

# Sutural growth of the upper face studied by the implant method

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**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. 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.

## Introduction

The change in size and proportion of the upper face in man during growth and development is familiar to us from several biometric studies. With its pattern of growth and with the rate and timing of the growth of its various tissue components we are less familiar, however, as our knowledge is based essentially on studies on animals, where the conditions are not fully analogous. By applying the implant method in man it is possible to widen our knowledge in this field in many directions. In this technique small metal pins inserted in the jaws serve as fixed reference points in the 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 this implant method were begun 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 is divided into groups representing both normal craniofacial growth (Björk, 1963) and selected cases of pathologic growth (Björk, 1962a), and analysis of some forms of orthodontic treatment (Lager, 1958; Krebs, 1959, 1964; Skieller, 1964; Thors, 1964). The radiographic analysis of growth covers both lateral and postero-anterior views of the head and is compared with the dental development and body growth.

My object in this paper is to describe the implant method as applied to the maxilla, to examine the general pattern of maxillary growth in a lateral view, and to report the results of an analysis of the sutural growth of the upper face in the sagittal plane. The study was performed on Danish boys.

## Material

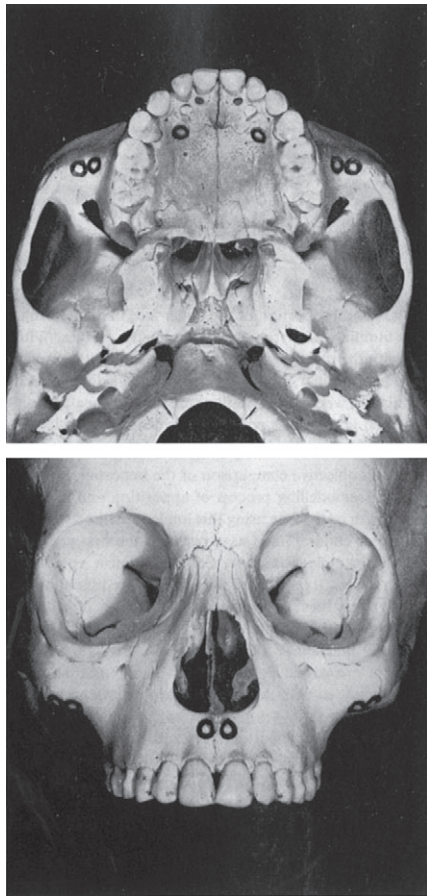
The part of the sample with which this account is concerned consists of 45 normal, healthy boys with different types of malocclusions, from slight rotation of individual teeth to severe occlusal disharmony. They are children attending

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; by this means the time for the puberal growth spurt can be differentiated in months instead of years.

## Maxillary implant technique

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 anaesthesia, 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. Experience gained over a number of years has shown that there is 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). 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.



**Figure 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.

- (2) After the permanent central 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 great 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 great 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.

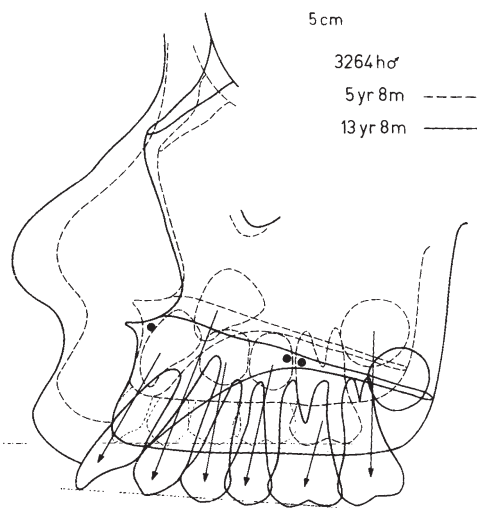
Implants in the zygomatic processes of the maxilla are suitable for measuring the growth in width of the maxilla in the central part of the median suture and this determination is performed with great accuracy. Since such implants are situated remote from the median plane of the face, they are not so suitable for examining the sutural growth of the upper face in the sagittal plane. For the same reason any determination of the rotation of the maxilla in the sagittal plane during growth using these implants incurs a large 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 I have mentioned have proved to be unstable – for instance in the part of the alveolar process where the teeth are situated.

