Maxillary Implants and the Growing Patient

Larry J. Oesterle, DDS, MS/Robert J. Cronin, Jr, DDS, MS/Don M. Ranly, DDS, PhD

Maxillary skeletal and dental growth results in dramatic changes in all three dimensions during active growth. Experimental evidence and the behavior of ankylosed teeth suggest that an osseointegrated object remains stationary in the bone surrounding it and does not move or adapt to bone remodeling. Growth changes may result in the burying or loss of implants depending on the placement site. Hence, implants placed in the early mixed dentition have a poor prognosis of continued usefulness through puberty. When placed early implants may disturb growth or have to be replaced. Implants placed during late puberty or early adulthood have the best chance for long-term usefulness. (Int J Oral MaxillofacImplans 1993;8:377—387.)

Key words: dental implants, maxillary growth, osseointegration

The use of implants in the growing individual differs significantly from implants placed in the adult patient. In adults consideration is given to bone quality and quantity potential for function and esthetics and appliance design. In children similar considerations are required; however, there is an additional factor—growth. A wide variety of changes occur both in the dentition and the jaws of the growing patient. Only by recognizing such changes can a rational approach to implants in the growing individual be made.

Because dental implants for children are a new treatment modality the impact that a bone-supported prosthesis might have on facial growth or conversely how growth might influence the longevity and esthetics of the implant is uncertain. There are two primary concerns. First if implants are present during several years of facial growth is there a danger of them becoming embedded, relocated or displaced as the jaws grow? Any of these outcomes is possible because implants unlike teeth are not capable of compensatory eruption or other physiologic movements.

The second area of concern is the effect of a prosthesis on growth. Can a rigid prosthesis attached to implants that bridge a growth area inhibit activity there? As a corollary are there design changes that must be incorporated into such a prosthesis to compensate for growth changes?

Craniofacial growth and dental development are complex subjects that have been extensively researched and documented. Fortunately the important areas of growth and development relative to implant placement are limited to the maxillary and
mandibular arches. This paper addresses growth of the maxilla and the development of the maxillary dentition in the context of implant treatment.

**Behavior of Implants**

Implants in adult patients are well documented in the literature, but there are few reports of the use of implants in growing children. Consequently, little clinical data exist to help formulate concepts about the importance of growth and development relative to implants. However, there is considerable indirect information that suggests how implants might behave in a growing environment. This information is based on the fate of ankylosed teeth, research implants, and implants in adults.

**Behavior of Natural Implants.** The ankylosed primary tooth appears to be a good model of behavior for an osseointegrated implant in a growing child. Although the etiology of ankylosed primary teeth is poorly understood, it appears that even a microscopic lack of periodontal ligament in one or more areas of the primary tooth can produce ankylosis. Thus, the ankylosed primary tooth is "osseointegrated" much like the titanium osseointegrated implant. Severe cases of ankylosis may indicate the potential fate of an osseointegrated implant. For example, Figs 1a and 1b show two patients with severe impaction of maxillary primary teeth that are significantly inferior to the plane of occlusion. Restorations are visible in the primary molars of both patients, verifying that the primary tooth was in the oral cavity at one time. While these are extreme examples, they perhaps illustrate the potential for anything "osseointegrated" to become buried in alveolar bone.

Ankylosed primary teeth are often accompanied by disturbances in alveolar bone growth, because during growth, teeth normally continue to erupt and form alveolar bone in synchrony with vertical growth. Ankylosis arrests both dental eruption and alveolar bone formation in the affected area. An osseointegrated implant would behave much like an ankylosed primary tooth with the same lack of alveolar growth and dental eruption. This example of aberrant growth provides a clue to proper treatment planning and use of implants.

