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Review Article

Maxillary Growth and Development, and "Structural Analysis" of Maxillary Treatment Changes

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Abstract

The maxilla is a complex structure, and its growth and development are often not considered in the treatment planning of an orthodontic patient. Whereas the mandible has received great attention in the orthodontic literature, partly because it largely determines the facial appearance of most individuals, the maxilla has often been left behind. In this review, we will look at the early development of the maxilla, its anatomy, and its relationship to the surrounding bones. We will also examine the normal growth of the maxilla without the influence of treatment, to better understand its role in the development of malocclusions. We shall further review the normal sutural changes in all three dimensions over time and how these changes determine growth and displacement of the maxilla. The use of metallic implants has greatly contributed to a better understanding of maxillary growth. Studies employing this technique have revealed the complexity of changes over time. Implant studies have also shown that the maxilla, like the mandible, undergo rotational changes during growth. Such rotational changes during growth are not limited to humans but also occur in non-human primates that have been studied in detail using the implant technique. Maxillary growth changes after orthodontic treatment has long been challenging to study accurately. The most common approach has been to analyze cases using the so-called "best fit technique," where two cephalometric headfilms are superimposed on the palatal plane registered at the anterior nasal spine. Prior to the implant studies, orthodontists were unaware that the maxilla undergoes extensive modeling during growth, which can mask the actual changes. In this review, we present an analysis approach called the "structural technique," which is based on information from implant studies. Finally, we will present an example of a treated case where this analysis is applied. We shall also present a new analysis that includes the dental changes.

Keywords

Early maxillary development; The maxilla's anatomy; Maxillary skeletal development; Dento-alveolar development of the maxilla; Structural analysis of maxilla

Introduction

The maxilla is an important part of the facial components that is affected during orthodontic treatment. The mechanics used during treatment in most cases affect not only the mandible but also the maxilla. During the early stages of facial growth, the maxilla, which consists of several bones, including the so-called premaxilla, is connected by sutures to several other cranial structures. Shortly after birth, one of these sutures that connect the premaxilla with the maxilla proper begins to close along with the midline palatine suture and the suture between the palate and the palatine bones (Figure 1). This development has been described in great detail by Fields (1991); Behrents 1991 and Laowansiria, et al. (2013). As seen in figure 1 the pre-maxilla segment includes the four maxillary incisors [1-3].

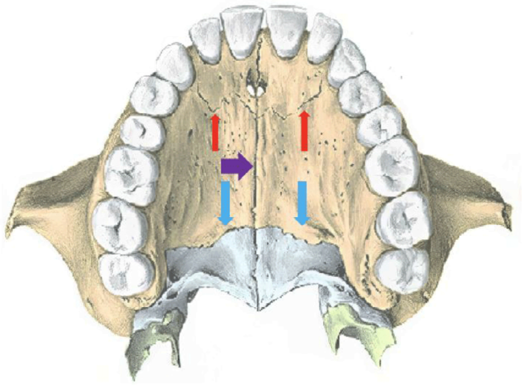


Figure 1: Adult maxilla showing remnants of the premaxillary suture (red arrows). The purple arrow indicates the midline suture that separates the left and right maxilla. Blue arrows show the maxillo-palatine suture.

In some adult skulls, the same structure has been identified, but according to Behrents, et al. (1991) in their study of 50 subadult skulls, they never observed it as a continuous structure [2]. Trevizan, et al. (2018) evaluated the topographic and temporal aspects of the premaxillary bone in 1138 human skulls, comprising 116 children and 1022 adults [4]. The progression of premaxillary suture closure from birth to 12 years of age was 3.72% per year. In 100 percent of the skulls up to 12 years of age, the premaxillary-maxillary suture was observed to be open in the palatal region. They concluded that the premaxilla exists independently of the maxillary complex and that the presence of the premaxillary-maxillary suture justifies the success of anteroposterior expansions to stimulate growth of the middle third of the face, thereby solving anatomical and functional problems.

Early bone development of the maxilla

According to Kjær, et al. (2024) the bony formation of the maxilla begins in the canine and palatine regions and develops intra-membranously [5]. Ossification of the palate occurs in spiculae radiating out from the canine areas and palatine areas. The primary dentition according to Kjær (2024) develops early from the dental lamina. Early dentin and enamel develop in the coronal part of the surrounding dental follicle. The alveolar process develops after the tooth buds have been formed. The permanent tooth buds develop from the dental lamina after gestational age of 20 weeks [5].

The maxilla is an important part of the structures that are affected by treatment. Much effort has been made in the past to understand the effects orthodontic treatment has on growth of the mandible but much less attention has been paid to the maxilla according to Laowansiri, et al. (2013) [3]. Numerous studies have looked at early maxillary growth and development to better understand this complex structure. One particularly challenging problem is understanding the development of cleft palate that can be either bilateral or unilateral. In cases where there is lack of fusion or union of the anterior parts of the maxilla it can prevent the normal closure of these sutures and results in clefts of the palate [5]. However, further details with respect to the development of CLP are outside the scope of this article.

Normal maxillary anatomy

As seen in figure 2 the normal maxillary anatomy includes several sutures that connect it with the surrounding skeletal structures. Most notable of these is the midline suture that connects the two halves of the maxilla. Posteriorly the maxilla is connected *via* sutures to the palatine bones as indicated by the arrows in figure 2.

