Lifelong Craniofacial Growth and the Implications for Osseointegrated Implants

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Purpose: *The sequence of observations presented is intended to alert the dental profession to complications that may occur when teeth and implants co-exist and subtle adult craniofacial growth occurs.* ***Materials and Methods:*** *The authors' observations of partially edentulous implant restorations with more than 20 years of follow-up included some observed changes relative to patients' remaining teeth and jaw structures. These changes, which were not easily explained and appeared to be random deviations from expected implant-restorative stability, conformed with research findings of craniofacial growth continuing into adulthood. The authors identified several distinct areas in which such adult craniofacial growth could potentially influence the relationship of implant restorations to the remaining teeth and jaw structure.* ***Results:*** *Potential esthetic, occlusal, and periodontal ramifications of continued adult craniofacial growth were found to include changes in occlusion, opened contact as a result of teeth migration, and changes in anterior esthetic results. The latter may include labialization of the anterior implant restoration and a progressive discrepancy of the cervical gingival margin of the implant restoration relative to the adjacent teeth. Cases are presented showing poor sequellae of treatment due to growth occurring after the assumption was made that a stable jaw dimension had been reached. While continued adult craniofacial growth sufficient to cause clinical problems is not common, it is also presently not predictable.* ***Conclusion:*** *When changes in tooth position relative to implant restorations secondary to long-term adult growth occur, they can cause problems that are difficult or even impossible to correct. Future research will ideally enable identification of patients at risk for developing such problems.*
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Early potential implant applications for single and multiple-tooth replacement included solutions for children with congenitally absent dentition or teeth missing due to oral trauma. Insightful work by Ödman et al led to the understanding that with growth in the baby pig, implants do not move with the growing jaws and face as do teeth and tooth buds.[1] Due to their ankylotic nature, implant-supported restorations thus have not been recommended for patients who are still growing.[2–5] Op Heij et al[6] refined this understanding, reporting on the influence of facial type, eg, short vs long, on the cessation of growth to determine the optimal timing for implant placement for adolescents with absent teeth. This included the recommendation that chronologic age alone cannot be the determinant, with analyses provided to guide the clinician in this assessment.

Craniofacial growth has not been a factor considered in the course of implant treatment planning for adults. Until recently, the effects of craniofacial growth on adult patients treated with dental implants have been absent from the dental literature, in part due to the fact that these changes take variable periods of time to manifest.[7–9] Clinical observation periods were short, or if any craniofacial growth was noted, the effects were overlooked or dismissed as artifacts. However, with decades of posttreatment observation of single-tooth and multiple-tooth implant restorations, it is becoming apparent that for some people there are indeed esthetic, functional, restorative, and periodontal ramifications of subtle continued growth. With implant use prevalent, the purpose of this article is to describe several effects of the potential impact of adult craniofacial growth. Follow-up results are presented, showing poor sequellae of treatment due to growth that occurred after the assumption was made

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that a stable jaw dimension had been reached. A subsequent paper will describe risk assessment with the possibility of prevention, as well as treatment options and complications for patients who have experienced untoward effects of growth.

Growth can be defined as an increase in size or dimension. Growth begins with early fetal cellular development and continues from birth through adolescence. The progressive growth of the skeletal structure notably slows approaching adulthood, while body mass may continue to increase. Hair and nails continue to grow throughout life. Growth can also be defined as continued development. This is a much slower process that occurs throughout adulthood. From a visibly measurable perspective at year-to-year intervals, the increase in size or dimensional growth through infancy and childhood is obvious. Through adulthood, continued development is subtle.