**Behavior of Research Implants.** Björk implanted 0.5 x 1.5-mm tantalum pins in the jaws of growing children as "stable" landmarks for longitudinal cephalometric studies. Although most implants were in fact stable, those pins affected by growth were not. Pins in the path of erupting teeth and pins placed near a bone surface undergoing resorption were displaced. Orthodontic tooth movement also displaced the pins. Nearly all the pins placed in resorptive areas, such as the anterior mandibular ramus, were lost and had to be replaced. In addition, pins placed in areas of appositional bone growth gradually became embedded. The increased likelihood of implant failure in younger children is suggested by similar studies undertaken on infants. Shaw attempted to use Björk's tantalum pins in cleft lip and palate infants to monitor growth. Shaw abandoned the study when he found that up to one third of the implants that were placed shortly after birth were lost. High rates of implant loss occurred in the molar and canine areas. Implants placed in the lateral portions of the
maxilla were particularly unstable. The dramatic growth changes occurring in infancy and early childhood were not conducive to the maintenance of implants.

Thilander et al\(^4\) and Odman et al\(^5\) recently reported the behavior of osseointegrated implants in growing pigs. Even though the implants were in place for only 165 days, significant remodeling changes were seen in the erupting adjacent teeth. While the implants maintained a constant relationship to each other as judged radiographically, some implants became more embedded in bone and others were lost because of bone resorption. The implants also caused a deviation of the erupting adjacent teeth, much like the distortion experienced with ankylosed human teeth.

**Behavior of Dental Implants.** Implants in adults are not only extremely stable but become so firmly attached to the bone that they can be successfully used as anchorage for orthodontic tooth movement. A variety of materials have been reported, varying from bioglass-coated endosseous implants,\(^6-9\) vitreous carbon implants,\(^10-12\) and Vitallium implants\(^13\) and screws.\(^14\) Of all of the implants used, osseointegrated titanium implants have been the most, even when used as anchorage for orthodontic tooth movement in humans\(^15,16\) and animals,\(^17\) including heavy orthopedic forces.\(^18,19\) They have also exhibited excellent retention when in use up to 3 years with heavy orthopedic forces.\(^15\) Only implants placed in a one-stage procedure or in the mandibular lingual cortical plate had a high rate of failure.\(^13\)

Literature on implants in children is scarce. A case report of the replacement of a maxillary central incisor in a 7-year-old child with a fibrointegrated blade implant (nonosseointegrated) has been published.\(^20\) When the child's Class II division 1 malocclusion was treated at 12 years of age, the implant moved with the adjacent anterior teeth as the horizontal overlap was reduced from 8 to 3 mm. The implant remained stable but was followed for only 1 year. Because this implant was not osseointegrated, no conclusions can be drawn. However, because osseointegration is now routinely achieved, orthodontic movement ordinarily is not possible. Thus, the osseointegrated implant requires long-term treatment planning.

To clearly predict the response of an osseointegrated implant and plan its use, familiarity with growth and development is essential.

**Maxillary Skeletal Growth**

**Anteroposterior Skeletal Changes.** The midface grows generally in a downward and forward direction relative to the anterior cranial base (Fig 2a). Maxillary growth is intimately associated with growth of the cranial base but shows greater change from 4 years to adulthood than does the cranial base. Maxillary growth occurs as a result of both passive displacement and enlargement. Passive displacement occurs when the maxilla is carried downward and forward by the growth of the bony tissues on which it is based. During early childhood (primary dentition period), passive growth is a major factor in maxillary growth but becomes less important as the anterior sutures (synchondroses) of the cranial base close. After 7 years of age,
approximately one third of maxillary growth is accounted for by passive displacement, the change in maxillary position that is caused by the growth of bones on which the maxilla is based. The other two thirds of maxillary growth occurs as a result of enlargement of the maxilla itself.\textsuperscript{21} Maxillary enlargement is variable between individuals (Fig 2b) and is particularly important to implant behavior.\textsuperscript{22}