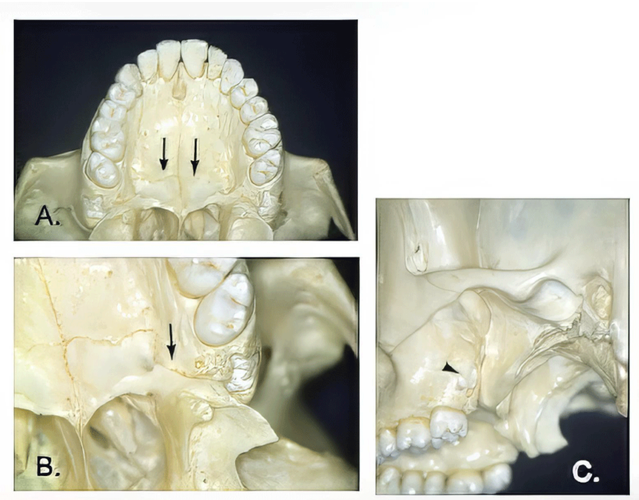


Figure 2: A. Occlusal view of maxilla and its connection to the palatine bones indicated by arrows. B. The bony contact between the tuberosity of the maxilla and the lateral pterygoid bone. Notice the partially erupted third molar. C. Lateral view of the contact between the maxilla's tuberosity and the lateral pterygoid plate.

In the lateral and posterior region, the maxillary tuberosity has a tight contact with the lateral plate of the pterygopalatine bones figure 2 (B), but there is no suture involved. This relationship can also be seen in figure 2 (C). The sutural connections between the maxilla and the adjacent bones can be seen in figure 2 (A,B). As shown in this illustration there are sutures that connect the maxilla with the nasal bone (green arrow) and the frontal bone (blue arrow). There is also a sutural connection between the maxilla and the zygomatic bone laterally (red arrow). Finally, the midline suture with the opposite side of the maxilla can be seen, which is where the transverse development takes place.

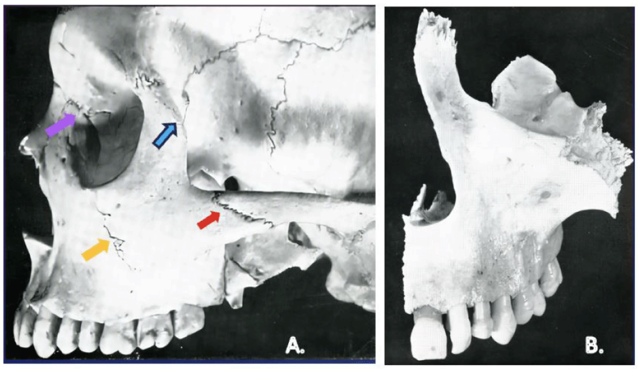


Figure 3: A. Lateral view of a skull with arrows indicating the sutures against the adjacent bones. Purple arrow indicates the naso-maxillary suture. Red arrow the suture between the maxilla and the zygomatic bone. Yellow arrow the maxilla-and the tuberosity. Blue arrow indicates the maxilla-frontal suture. B. Frontal view of the maxilla. Notice the sutural surfaces.

Early growth and maturation studies of the maxilla

Laowansiria, et al. (2013) examined serial headfilms of 210 subjects from the Bolton-Brush study [3]. Each subject had at least six consecutive headfilms between birth and age 5 years. A series of linear and angular measurements were performed to determine the size changes over the time. The results showed that the greatest postnatal growth occurs between age 3 and 6. With this knowledge in mind, it seems logical to correct any transverse discrepancies as early as possible to make the best use of the open sutures for expansion. Brodie (1949) described in detail the facial growth pattern of the human skull from the early age of 3 months to 8 years of life. He concluded that while the overall shape is established early individual bones within the skull have their own individual linear growth [6].

Implant studies of Maxillary growth and development

Most of the early studies of maxillary growth used techniques that were based on superimposing serial headfilms on what appeared to be stable structures. The structures used were mainly the nasal floor and the tracings were registered at anterior nasal spine (ANS). Not until the introduction of the so-called "implant technique" did it become evident that the structures previously used were undergoing remodeling changes over time and therefore were unreliable for registration.

This new technique that was developed and introduced by Björk in 1955 eliminated the errors in the best fit technique [7]. Numerous studies over the years have thanks to the implant technique provided us with valuable information about growth and the development of the maxilla. We have previously described the implant technique and its application so in this context we shall only briefly review its application [8]. Figure 4 shows the implant instrumentation and the placement of the metallic pins that was done under local anesthesia.

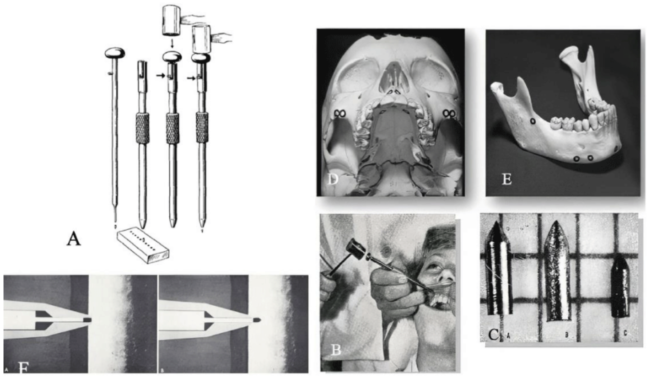


Figure 4: Instrumentation and placement of implants. A. Pencil like instrument carrying the implants. A lead mallet is used for the insertion. B. Patient having implant placed. C. Varies sizes of implants shown on millimeter grid [9].