To better understand the relationship between aging and dental implants, one must look at early growth. Due to the rapid growth rate of young individuals, issues resulting from growth and remodeling can be observed and studied in a relatively short time period. Some of the early work on the interaction between growth and osseointegration was done in the animal model. In these experimental series, investigators extracted several teeth from young pigs, replaced them with dental implants, and recorded all dimensional changes. The animals were then sacrificed, and various measurements and histologic studies were performed. Ödman and co-workers showed that in a growing pig the new teeth erupted more coronally and buccally, relative to the implants, as the jaws grew.[1] Thilander et al further described this process, showing that implants stay in the same three-dimensional spatial coordinates as the body continues to develop around them.[10] Sennerby et al demonstrated histologically that the presence of implants in growing pigs blocked further growth of the alveolar process.[11] The implants also had the effect of displacing tooth bud eruption in adjacent sites and causing deformation of the tooth bud structures that grew in contact with the implants.

In several case series, it has been demonstrated that the human model behaves similarly.[12] Thilander et al followed 15 patients with dental implants and a mean age of 15 years, 4 months for a period of 3 years. They concluded that infra-occlusion of the implant restorations was noticed in patients who were still growing. Therefore the patients' dental maturation vs chronologic age should be considered.[12] When the same group of patients was followed for an additional 5 years, infra-occlusion of the restorations continued to increase despite the fact that the patients had zero skeletal growth. This phenomenon was attributed to lack of incisal stability.[13]

In 2004, Bernard et al compared the vertical changes of teeth adjacent to single-tooth implants in young and mature adults.[14] They followed 28 patients—14 young adults and 14 mature adults—for a mean period of 4.2 years (1 year 8 months to 9 years 1 month). Their findings demonstrated that the infra-occlusion of implant restorations in the anterior maxilla is not a phenomenon strictly reserved for the patients who might have some "residual growth" left. In actuality, similar changes occur in the young and mature patient alike.

Independent of dental implants, stability of the occlusion and craniofacial changes in the adult patient are important aspects of orthodontics. Bishara and coworkers studied the changes in the dental arches and dentition in adults between the ages of 25 and 45 years.[15] Their findings indicated increased vertical overlap, especially in females, as well as a decrease in arch-length measurements indicating crowding or mesial drift of teeth with aging.

Forsberg et al in a longitudinal study examined the vertical craniofacial and dentoalveolar changes in 30 subjects (15 male, 15 female) throughout 20 years of adulthood (between the ages of 25 and 45).[16] They demonstrated that anterior face height was increased by 1.6 mm on average during the study period. The most significant amount of increase, 80%, was in the lower dentoalveolar region. Analysis of angular measurements also demonstrated posterior rotation of the mandible associated with an uprighting of maxillary incisors. A longitudinal study by Iseri and Solow demonstrated a significant amount of eruption of the maxillary incisors and first molars in females between the ages of 9 and 25.[17] Although the most significant amount of eruption occurred in the teen years, the eruption continued well into adulthood. Sarnas and Solow measured the vertical and angular changes in a longitudinal study of 151 Swedish dental students between the ages of 21 and 26 over a 5-year period.[19] Their findings were strikingly similar to those of Forsberg et al.[18] They found a 1.5 mm increase in facial height and an increase in the amount of vertical overlap, indicating uprighting of the maxillary incisors.

In a cross-sectional study, Tallgren and Solow measured differences in dentoalveolar heights in three distinct age groups.[19] Their findings corroborated the results of previous longitudinal studies. Maxillary and mandibular anterior dentoalveolar heights were significantly greater in the middle and older groups when compared to the younger sample. On average, the maxillary ridge height increased more than that of the mandible with advancing age. Also, the angle of the mandible increased with time, indicating an uprighting of the maxillary incisors.

Bondevik studied changes in occlusion in 144 Norwegian subjects over a 10-year period (between the ages of 23 and 34 years).[20] His findings indicated an average increase in the intermolar distance, a decrease in the intercanine distance, and changes in the horizontal and vertical overlap. In two separate cross-sectional radiographic studies, Ainamo and co-workers demonstrated that alveolar growth continues from age 23 to 65 years,[21,22] with the width of the attached gingivae increasing significantly between the ages of 23 to 45years. Further increases continue to age 65 years at a slower rate. The dimension of the basal bone in the maxilla also increases but that in the mandible does not.