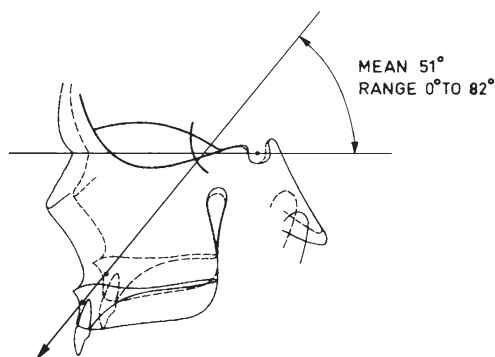
The setting of the head in the cephalostat must be done with great accuracy if the structures of the right and left sides of the face are to correspond on the lateral radiograph, and at each annual check the radiographs are compared with earlier ones in the series before they are accepted.

#### *Maxillary growth pattern*

The pattern of maxillary growth in profile is illustrated in Figure 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



**Figure 2** Growth of the maxilla in an untreated case, analysed by the implant technique, representing the usual growth pattern.



**Figure 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 indicated. The first and last radiograph of each series was orientated with respect to coincident structures in the anterior cranial fossa and the pterygopalatine fossa.

the alveolar arch elongated forwards; if eruption involves a backward component, the alveolar prognathism will be reduced and the alveolar arch 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 determining 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.

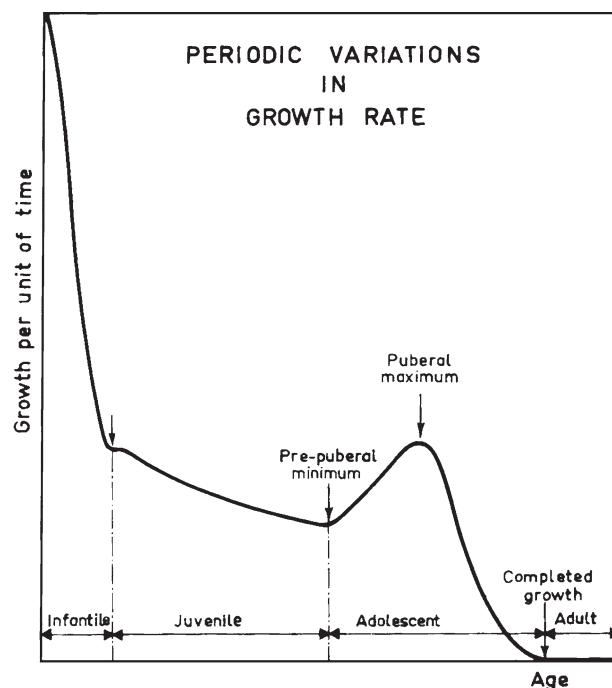
#### *Direction of sutural growth*

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 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 and Solow, 1962). One line was placed through the nasion and sella point 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  $\pm 5$  degrees. The mean angle for 37 of the boys in which it could be studied was 51 degrees, 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 Figure 9. This picture shows a direction of growth that follows a steady curvilinear course. The growth of the upper face in this case (Fig. 7) is mainly sagittal in direction in the juvenile period, becoming predominantly vertical during adolescence; this results in a constant change in the facial proportions. From the available evidence it would seem as if this pattern of growth is the commonest, but closer investigation is called for.