The size of these radiographic markers varied from 1-2.5 mm. The material used was initially chrome-cobalt that later was changed to Tantalum, a metal better tolerated by the tissues. The markers were easily identified on cephalometric headfilms and remained in place for life. To distinguish the left from the right side of the patients Björk (1955,1966,1968) placed smaller implants on the side near the headfilm so that the magnification difference between the two sides further helped separate the sides [7-9]. In the maxilla there are four regions where implants

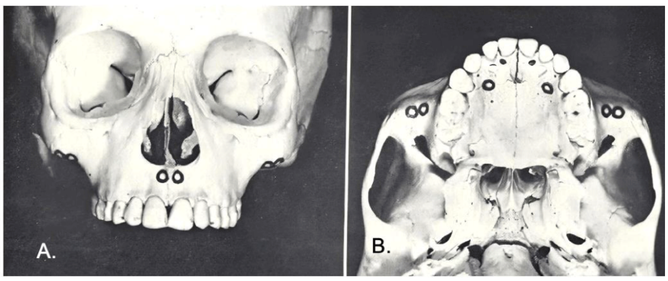


Figure 5: Human skulls with location of the maxillary implants. A. shows the anterior implant position. B. Palatal and zygomatic implants [9].

can be inserted with minimal chance they will be disturbed. These stable locations can be seen in figure 5.

As the maxilla consists of two parts, implants must be placed on both sides of the jaw. Routinely, implants were also placed in the palate behind the upper incisors. In the zygomatic process, Björk would place two implants on either side of the anterior inferior part of these bones. Anteriorly, once the incisors had erupted, two implants, one on either side, were placed below the anterior nasal spine. An important detail of the implant studies is that the subjects did not undergo treatment while in the study. It is also worth noting that the sample size comprised more than 300 subjects with and without malocclusion. These subjects were seen annually for records during the study period.

In his first publication introducing the implant technique, Björk analyzed facial growth in five subjects. In this article, he not only explained the implant technique, but also demonstrated the surface modeling of the jaws [7]. A second study by Björk using this new technique of implants was published in 1966 [8]. In this article, he reported on the growth changes of the maxilla in 32 boys over four years. The direction of the maxilla's growth was measured from the cranial base to the anterior implant in the maxilla, as seen in figure 6.

The results showed that the average growth direction of the maxilla was downward and forward at an angle of 51 degrees in relation to the anterior cranial base (Figure 6). Most importantly, the study also revealed significant individual variation in growth direction, ranging from 0 to 82 degrees. This study was one of the first to emphasize the great individual variation in the maxilla's growth pattern. In this study, the annual sutural growth changes were measured by using the implants as stable reference markers. The data showed that sutural growth during the juvenile period varies unpredictably from year to year. The maximum sutural growth rate was reached at puberty, coinciding with the growth rates of the mandibular condyles and body height. Figure 7 shows a close correlation between growth in body height, condyles, and sutures, as they all reach a maximum at nearly the same time.

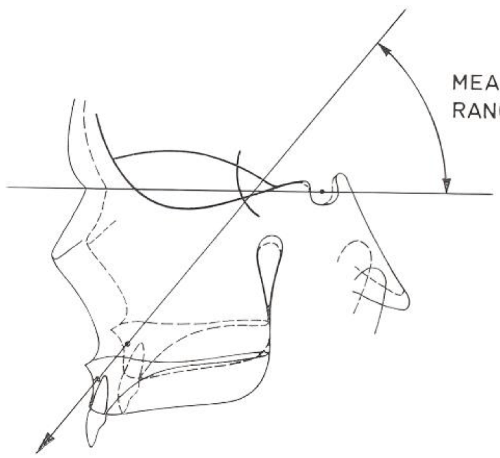


Figure 6: Average sutural growth of the maxilla in 32 Danish boys measured to the anterior cranial base. Notice the mean direction of 51 degrees and the considerable variation of 82 degrees [8].

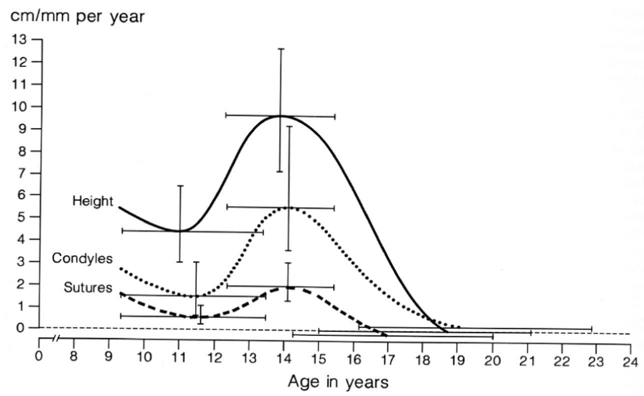


Figure 7: Mean growth and individual variations for pre-puberal minimum, puberal maximum, and completed growth in body height, condyles, and sutures in25 boys. Notice the large standard deviations for all three events. Notice also that sutural growth on average is completed 2 years prior to condylar growth, and that condylar growth can continue until age 23 [8].

This comprehensive study revealed that, on average, completion of sutural growth occurs two years earlier than condylar growth. A clinically important difference, as it can explain late changes in occlusion after puberty that may affect post-treatment stability.

Maxillary growth in non-human primates studied with implants

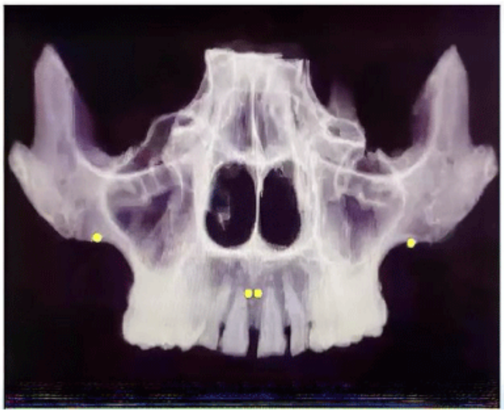
The growth rotations of the maxilla and mandible, as seen in humans using the implant technique, also occur in non-human primates. Bravo and Nielsen (1989) studied facial growth in 10 Macaca Mulatta monkeys, using metallic implants and semiannual serial head films between the ages of 2 and 5 years [10]. Their results showed that, like humans, the jaws of the monkeys undergo rotational changes that, in the mandible, on average, are twice as great (9.4 degrees) as in the maxilla (4.2 degrees). The rotational changes were masked mainly by modeling with 90% in the mandible and 75% in the maxilla [10,11].