In a longitudinal cephalometric study, West and McNamara measured dental and craniofacial changes occurring from adolescence to an average age of 48.[23] Their findings support the observations that the maxillary teeth continue to erupt over time into adulthood. In males the incisors erupt a small amount while maintaining their facial/palatal position, but in females the incisors erupt, and the crowns tip toward the palate. Males showed an anterior rotation of the mandible, while in females posterior rotation of the mandible is more common. Maxillary molars in both genders erupted and moved toward the anterior during adulthood.

As an overall review of adult growth relative to orthodontics, these findings demonstrate that subtle adult growth of dentoalveolar and facial structures is routine and a potential consideration in adult orthodontic planning and achievement of stable long-term results after implant treatment.

MATERIALS AND METHODS

The authors have coupled this foundational understanding of adult craniofacial growth potential with long-term observation of implant restorations in partially edentulous patients, spanning from short-term to more than 20 years of follow-up for many cases. As these longer observation periods have accumulated, occasional spatial discrepancies between implant restorations and the adjacent and/or opposing dentition have become evident. The location of an implant provides a fixed marker of position around which any growth occurs. By definition, any time a tooth or implant restoration requires modification or adjustment, the occurrence has clinical significance. The degree of significance is generally minor and often not observed by the patient. However, on rare, unpredictable occasions, the ensuing discrepancies are dramatic and not easily resolved.

The authors identified several ways in which adult craniofacial growth may influence the relationship of implant restorations to the remaining teeth and jaw structure.

RESULTS

The following ways in which adult craniofacial growth may influence the relationship of implant restorations to the remaining teeth and jaw structure were identified.

Changes in Occlusion

Changes in occlusion can be due to continued growth in the arch containing the implants as well as in the opposing arch. In both situations, the position of the implants and associated restoration are static, whereas the teeth are subject to movement in both facial and occlusal directions. These potential changes are not gender-specific. For situations such as posterior free-end implant restorations supporting significant occlusal loads, these movements can negate the effectiveness of the implant restoration over time, placing unfavorable stresses on the remaining dentition. Figure 1 illustrates this phenomenon.

Migration of Teeth with Subsequent Effect of Opening Contact

When natural teeth are present in the same arch with dental implants, an unforeseen long-term complication observed by many has been the opening of contacts between the implant restoration and, typically, the natural tooth anterior to the implant restoration. Koori et al found this in up to 40% of restorations, with loss of the natural tooth contact mesial to the implant restoration significantly affected by age, condition of the opposing dentition, vitality of the adjacent tooth, and splinting of the anterior natural teeth.[24] Loss of the contact was not gender-specific but was more common in the mandible, and the rate increased over time. Figure 2 illustrates this.

Changes to Anterior Esthetic Results

Besides functional changes and consequences in occlusion and opening of contacts, the authors have observed that subtle growth over time also can change esthetic results once thought to be stable. Discrepancies have become manifest in three visible areas relative to adjacent teeth: the incisal edge length, the gingival margin height, and the facial contour alignment. Extrusion and lingual tipping of the anterior maxilla and teeth can simultaneously cause all three discrepancies. Thinning of labial soft tissue over the implant or abutment can be a further consequence accompanying this subtle growth process. Figures 3 and 4 illustrate this problem.

A discrepancy in facial alignment making the anterior implant restoration relatively more labial may or may not be able to be suitability modified or revised, depending not only on the severity of the occurrence but also on such factors as implant axial alignment, available soft-tissue depth, and labial/palatal positioning of

Figs 1a to 1d Male patient with maxillary reconstruction supported by posterior implants and anterior combination of teeth and implants. *(a)* Maxillary arch before placement of tooth and implant restorations. *(b)* Posttreatment radiographs. Note that tooth and implant restorations were kept separate. *(c and d)* Anterior rotation of the mandible accompanied by downward maxillary growth in areas of teeth but not implants can cause overload on the natural teeth with subsequent tooth fracture. Retrospectively, restoration of anterior teeth can be expected to compound the problem due to weakening by removal of additional tooth structure.