#### *Sutural growth rate*

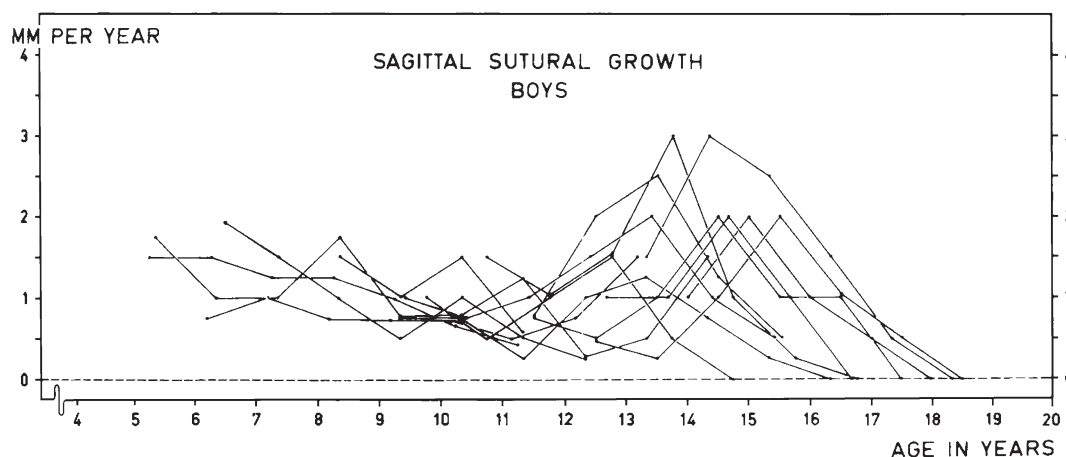
The velocity curve for the yearly rate of growth has a characteristic form with a pronounced periodicity (Fig. 4).



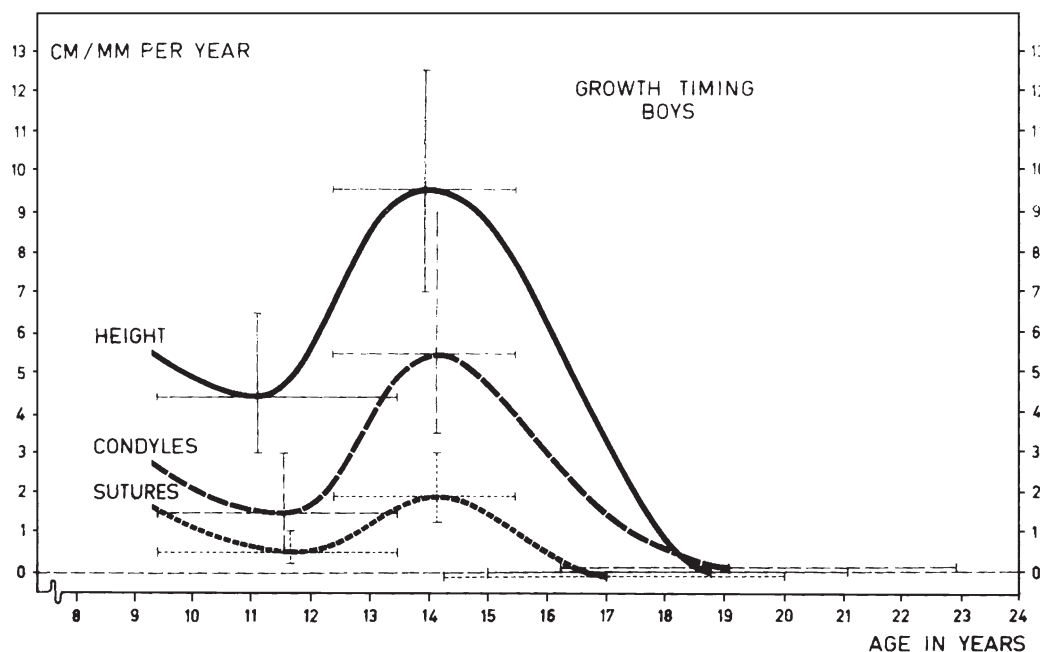
**Figure 4** Periods in the development of the child, divided according to the rate of growth.