Maxillary sutural growth in general

Normal growth of the maxillary sutures was studied by Scott (1956), and based on his findings, he developed theories regarding the sutures, normal growth, and function [12,13]. He stated that each suture has two growth sites, one for each of the bony elements. During the early growth period, the maxilla is thrust forward and downward relative to the anterior cranial base, not by growth in the sutures but by growth of the septal cartilage and the orbital contents. In Scott's opinion, this, as he says, cannot be verified by lateral cephalometric headfilms in the analysis of changes in the maxilla. Melsen (1975) and Melsen, et al. (1982) studied the postnatal development of the palatomaxillary region using autopsy material and skull material [14,15]. The samples consisted of thirty-three boys and twenty-seven girls, aged 0 to 18 years [15]. The results showed growth in length continued until age 13 in girls and 15 in boys, and was associated with growth in the transverse suture and apposition on the posterior margin of the palate. They found that the apposition would continue beyond this age for a few more years. Growth and shape of the transverse suture changed over time from initially short and broad, as well as "y" shaped. Later, it became more sinuous, and finally, heavy interdigitation made it challenging to separate the two halves without fracturing the interdigitated processes [15].

Maxillary growth in width

The discussion of the growth in width of the maxilla has mainly been concerned with the extent to which growth in the median suture contributes to this growth and the degree to which appositional remodeling of the outer aspects of the maxilla contributes. As early as 1922, Keith and Champion attempted to evaluate the problem by comparing crania in children and adults. They took the view that the median suture must be an active factor in the growth in width of the palate [16]. The opposite view, that the suture does not contribute to growth in width, has been advocated by several authors. Scott (1956,1967) described the median suture as a site of active growth during fetal life, but claimed that it was uncertain whether growth continued to occur in the suture after birth [12,13]. Latham (1971) examined the structure and growth pattern of the mid-palatal suture of the maxilla [17]. He found no histological evidence of active growth in the median suture after age 2 to 3 years. Enlow and Bang (1965) considered that the widening of the hard palate and the upper dental arch was only due to remodeling processes [18]. Recent histological studies have confirmed that growth in the median suture takes place up to adolescence. Studies by Linder-Aronson, et al. (1965) on the postnatal growth of the median palatine suture provided detailed descriptions of its development [19]. The transverse development of the maxilla using metallic implants was examined by Björk and Skieller (1967) in a sample of 14 4-year-old boys with normal occlusion, who were studied through the permanent dentition [20]. As some of the boys developed malocclusion during the study period, they had to be



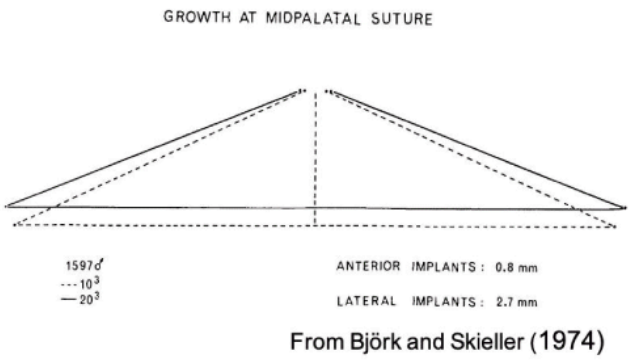


Figure 8: A. Frontal image of cranium with location of maxillary implants. B. Schematic illustration of a subject's transverse sutural increase during a ten-year period. Notice the posterior transverse increase in this case is 2.7 mm whereas the anterior change is only 0.8 mm [20].

excluded, so the final sample included nine boys who were examined with annual records. The transverse changes were studied on frontal X-rays, and an example of the implants used as fixed references is shown in figure 8A.

This study revealed an interesting new observation: sutural growth in the midline suture is greater posteriorly than anteriorly. This difference creates a horizontal rotational movement of the two parts of the palate during growth that shortens the anteroposterior distance of the palate, as illustrated in figure 8 B. Another finding from this study confirms what previous implant studies have shown: that the transverse growth of the maxilla continues beyond puberty until the completion of growth in other facial sutures. Previous implant studies have shown that growth in length occurs towards the palatine bone and by apposition on the maxillary tuberosities. Past discussions have also debated whether resorption occurs on the anterior surface of the zygomatic process, as believed by Enlow (1965), or apposition, as claimed by Scott (1967) [13,18]. However, implant studies have shown that none of these changes occur over time; instead, the structure remains stable. One might argue that if there was resorption of the anterior surface of the zygomatic process during growth, Björk's implants would have fallen out; however, they never did. The implant studies also showed that an increase in the height of the maxilla occurs through growth at its processes and at the sutures against the frontal bone, as well as against the zygomatic bones. Additionally, there is appositional growth on the inferior aspect of the alveolar bone, which increases the alveolar height. Another important finding was that the nasal floor undergoes local resorption, whereas the orbital floor has apposition. One new observation was that the maxilla undergoes varying degrees of rotation during growth [21].

Vertical and transverse maxillary growth studied with implants

In a study of postnatal growth of the maxilla, Björk, et al. (1974,1977) measured the modeling changes of the maxilla during growth [21,22]. In 9 subjects with metallic implants who had been followed with annual examinations from age 4 to adult age, the transverse growth in the median suture was measured. The results showed that on average, the midline suture increased the maxillary width by 6.9 mm (range, 5.5 to 8.2 mm) during this period. When the bimolar width in the same subjects was measured, it had increased by 9.5 mm, which indicates that alveolar eruption further added to the transverse distance between the two parts of the maxilla during growth. A key finding from this study is that, for the first time, the vertical modeling changes of the maxilla also were measured. The findings from this study are illustrated in figure 9, which summarizes the changes in 9 boys.