**Transverse Skeletal Changes.** As transverse growth of the cranial base occurs, the midface expands in harmony, first at the sagittal sutures that run from the metopic suture of the frontal bone back to the foramen magnum, and later by drift remodeling after the sutures close. It is principally the midpalatal suture of the maxilla that enables the midface to synchronize its lateral growth With that of the cranial base above. Growth in width of the median suture accelerates at puberty and is the most significant factor in transverse growth of the maxilla (Figs 3a and 3b).\textsuperscript{21}

The importance of the median suture in growth has been shown in other studies. Voss and Freng\textsuperscript{23} surgically created submucous midpalatal clefts in growing cats and found a significant decrease in both maxillary and mandibular widths as compared to controls. In his surgical treatment of choanal atresia, Freng\textsuperscript{24} resected the posterior two thirds of the midpalatal suture in 35 children Extirpation of the midpalatal suture during growth resulted in a significant decrease in maxillary width, with 52% of the children having a reverse occlusion. Thus, the midpalatal suture is an important growth site that must be allowed to grow undisturbed.

**Vertical Skeletal Changes.** Vertical growth of the maxilla occurs by sutural lowering (passive displacement) of the maxilla and apposition on the occlusal surfaces of the maxillary alveolus. The orbits do not enlarge in synchrony with the displacement because of compensatory apposition at the floor of the orbits. The nasal floor is lowered by resorption on its nasal surface. Hence, as the alveolus increases in height by apposition on its occlusal aspect, it is simultaneously decreased by resorption at the nasal floor. Approximately one third of the total increase in alveolar height is nullified by this resorption Therefore, measurements made from dental casts reflect less than two thirds of the total amount of vertical alveolar growth (Fig 4a). Resorptive lowering of the nasal floor is strongly differentiated and is usually greater anteriorly than posteriorly. This differential pattern is apparently compensation for the rotational displacement of the maxilla, in which the posterior segments "roll" downward at a greater rate than the anterior segments.\textsuperscript{21} Vertical maxillary growth would dramatically affect an implant's position (Fig 4b).

How can one judge the amount of facial growth occurring or remaining? Although there is a fair correlation between facial growth and growth in stature, the correlation is not a perfect one, with additional variation occurring between the sexes.\textsuperscript{21,25} Unfortunately, the variation in the amount and direction of facial growth is substantial enough that facial growth prediction for more than 1 to 2 years is unreliable. Hence, changes in skeletal body height can only be used as an
approximate guide to estimating facial growth.

**Maxillary Dental Growth**

**Transverse Dental Changes.** A number of longitudinal studies of developing dentitions have demonstrated that the succedaneous teeth tend to erupt labially to their antecedents. Once erupted, many permanent teeth do not maintain a fixed position. While dental width changes vary little with the primary dentition, a significant change in arch width occurs with eruption of the permanent teeth (Fig 5). In general, males have a greater increase in the molar areas than females.

Although the basic trends in growth are the same, there are differences in arch width between the sexes. The average size of dental arches is generally greater in males than in females, with a variation in differences of from 0.5 mm in the lateral incisor area to 3 mm in the molar area. The greater size of the male dental arch is the result of a faster male pubertal growth rate combined with a longer growth period in males than in females. Female growth is nearly complete by 15 years of age whereas males continue to grow until 17 to 19 years of age and beyond. If growth is viewed as a negative factor in the placement of implants, placement in adolescent males must be delayed longer than in adolescent females to allow the substantial completion of growth.

**Anteroposterior Dental Changes.** Changes in arch length and arch circumference also occur during development. Arch circumference (the distance from first molar to first molar around the arch) decreases a small amount during growth. Arch length (distance from the labial surface of the incisors at the midline to a line between the mesial surfaces of the first molars) decreases slightly, starting before the emergence of the permanent first molar as the spaces close between the primary molars. As the maxillary incisors erupt, arch length increases a small amount but then decreases as the primary molars are lost. The early and late decreases in arch length exceed the increase in arch length associated with incisor emergence. A part of this decrease is the result of transverse rotation of the maxilla (Fig 3b). Hence, the net result is that arch length is shorter at 18 years of age than at 4 years of age.