During the infantile period, covering approximately the two first years of life, the rate of growth falls off steeply to a point at which there is a sudden change 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 occur constitute a manifestation of the physical maturity of the individual. These stages are associated with hormonal development, and familial consistency 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 and 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 the guidance of implants in region (1) or (2). Figure 5 shows individual velocity curves for 25 Danish boys; the puberal growth spurt is clearly seen. The annual growth in the

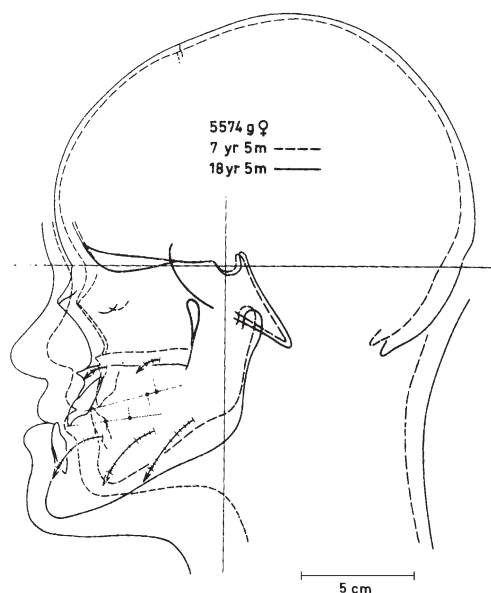


**Figure 5** Individual curves for the rate of growth in the sutures of the upper face measured by means of metallic implants; 25 Danish boys. The rate is measured as the annual growth in its direction in the sagittal plane.

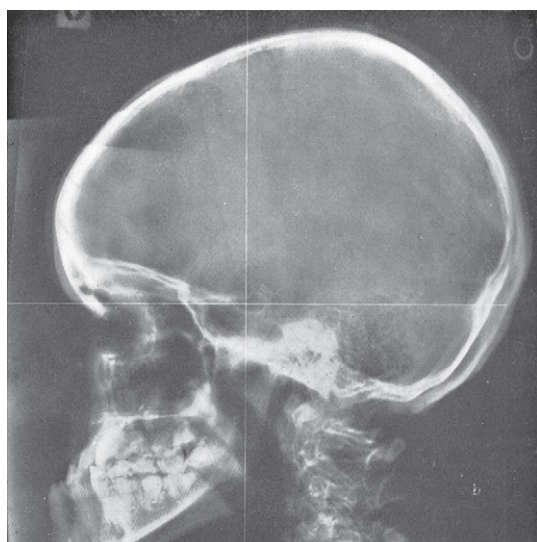


**Figure 6** Mean times and individual variations for pre-puberal growth minimum, puberal growth maximum and completed growth in body height, the growth at the mandibular condyles and the sutural growth of the upper face in the sagittal plane. For the pre-puberal minimum and puberal maximum, the mean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