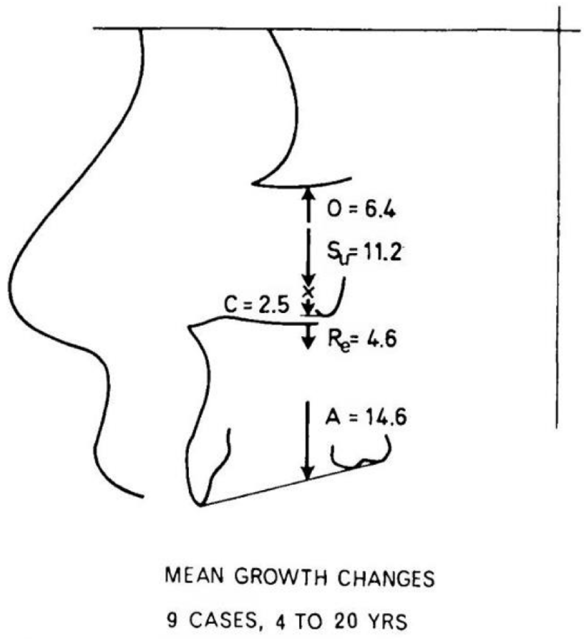


Figure 9: The figure shows the mean maxillary growth changes and modeling between the ages of 4 and 20 years. Notice the apposition at the orbital floor and the resorption of the nasal floor.

Other studies have confirmed these growth and modeling changes. Baumrind, et al. (1987) examined the so-called masking effect on the maxilla of surface modeling [23]. They emphasized that if these changes were not taken into consideration when analyzing a lateral headfilm error would be made with respect to the eruption of the teeth and the changes of the bony landmarks. Surface modeling of the maxilla was also studied by Iseri and Solow (1995) [24]. The results showed that the anterior nasal spine (Downs point A) was relocated on average 4.5 mm downward and 0.5 mm forward over this period. Pterygomaxillare (PNS, pm) was relocated 6 mm posteriorly and 1.5 mm down by surface remodeling. They also reported that the changes of point A and PNS resulted in a rotational change of the palatal plane by 2.5 degrees. They conclude that great caution should be exercised when analyzing clinical treatment based on superimposition that relies on lines

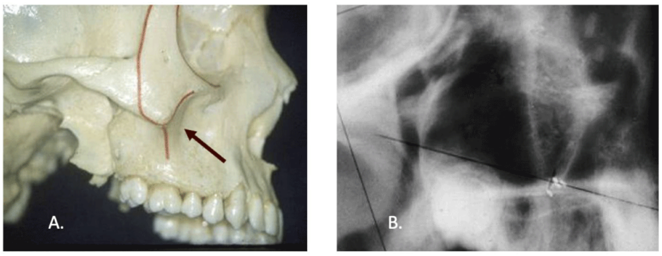


Figure 10: A. The zygomatic process of the maxilla. The outline of the process is shown in red. The arrow points to the typical location of the lateral implants. B. Section from a cephalometric headfilm showing the zygomatic process and implants located in the anterior inferior portion of the bone. Notice the reference line that is placed on the initial film and then transferred to the subsequent film after superimposing on the structures. The angle between the two lines measures the rotational change.

and structures defined by the bony palate during growth [24].

The" structural" cephalometric analysis of maxillary growth and treatment

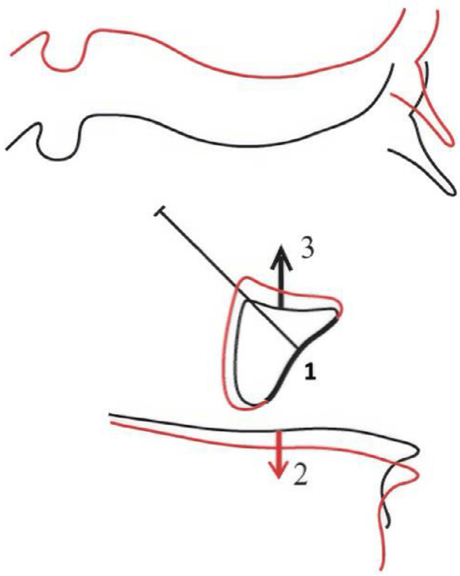


Figure 11:

Figure 11: Alignment of two headfilm tracings on the anterior outline of the zygomatic process of the maxilla (1). The resorption of the nasal floor (2) and the apposition at the orbital floor have been divided in a 3:2 ratio. Notice the greater amount of resorption anteriorly than posteriorly of the nasal floor.

Based on the information from the implant studies of the maxilla, Björk in 1975 recommended a new technique for cephalometric analysis of growth and treatment of the maxilla. The technique called the "structural technique" is based on superimposing the two maxillae on the anterior outline of the zygomatic process and then corrections are made for the resorption of the nasal floor and the apposition on the orbital floor by sliding the second film up and down on the anterior outline until the ratio of apposition to resorption is 3:2. To demonstrate the structures involved and the location of the implants a tracing of the zygomatic process and the implants as they appear on a lateral implant are shown in figure 10.

The illustration seen in figure 11 summarizes the process of aligning serial headfilms according to the "Structural Technique." Notice the changes of the nasal and orbital floors after the two tracings have been aligned on the zygomatic process and adjusted using a ratio of 3:2.

To examine the validity and reproducibility of this technique, several studies have been done by other researchers on both untreated and treated subjects with metallic implants. Nielsen (1984) compared two anatomic methods with the implant method in a series of headfilms from 18 patients [25]. The structural technique based on the use of stable structures in the maxilla showed no significant differences from the implant method in vertical displacement of selected landmarks. However, when comparing the traditional best-fit method with both the structural and implant methods, significant differences were found, with the latter underestimating the eruption of the molars by as much as 30% and the incisors by 50%. Dopple, et al. (1994) found varying degrees of rotational changes of the maxilla and that PTM, ANS, and PNS, as well

Table 1: Classification of transverse malocclusions.