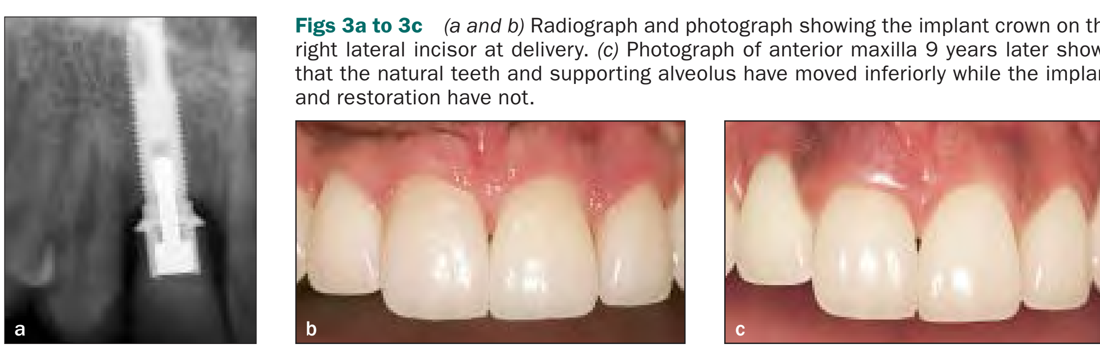
the implant in the ridge. A progressive discrepancy between the implant restoration's cervical gingival margin and that of the adjacent natural teeth may be an esthetic complication with no easy resolution.

DISCUSSION

Restorations supported by endosseous dental implants with adjacent and/or opposing teeth have enjoyed high published success rates with results duplicated by thousands of clinicians. Over the years, the criteria for defining success have evolved. The criteria for success with blade implants merely considered function and the continued presence of the dental implant(s) in the oral cavity in the absence of pain and infection. Later the definition of success was fine-tuned to include parameters such as bone levels, bone loss, microscopic adaptation of bone to the implant, and soft-tissue stability, necessary for an esthetic outcome.[25–28] Early definitions of success based on osseointegration assumed that if osseointegration was maintained steadily then the system was static. This is still the case for fully implant-supported reconstructions within an edentulous arch. However, in a mixed reconstruction with both teeth and implants, the system may not be as static as once thought.

It now appears that a further evolution of the criteria for long-term success is required. Osseointegration may occur, and both the implant and restoration may meet the criteria for short-term success, but the influence of long-term craniofacial growth may still compromise the overall long-term results. The potential for such functional or esthetic compromise does not derive from the implant performance per se, but from the inability of the bone and soft tissue associated with an implant restoration to keep pace with continued subtle growth of the adjacent jaw structure and natural teeth. The stable bone and gingival levels around the implants and restoration may indeed meet all current success criteria and still be bracketed or opposed by relatively unstable movement and/or incisally advancing gingival margins of natural teeth. This presents a dilemma; the same implants utilized to stabilize the resorptive process that would occur while wearing a removable appliance also function as a barrier to further local alveolar growth.

Figs 2a to 2d *(a and b)* Cast of mandibular right quadrant reproducing the opposing dentition for maxillary restorations shows closed contact between the right mandibular implant-supported premolar restoration and canine natural tooth. *(c and d)* Intraoral photograph 6 years later shows obvious open contact anterior to the implant restoration.