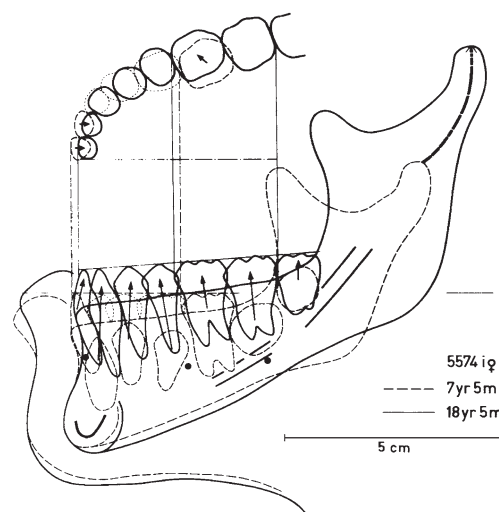


**Figure 7** Facial growth in an untreated girl with bicondylar hyperplasia, analysed by the implant method.

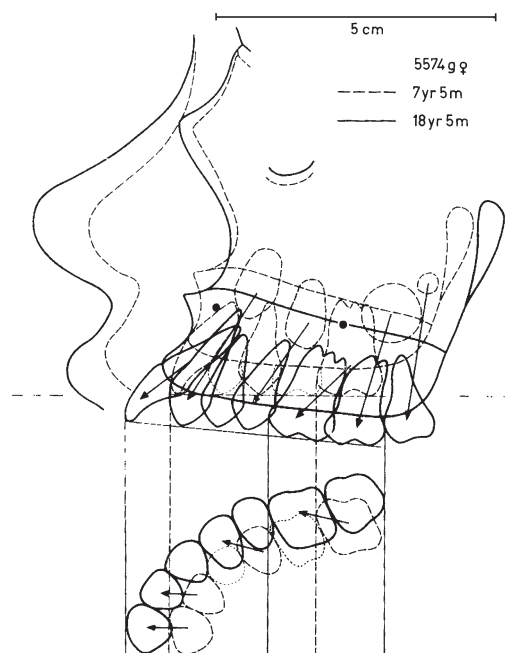


**Figure 8** Logetronic growth picture at the ages 7, 11 and 18 years.

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 average, at 17 years. The times for the pre-puberal minimum, puberal maximum and completion of growth are shown in Figure 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