Posterior Occlusion	Anterior Occlusion
Lingual crossbite	**Maxillary midline deviation**
Unilateral	Skeletal
Skeletal	Dental
Dental	Postural
Postural	**Mandibular midline deviation**
Bilateral	Skeletal
Skeletal	Dental
Dental	Postural
Postural	
Buccal crossbite	
Bilateral	
Skeletal	
Dental	
Postural	
Unilateral	
Skeletal	
Dental	
Postural	

as A point, were not stable reference markers for maxillary superimposition [26].

Classification of transverse malocclusions

The most common malocclusion related to the maxilla is a posterior crossbite, which can be either unilateral or bilateral, and can also be primarily skeletal, dental, or a combination of both. Additionally, a crossbite that involves only one side is often associated with a midline deviation. Crossbite of the anterior teeth, which includes one or more incisors, is frequently associated with a postural effect where the patient holds the mandible forward to achieve maximum occlusion of the posterior teeth. Table I lists the possible combinations of anterior and posterior malocclusions associated with the maxilla [27].

Clinical application of the maxillary "structural superimposition"

For many years the cephalometric analysis of maxillary growth and treatment changes has been difficult and unreliable, as previously explained. In growing patients, the remodeling of the maxilla during growth masks the actual changes, and as a result the growth and dental changes have been incorrectly determined. As this "structural technique" now has become the gold standard for analysis of cases submitted to both the American Board of Orthodontics and the European Board of Orthodontics, we shall show the analysis applied to a treated patient.

Case Report Pt. S. G. H. 12 yrs. 9 mos. (Class II, Div. 2 malocclusion and deep bite).

The young man seen in figure 12 was treated without extractions of permanent teeth despite having severe crowding in the lower arch. By developing the dental arches through transverse and sagittal expansion sufficient space was developed to avoid extractions.

The post-treatment cephalometric analysis of general facial growth seen in figure 13 shows that during treatment the mandible grew downward and forward. The maxilla on the other hand descended vertically. To correct the Class

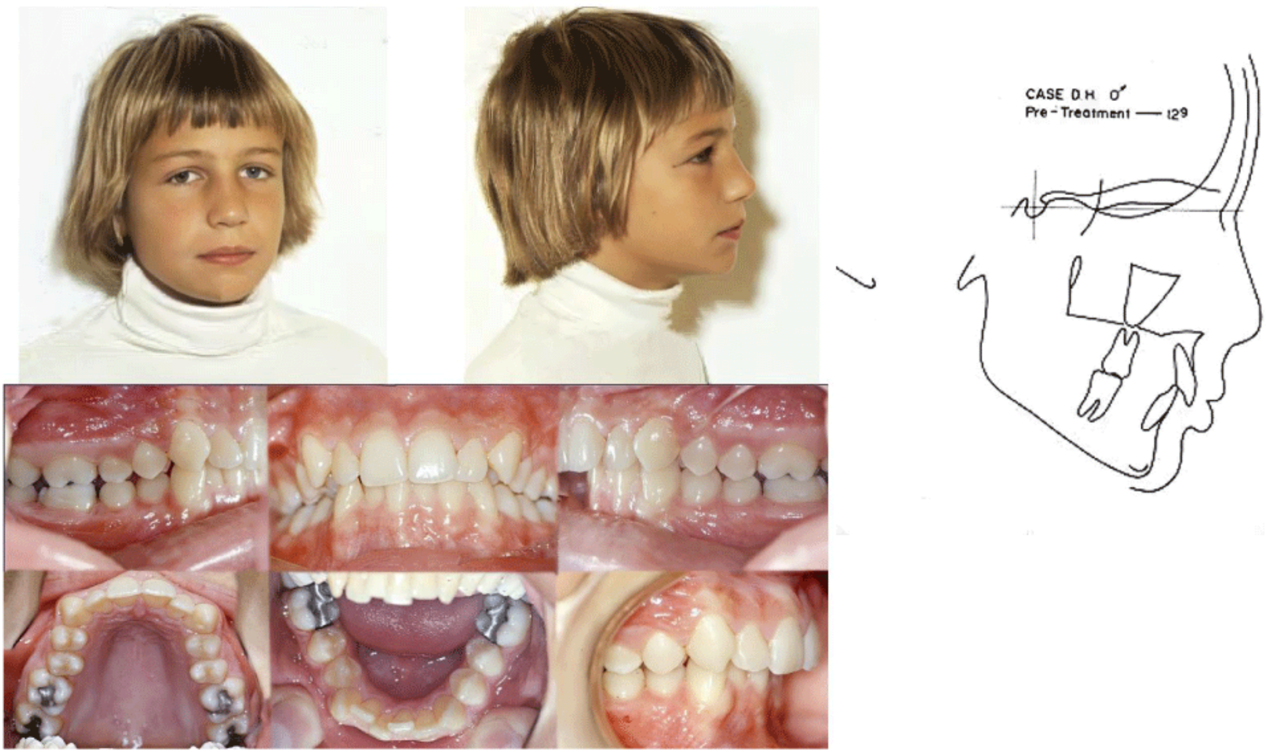


Figure 12: 12 yr. 9 mos. old boy with Class II, Div. 2 malocclusion. There is a deep overbite and moderate crowding in the upper and severe crowding of the lower dental arche. The tracing shows a mildly increased sagittal jaw relationship that has resulted in a Class II malocclusion.