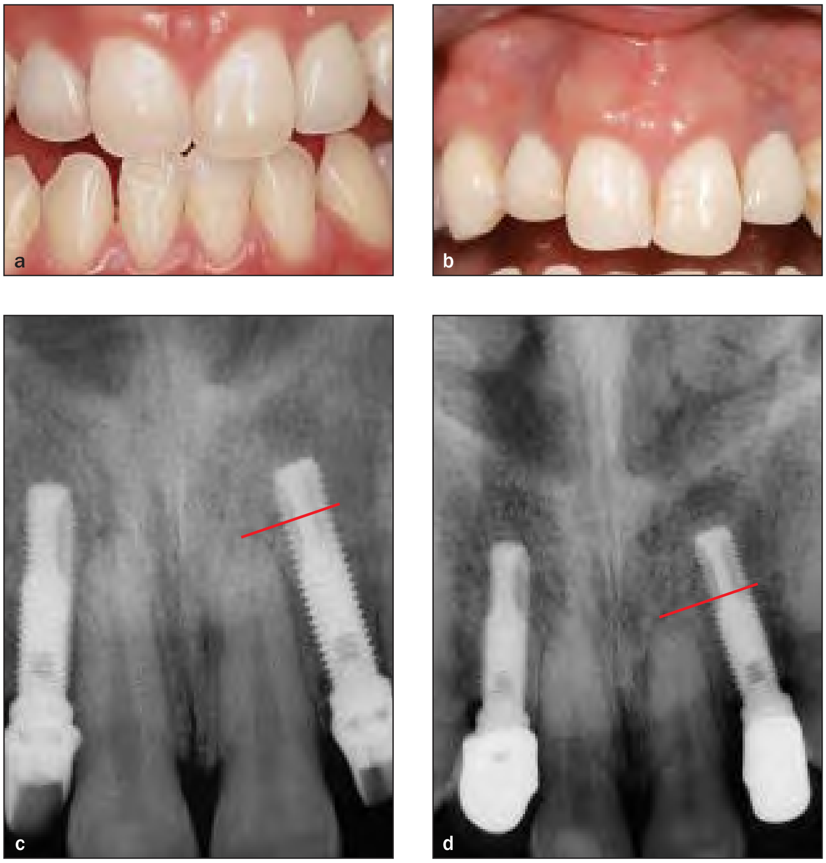


Figs 3a to 3c *(a and b)* Radiograph and photograph showing the implant crown on the right lateral incisor at delivery. *(c)* Photograph of anterior maxilla 9 years later shows that the natural teeth and supporting alveolus have moved inferiorly while the implant and restoration have not.

CONCLUSIONS

The authors have observed that in certain adult patients for whom growth was assumed to have stopped, ongoing subtle growth can have an unexpected impact on both functional and esthetic outcomes of implant restorations. This impact extends beyond current definitions of success.

Some of the effects of this growth in adults may require modification or replacement of implant restorations. These include opening of contacts adjacent to implant restorations, especially anterior to the restoration; changes in occlusion relative to continued growth and subsequent tooth position in both the same and the opposing jaw; and discrepancies of incisal edge length between implant restorations and adjacent natural teeth.



Figs 4a to 4d *(a)* 1993 and *(b)* 2008 photographs show change in both incisal edge and dentogingival junction of central incisor teeth relative to implant restorations of lateral incisors. *(c)* 1993 and *(d)* 2010 radiographs showing 17-year follow-up of 3.0 × 13–mm implants. The implant in the left lateral incisor position shows consistently sharp implant threads in both films indicating perpendicularity of x-ray beam for comparison. Root apices of incisors roughly aligned with middle of apical cut-out area of implants are shown in *(c)*, whereas *(d)* shows tooth apices toward lower border of cut-out areas, indicating downward movement of teeth as implants maintain stable position relative to the nasal floor.

Any time implant restorations co-exist with remaining teeth, whether those teeth are within the same arch or the opposing one, the teeth and soft tissue can change position relative to the static implant restoration. Possible future effects of growth should be addressed as part of the patient's informed decision-making process. Definitions of success should also be expanded to account for the effects of growth relative to the implant restorations over the long term.

Ideally, future research will provide predictive diagnostic factors to identify patients at risk for such developments. Another future consideration is the potential for growth of edentulous sites without implants in place. Future classification schemes for potential growth relative to dental implants and edentulous spaces may facilitate both investigational reporting and clinical decision-making.

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