Not only do the teeth move within the arch relative to each other, but there is a change in position of the entire maxillary dentition. When all changes within the dental arch relative to the body of the maxilla are summed, a significant mesial shift of the teeth is seen relative to the body of the maxilla (Fig 6). Hence, while the maxillary dental arch increases in width, it also decreases anteroposteriorly in length and moves anteriorly as a unit.

Although the largest amount of change occurs during the change from the primary to the permanent dentition, arch dimensions continue to change even after the eruption of the permanent dentition. DeKock found that arch depth (measured from a line mesial to the first molars to the contact point of the central incisors)
continued to decrease slightly, until 26 years of age, when his study ended.

When implants are placed in this dynamic environment, they cannot respond as do natural teeth. When the implant and associated dentition are unable to move mesially with changes in growth, disturbances in alignment and occlusion may occur. Hence, care must be taken to avoid placing maxillary implants before eruption of the permanent teeth.

**Vertical Dental Changes.** Vertical growth of the maxilla exceeds growth in any other dimension. To partially compensate for vertical growth, the teeth continually erupt to maintain interocclusal distance. In addition, the shorter primary teeth are replaced by longer permanent teeth. In a longitudinal study, anterior height of the maxilla, as measured from the anterior nasal spine to the height of the alveolar bone between the central incisors, was observed to increase 3 to 4 mm between eruption and exfoliation of the primary incisors. The increase in alveolar height continues with the eruption of the permanent incisors. However, with the remodeling of bone during eruption of the permanent teeth combined with the downward and forward growth of the nasal spine, the actual distance from the anterior nasal spine to the crest of the alveolar process increases very little. Actual dental height increases between the ages of 5 and 15 years of age, with an increase of 5 to 6 mm measured between the height of maxillary and mandibular interdental crestal alveolar bone (with the teeth in occlusion); however, this increase is primarily caused by the larger vertical size of the permanent teeth. As with all the studies noted above, a great deal of variation between individuals occurs in anterior maxillary vertical changes. Correlation coefficients to predict the size at 15 years from the size at 4 years of age are low, with prediction efficiency at 50% or below. Hence, the amount of change when applied to an individual is unpredictable, making implant treatment planning at an early age impossible.

Changes in the height of the palate partially reflect the increase in alveolar height. The results of studies are variable in their findings; however, in general there is an increase in palatal height as seen on dental casts (Fig 7). The dimensional changes seen on dental casts do not reflect the real vertical changes that are occurring. While vertical growth of the alveolar process is outpacing that of the palate by a slightly greater rate, both are undergoing considerable other changes. As a result, an implant would become embedded in bone much more than would be suggested by the differential alveolar and palatal growth seen on dental casts. Dental casts are not an accurate method of assessing vertical alveolar change.

**Maxillary Growth and the Osseointegrated Implant**

Research has clearly shown that the maxilla changes dramatically during growth in all three planes of space. As the maxilla moves downward and forward with growth, the alveolar process undergoes considerable remodeling and conformational changes. The behavior of implants cannot be predicted with any certainty in this environment. No studies were found on the behavior of osseointegrated implants in
the growing human. However, the behavior of Björk's tantalum implants, osseointegrated implants in pigs, and ankylosed primary teeth provide strong suggestions regarding their possible behavior. The burying of implants in areas of bony apposition and the loss of implants in areas of bone undergoing resorption attest to the dynamic nature of the alveolar process.

