Facial Development, Continuous Tooth Eruption, and Mesial Drift as Compromising Factors for Implant Placement

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The replacement of teeth lost by children because of trauma can be an important indication for early implant therapy. Osseointegrated dental implants, like ankylosed teeth, alter position as growth-related changes occur within the jawbones (displacement, remodeling, mesial drift). Facial growth of the child and even of the adolescent, as well as the continuous eruption of the adjacent anterior teeth, create significant risk of a less favorable esthetic and/or functional outcome. For patients with a normal facial profile, the placement of an implant should be postponed until growth is complete. For patients with a short or long face type, further growth, especially the continuous eruption of adjacent teeth, creates a serious risk even after the age of 20 years, as illustrated by some recent clinical studies. This review aims to explain these phenomena and provides some recommendations for implant placement.
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A recent systematic review underlined the success and long-term predictability of dental implants in partially edentulous patients.[1] Young children who do not have permanent teeth in the anterior maxilla because of trauma or aplasia pose a specific therapeutic problem. Osseointegrated implants behave like ankylosed teeth; artificial abutments pose a problem during continuous tooth eruption (defined as further eruption of teeth after the establishment of occlusal contact and drift of the natural dentition). The restored implant's lack of eruptive potential causes a discrepancy in the occlusal plane in young individuals (eg, relative infraocclusion of the implant), with esthetic complications in the long term. For the growing child, early implant placement poses even greater risk, because it may disturb normal development of the jawbones.

Studies in young pigs have confirmed that osseointegrating implants do not follow changes in the alveolar processes caused by the continuous eruption of adjacent teeth.[2–4] At some distance from the implants the tissues developed normally; however, in their immediate vicinity, further development was slowed. This resulted in a loss of occlusal contact for the implant and angular bony defects around the adjacent teeth.

Similar phenomena have been observed with ankylosed teeth. Malmgren and Malmgren followed 42 children with reimplanted, ankylosed incisors for up to 10 years to estimate the degree of infraposition.[5] In children less than 10 years old, an infraocclusion of more than 3 mm (± 1.5 mm) could be observed; for those between 10 and 12 years old, infraocclusion of the ankylosed teeth reached about 2.5 mm; for those 12 to 16 years old, infraocclusion reached about 1.5 mm.[5] A clear relationship between

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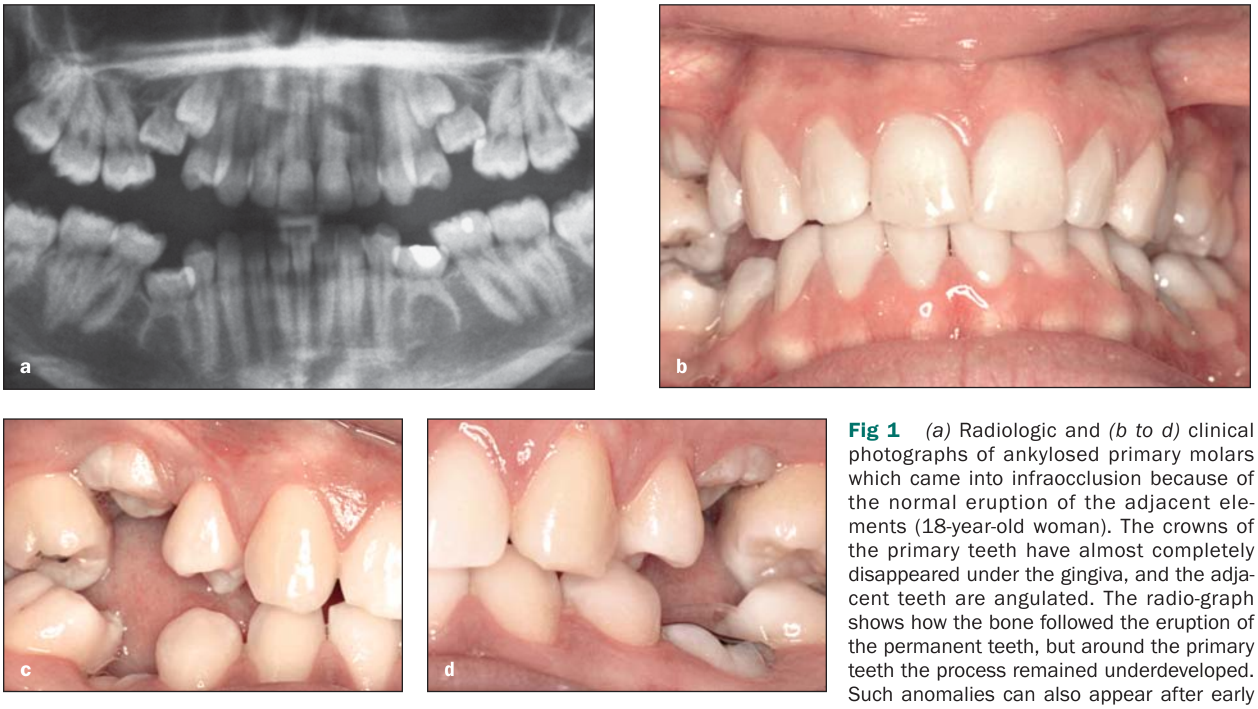