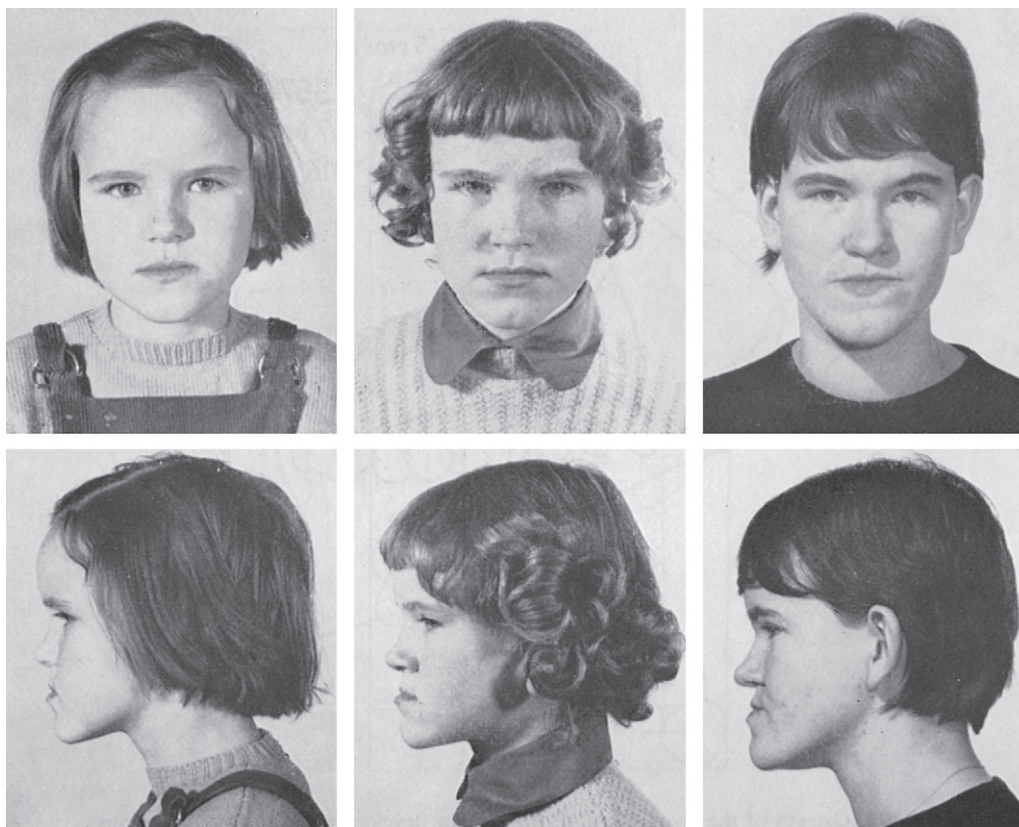


**Figure 9** Growth of the mandible and dentoalveolar development, analysed by means of the implants.

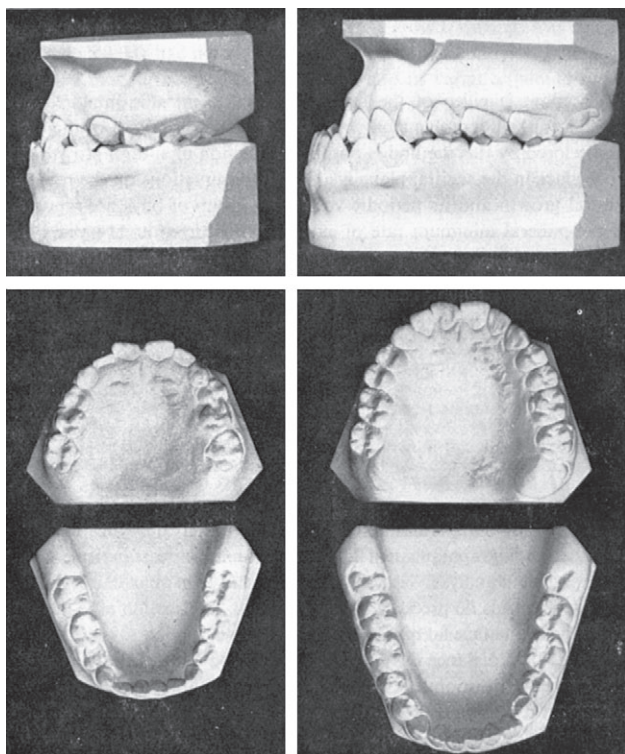


**Figure 10** Growth of the maxilla and dentoalveolar development, analysed by means of the implants.

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. Incidentally, it would seem that an annual record of the 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.



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



**Figure 12** Dental casts at 7 and 18 years.

Condylar growth was complete 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 report*

To illustrate the application of the implant method in analysis of growth in the sagittal plane of the face a case of bicondylar hyperplasia with development of extreme mandibular overjet will be described.

The patient, a girl, 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 Figure 9 by an arrow on which the annual growth is indicated.

The development of the face as a whole is illustrated in Figure 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 forwards direction at a juvenile age to a predominantly downwards 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. Such changes in proportions are apparently 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 Figure 8, and photographs at the same stages are shown in Figure 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 Figure 12. By means of a special technique (Björk, 1962b) drawings of dental casts can be transferred to radiographic growth tracings of the lower and upper jaws and orientated so that the movement of the teeth can be defined in three planes in relation to the implants during occlusal development (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 intercuspation. This compensatory dentoalveolar 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 dentoalveolar increase in width in the maxilla, which took place as a result of intercuspation.

By virtue of the limited size of the series and the special selection, 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.

## Discussion

Professor Lundström commented that this was another example of Professor Björk's impressive series of studies with the implant method. He had measured the direction of growth from the sella-nasion line and he had found great variance. He wished to ask to what extent was this variance due to variance in the sella-nasion line itself. He also wished to ask if Professor Björk had any explanation for the lateness of the growth of the mandible in comparison with general growth, for instance, the height of the individual, and

whether this applied to females as well as males.

Professor Björk replied that it would take too long a time to discuss fully the variance in the orientation of the sella-nasion line. In fact, using the logetronic film copies for comparison the error in the growth tracings was considerably reduced. He had demonstrated that the direction of condylar growth may be curved, but further definition of this curve and its variation would require a lot more work. With reference to the second question, he replied that from the prepuberal minimum onwards the periodic variations in the velocity curves for girls are about one year and a half earlier than for boys in the Danish samples studied and this applied to body height as well as to condylar and sutural growth.

## Acknowledgement

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