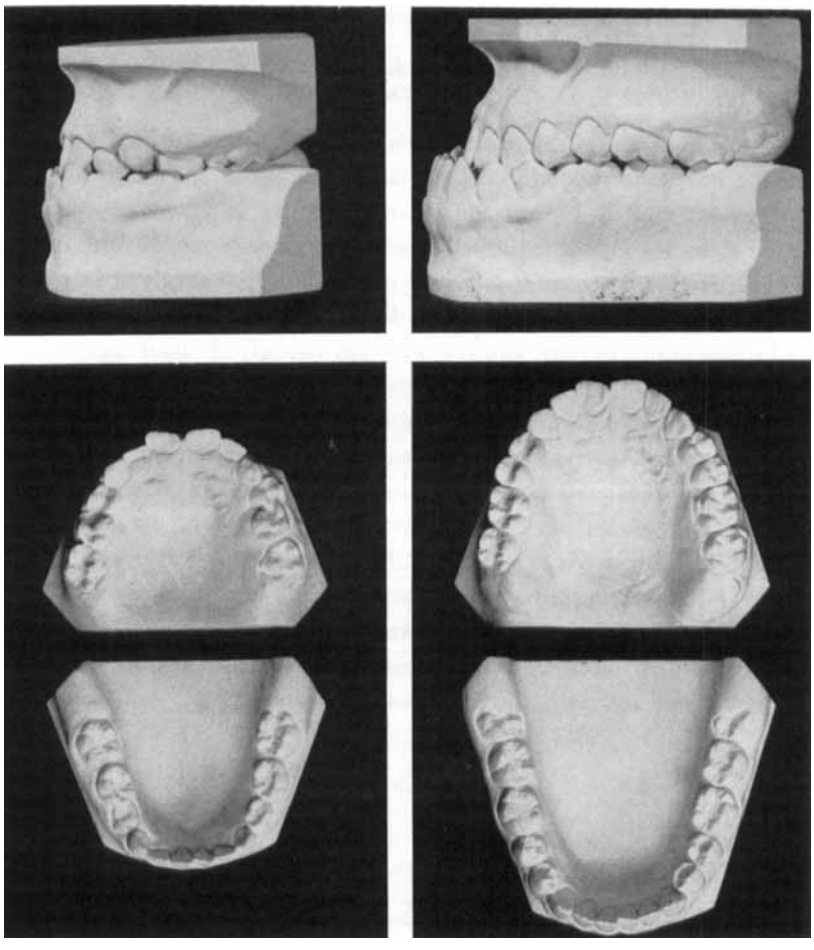

Fig. 12. Dental casts at 7 and 18 years.

The direction of sutural growth of the upper face in the sagittal plane is analysed and observations on the rate of the sutural growth and its periodic variations in a group of boys are reported.

A pre-puberal minimum rate of sutural growth occurred at 11½ years and a puberal maximum at about 14 years. These times correspond to those for the mandibular growth at the condyles but were a few months later than for the growth in body height. The sutural growth ceased at 17 years — that is, on an average about 2 years earlier than the condylar growth and growth in body height.

RÉSUMÉ

ETUDE PAR LA MÉTHODE DES IMPLANTS SUR CROISSANC AU NIVEAU DES SUTURES DE L'ÉTAGE SUPÉRIEUR DE LA FACE

L'auteur donne un compte-rendu des méthodes employées pour mettre en place des implants métalliques dans le maxillaire supérieur en vue de l'étude radiographique de la croissance. Il indique dans les grandes lignes le mode de croissance du maxillaire supérieur que cette méthode met en évidence. Il analyse la direction de la croissance au niveau des sutures de l'étage supérieur de la face dans le plan sagittal et rend compte d'observations sur le degré de la croissance au niveau des sutures et sur ses variations périodiques dans un groupe de jeunes garçons.

Un degré pré-pubertaire minimum de croissance au niveau des sutures se présentait à 11 ans ½, et un maximum pubertaire vers 14 ans. Ces périodes correspondent à celles de la croissance de la mandibule au niveau des condyles, mais elles prennent place quelques mois plus tard que les périodes de la croissance du corps en hauteur. La croissance au niveau des sutures cessait à 17 ans — c'est-à-dire environ 2 ans avant la croissance condylienne et la croissance du corps en hauteur.

ZUSAMMENFASSUNG

UNTERSUCHUNGEN ÜBER DAS SUTURELLE WACHSTUM DES OBEREN TEILES DES GESICHTES MIT HILFE DER IMPLANTATMETHODE

Es wird die Technik zum Anbringen der metallischen Implantate in der Maxilla für radiographische Untersuchungen beschrieben.

Der Wachstumsmodus der Maxilla, wie er aus dieser Methode zu schliessen ist, wird umrissen. Es wird die Richtung des suturellen Anwachsens des oberen Teiles des Gesichtes in sagittaler Ebene analysiert und Beobachtungen über die Geschwindigkeit des suturellen Anbaus und dessen periodischer Variationen bei einer Gruppe von Jünglingen mitgeteilt.

Einem präpuberalen minimalen suturellen Zuwachs bei elfeinhalb Jahren steht ein maximaler Anbau bei vierzehn Jahren gegenüber. Diese Altersangaben entsprechen dem Wachstum der Mandibel bei den Kondylen, sie sind jedoch um einige wenige

Monate später als die für das Längenwachstum des Körpers angegeben. Das suturelle Wachstum erreicht seinen Stillstand bei 17 Jahren — das ist durchschnittlich zwei Jahre früher als beim Kondylenwachstum und beim Grössenwachstum.

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