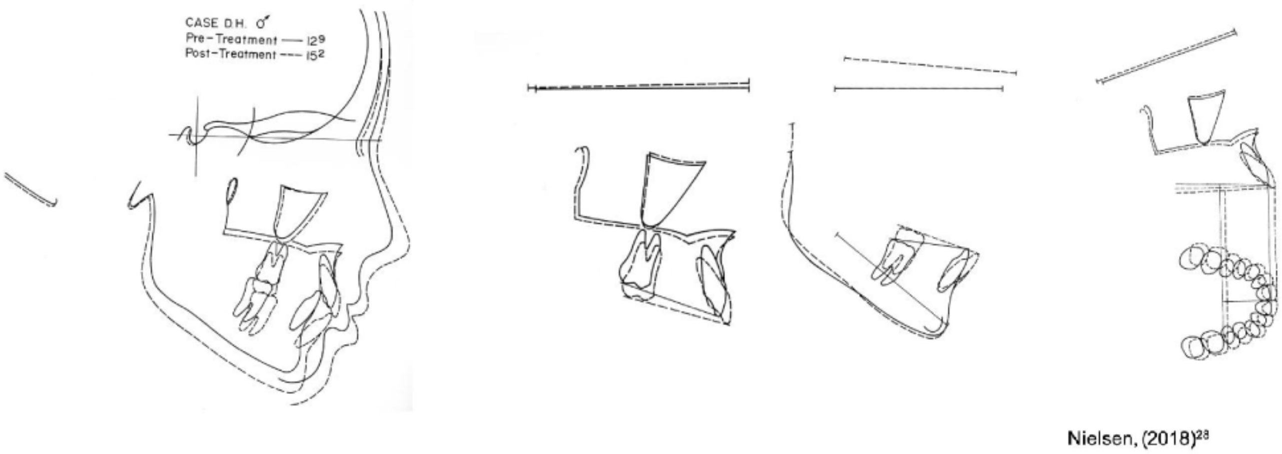


Figure 13: Cephalometric growth and treatment analysis. A. The general facial growth analysis, based on superimposition on stable structures in the anterior cranial base, shows that during treatment the mandible grew downwards and forwards. The maxilla, on the other hand descended vertically with no forward growth. B. Maxillary "structural" superimposition shows mild proclination of the incisors and mesial movement of the molars. C. The mandibular superimposition shows proclination of the incisors and anterior rotation of the mandible during treatment. D. Maxillary superimposition with occlusograms showing the expansion of the dental arch during treatment.

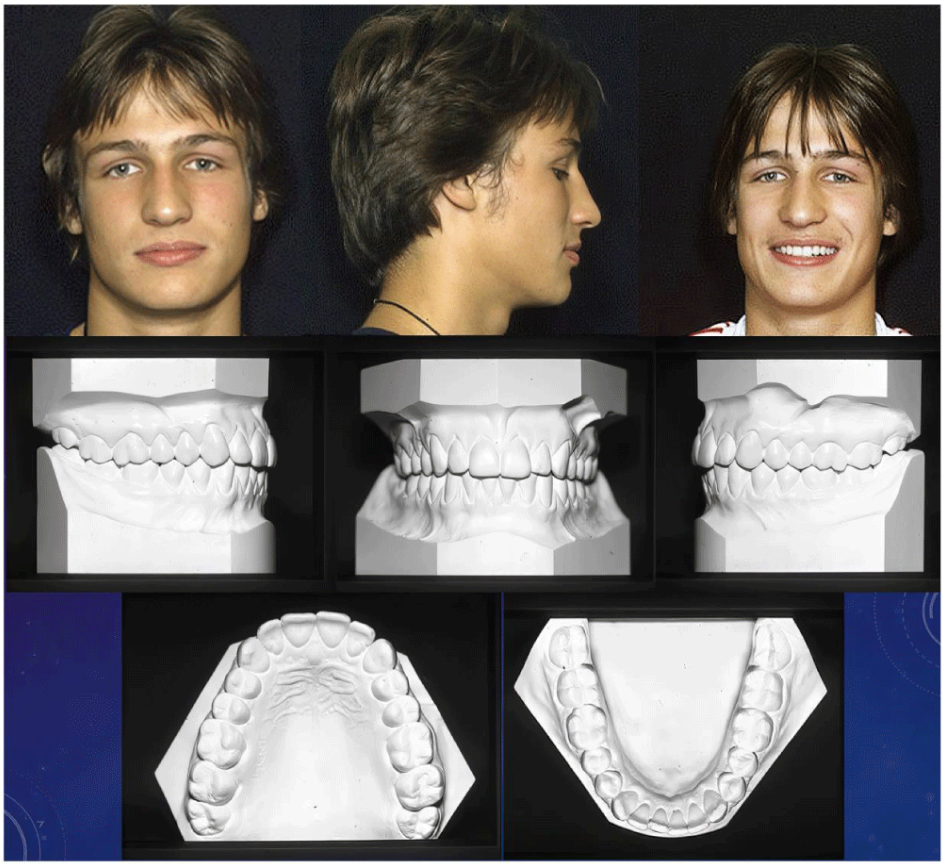


Figure 14: Out of retention records. The occlusion is Class I occlusion and there are a normal overjet and overbite. The crowding has been eliminated by dental arch development, and the third molars have erupted.

II and the overjet Class II elastics, and no headgear was applied.

In cases where we want to analyze the maxillary dento-alveolar changes and get a better understanding of the arch development we can include occlusograms of the dental arches from before and after treatment. This additional step in the analysis helps explains how the initial crowding had been eliminated. An example of this analysis applied to this case can be seen in figure 13D. The tracings show that during treatment the upper dental arch was expanded both transversely and sagittally. It should be noted that this type of superimposition can only include two stages, in this case the pre- and post-treatment, as the occlusograms are arranged in relation to a common occlusal plane bisector [28] (Figures 14,15).