Ankylosed primary teeth buried over a centimeter in the maxillary alveolus suggest how an osseointegrated object might be submerged. The obvious conclusion is that an osseointegrated object will remain stationary in the bone that surrounds it and will not move or adapt to the growth changes in bone, as does a tooth with a ligament between its root and the bone. Therefore, an osseointegrated implant placed in the posterior alveolus of a young, growing maxilla may become significantly buried in bone, and its apical portion may become exposed as the nasal floor remodels occlusally. Because the anterior portion of the maxilla is resorptive in the areas of the infradental fossa and nasal floor, any implant placed in the anterior alveolar process could be exposed or lost altogether as a result of remodeling.

Prostheses that cross the midpalatal suture and are attached to implants may potentially restrict transverse growth. When the maxilla widens at its midline suture, the central incisors are prevented from separating by the circumferential and interdental gingival fibers as well as the periodontal fibers that tie the teeth together. Implants, ankylosed as they are to bone, would not be subject to this compensatory system. Consequently, implants located on opposite sides of the midpalatal suture of a prepubertal child would be carried apart a significant distance by transverse growth. This separation would create esthetic and functional problems. In contrast, if these implants were joined by a fixed prosthesis, transverse maxillary growth might be inhibited. Evidence has been presented that implants can be used as an excellent skeletal anchor and that the destruction of the midpalatal suture can decrease transverse maxillary growth, hence an implant-supported prosthesis crossing the midpalatal suture would most likely limit transverse growth. The growth limitation would be greater the more posteriorly the implants were placed, because more growth occurs posteriorly than anteriorly. Thus, the attainment of normal maxillary width in the anodontic child would be stymied by a trans-sutural appliance, exaggerating the maxillary deficiency that already existed by virtue of the original edentulous condition. To compound these conditions, the inability of the implant to drift or move in an anteroposterior direction, as do natural teeth, would create an additional developmental distortion.

Recommendations for the Placement of Implants in the Maxilla
Considering the evidence presented, osseointegrated implants in the maxilla of growing patients must be undertaken with a great deal of caution. Implants placed before the cessation of growth are unpredictable in their behavior. Hence, implants placed in the early mixed dentition have a poor prognosis of continued usefulness through puberty. Dental and skeletal changes in the maxilla would probably be too
great and too unpredictable for the prosthodontist to overcome with an adjustable prosthesis. Rigid transpalatal prostheses in the prepubertal or early pubertal patient should be avoided to allow unrestricted transverse maxillary growth. Implants placed during the pubertal period (Figs 8 to 11) have a greater likelihood of success, but still less than the postpubertal or postgrowth implant. As case reports on the use of implants are published in the future, great caution must be taken in generalizing the results. The variation in growth from individual to individual in the amount and direction of change is great. Nearly all growth studies emphasize the difficulty in predicting at an early age the amount and direction of growth of a particular individual. A report of a successful implant in one individual cannot be applied universally. Implants placed in identical locations in two individuals may fail in one and prove successful in the other. A considerable amount of growth may have occurred in the former, while very little growth may have occurred in the patient with the successful implant. Careful attention to maxillary growth and development will enable the dental implant team to provide the best possible care to the dentally disadvantaged young patient.


15. Roberts WE Marshall KJ, Mozsary PG. Rigid endosseous implant utilized as anchorage to protract molars and close an atrophic extraction site. Angle Orthod


**Figs. 1a and 1b:** Examples of two different patients with ankylosed maxillary primary molars. In both patients, restorations are present in the primary molars, attesting to their being in the dental arch at one time. The amount of “submersion” of the primary teeth reflects the generous growth in these individuals. Also note the distortion of adjacent tooth eruption.

**Fig. 2a:** Anteroposterior maxillary growth changes. Normal maxillary growth is downward and forward (arrow) relative to the cranium.