In this patient the mandible continued its downward forward growth pattern during and after retention. The occlusion remained unchanged and only a small amount of crowding of the lower incisors had develop after retention had been discontinued. The third molars have now erupted and are in normal occlusion. Interestingly, the maxilla post treatment resumed its original growth pattern with downward forward growth. The nasion sella lines seen on the mandibular superimposition reflect the rotational growth of the mandible during treatment in the post treatment period. In this example the mandible as seen rotated anteriorly during both periods, but more so after treatment and retention. The illustration also shows the tooth movements and changes in the upper occlusal plane. The molar changes are adjusted by using the direct measurements from the occlusogram of the upper dental arch [28,29].

Conclusion

The accuracy of the maxillary growth and treatment analysis when using the "structural technique" is greatly dependent upon obtaining good headfilms, with minimal double contours of the used in the superimposition. The extent amount of the double contour of the structures must be limited, and particularly of the zygomatic process, and should remain consistent from film to film. So far, the modern CBCT technique does not offer a reliable superimpositioning technique that provide sufficient information for a reliable analysis. A reproducible head position in the CBCT machines using some form of head holder is unfortunately also not yet available, which makes alignment of the headfilms arbitrary at best.

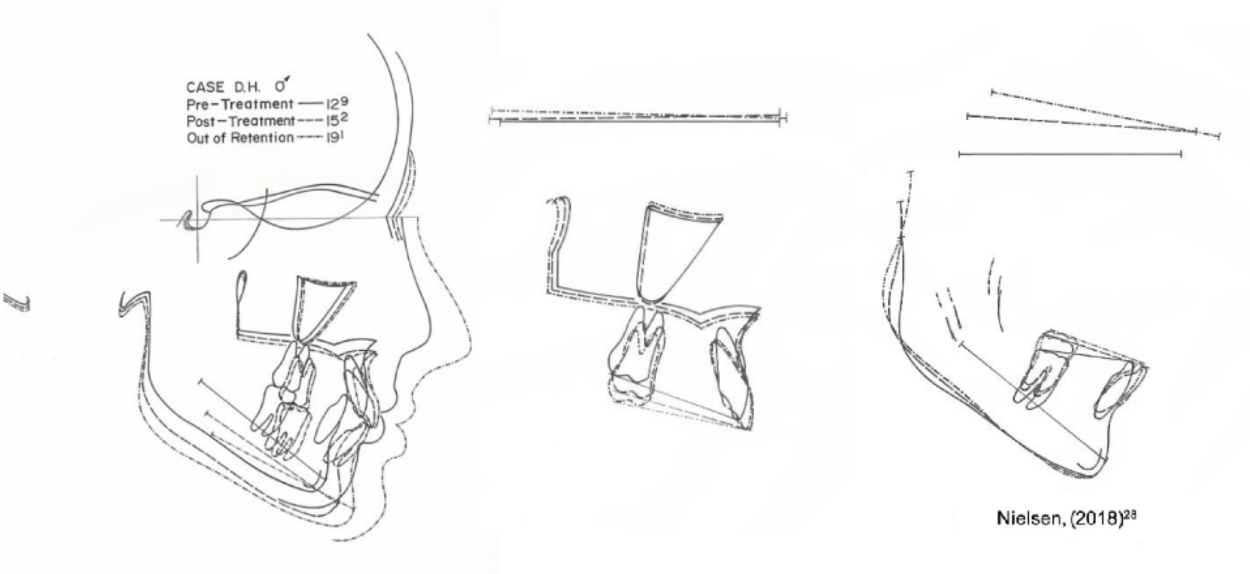


Figure 15: Cephalometric analysis of the Initial, post-treatment and out of retention headfilms. A. General superimposition shows continued downward and forward growth of the mandible. The maxilla has post-treatment resumed its forward directed growth. The mandibular reference lines show the continued forward rotation of the mandible. B. Maxillary "structural superimposition" showing the incisors position is maintained post-treatment. C. Mandibular superimposition showing the amount of condylar growth and its direction, which is vertical. The lower incisor proclination reduced during retention and post-treatment. Notice the forward rotation of the mandible as illustrated by the changes in the sell-nasion line.

Summary

In this review of the maxilla and its growth and development, we have reported on the changes of the jaw from the prenatal stage until adulthood. The changes in the maxilla over time have been studied extensively, with most studies focusing on sagittal and vertical development. Much discussion has in the past centered around the transverse growth of the maxilla. In this review, we have examined the early studies on the growth of the maxilla and the changes in its three dimensions over time. Some studies have claimed that growth in the midline suture, which is partially responsible for the transverse development of the maxilla, is completed at an early age, even shortly after birth. Histological studies, on the other hand, have shown that the midline suture continues to grow until adolescence. From a clinical perspective, late closure of the suture is of great importance, as it allows for the expansion of the maxilla even after puberty. In this review, we have also examined the average forward and downward displacement of the maxilla and discussed the significant individual variations reported in the literature. We have further reviewed the remodeling of the maxilla that takes place during growth, a change that remained undiscovered until the introduction of metallic implants in the mid-1950s. These radiographic markers serve as stable reference points within the jaws, as there is no interstitial bone growth. The implant studies demonstrated that the remodeling of the maxilla includes the nasal and the orbital floor and showed that the maxilla undergoes rotational changes over time. This phenomenon of rotational changes is not limited to humans but also occurs in non-human subjects. The remodeling serves to maintain the inclination of the jaw nearly unchanged over time. To obtain an accurate analysis of growth and treatment changes, a reliable and reproducible superimposition technique needs to be applied. Based on the implant studies, such a reliable analysis has been developed that utilizes stable anatomical structures in the maxilla. We have in this review described the so-called "structural analysis of the maxilla, its history, clinical application and illustrated it with a clinical example.

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