**Fig. 2b:** The direction of maxillary growth can vary considerably as demonstrated by these two patients from Björk’s study.22 The jaw of patient V132 grew more downward than forward, while the jaw of patient V177 grew more forward than downward. (Reprinted
Fig. 3a: Transverse maxillary growth changes. The average increase in maxillary bone width varies from 5 to 8 mm from 4 years of age to adulthood. The increase in molar width was approximately 1 mm less than the maxillary increase.21

Fig. 3b: Transverse maxillary growth changes are not symmetric at the midpalatal suture. The increase in width at the posterior portion of the suture (6.7 mm) is three times the amount of increase at the anterior portion of the palate from 4 years of age to adulthood. This rotation results in the molars growing not only laterally, but also anteriorly, contributing to the decrease in arch length seen during development. Not all of the increase in maxillary width occurs at the midpalatal suture; 2 to 3 mm of growth occurs because of increased size of the maxilla.21
Fig. 4a: Vertical maxillary growth changes. Mean growth changes from 4 years to adult, adapted from Björk's study.21 O = amount of apposition at floor of the orbit. Su = amount of sutural lowering of maxilla, which would carry an implant downward with the growth. C = amount of apposition at the infrrazygomatic crest, carrying the maxilla downward. R = amount of resorptive lowering of the nasal floor. A = the amount of appositional increase in the height of the alveolar process.

Fig. 4b: An implant placed in the growing maxilla at 4 years of age would behave like an ankylosod tooth, as seen in previous studies.4, 21 Increases in alveolar height by apposition and resorptive lowering of the nasal floor have the greatest effect on the implant. The osseointegrated implant would remain stationary in the alveolus, being buried by appositional bone growth on its occlusal surface and being exposed on its apical surface by resorptive lowering of the nasal cavity and sinuses. The closer to adulthood the implant is placed,
the less the adverse effect.

Fig. 5: Transverse dental changes. The arch width in the lateral incisor area increases 6 mm as the permanent incisors erupt, followed by a 1-mm decrease in width from 9 to 14 years of age but with little change after 14 years of age, for a net increase of 5 mm.\textsuperscript{25} Intercanine width increases by 3 mm as the incisors erupt, with an additional 2-mm increase after the eruption of the canine, for a total of 5 mm of increase in width.\textsuperscript{26-28} Width in the premolar area increases 2 to 4 mm before and during eruption of the premolars, followed by a 0.5- to 1-mm decrease and a net result of a 2-mm increase in width between 4 to 20 years of age.\textsuperscript{5,27} Permanent first molar width increases nearly 5 mm in males, but only 3 mm in females from 6 to 18 years of age. Second molars show only a 2-mm increase in males and no increase in width in females.\textsuperscript{28}

Fig. 6: Anteroposterior dental changes. Mesial repositioning of the maxillary dentition occurs during growth with 5 mm of change in the incisor area and nearly 4 mm in the permanent molar area reported in some studies,\textsuperscript{28,29} while another study\textsuperscript{21} of 10- to 21-year-olds showed the molars moving mesially 5 mm and maxillary central incisors moving 2.5 mm. The decreased amount of incisor movement results in a "packing" of the incisors against the
musculature with possible resultant crowding.\textsuperscript{21}

\textbf{Fig. 7:} Vertical alveolar changes. Much of the increase in total dental height increase is caused by the larger size of the permanent teeth as compared to the primary teeth. Most studies report an increase in posterior palatal height of from 4 to 6 mm, with more growth in males than in females.\textsuperscript{28} One study found an increase of only 2.5 mm in height.\textsuperscript{32}
Figs. 8a to 8c: Thirteen-year-old pubertal girl congenitally missing all permanent teeth with the exception of the maxillary and mandibular first molars and the maxillary central incisors. The patient had a functional and esthetic complaint.
Figs. 9a and 9b: Occlusal pretreatment views of patient in Figs 8a to 8c showing multiple missing permanent teeth.
Figs. 10a to 10c: The patient was orthodontically prepared by decreasing the maxillary incisor diastema and intruding the maxillary incisors prior to implant placement.
Figs. 11a and 11b: Patient esthetics, function, and facial height were restored with implants and maxillary and mandibular overdentures. Little additional growth change is expected because the patient is well into puberty.