Fig 1 *(a)* Radiologic and *(b to d)* clinical photographs of ankylosed primary molars which came into infraocclusion because of the normal eruption of the adjacent elements (18-year-old woman). The crowns of the primary teeth have almost completely disappeared under the gingiva, and the adjacent teeth are angulated. The radio-graph shows how the bone followed the eruption of the permanent teeth, but around the primary teeth the process remained underdeveloped. Such anomalies can also appear after early implant placement.

the degree of infraocclusion and growth intensity (before, during, and after growth spurt) was not obvious; intersubject variation was very large.[5] Kawanami and coworkers followed 52 patients (age range, 6 to 48 years at time of injury) with reimplanted and subsequently ankylosed permanent incisors for a period of 1 to 21 years (mean, 4.2 years).[6] In this study, marked infraposition was observed if the tooth was traumatized before the age of 16 years in boys and before the age of 14 years in girls (0.19 to 0.62 mm/y for boys, 0.08 to 1.00 mm/y for girls). Surprisingly, enough infraposition for ankylosis was also observed after puberty. In patients aged 20 to 30 years old in whom tooth reimplantation had been performed, a yearly mean infraposition rate of 0.07 mm/y (range, 0.0 to 0.21 mm/y for men and 0.0 to 0.12 mm/y for women) was recorded. Bjerklin and Bennett reported on the long-term survival of primary mandibular second molars (n = 59) in subjects (n = 41) with agenesis of the premolars (Fig 1).[7] The mean age at the last examination was 20.5 years. This study demonstrated an atypical pattern for the development of infraocclusion, with a mean value of 0.47 ± 1.13 mm at 11 to 12 years, which increased to 1.43 ± 1.1 mm at 17 to 18 years (not all teeth were ankylosed). At 20 years, 55% of the teeth showed an infraocclusion of 0.5 to 4.5 mm. This phenomenon was explained by the continuous eruption of the normally functioning teeth.

Ongoing growth of the teeth in an occlusal direction after puberty has also been observed by Ainamo and coworkers.[8] This group followed the increase in gingival width over time. In a cross-sectional study comparing volunteers at ages 23, 43, and 65 years, a mean increase in width of 4 mm in the anterior maxilla was measured.

Several longitudinal studies on young adults who received implant-supported restorations to replace missing teeth have found disharmony between teeth and implants (Fig 2).

Thilander and coworkers reported on a group of 15 adolescents (8 boys, 7 girls) with 27 implants (19 in the maxilla and 8 in the mandible).[9–11] The implants were placed when the subjects were between 13 to 19 years old. After 3 years of loading, a clear correlation was established between body length growth and the extent of implant infraocclusion. Although no further length growth could be measured from the fourth year on, and no further craniofacial alterations arose, the relative infraocclusion of the implants increased. This ongoing infraocclusion reached a mean of 0.5 (± 0.6 mm) mm over the last 7 years of the study (the postgrowth phase). For the entire 10-year study period, mean infraocclusion was 1.0 mm (range, 0.1 to 2.2 mm). Buccal/lingual disharmony was observed frequently. The authors also hypothesized that this infraocclusion of the implants caused marginal bone loss around the adjacent teeth.[9]

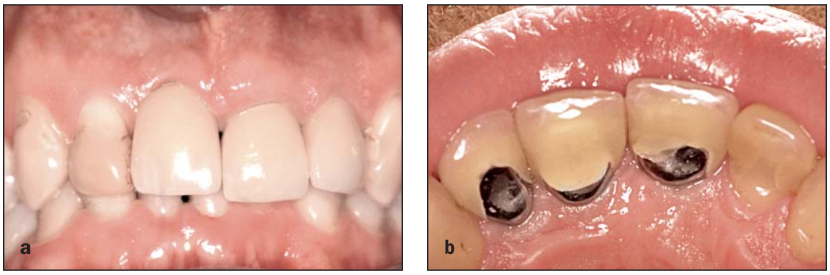


Fig 2 Clinical record of a patient (30 years old) where a solitary crown on an implant was placed 5 years ago (maxillary right central incisor). Infraocclusion and relative palatal positioning of the implant was related to continuous eruption of adjacent teeth.

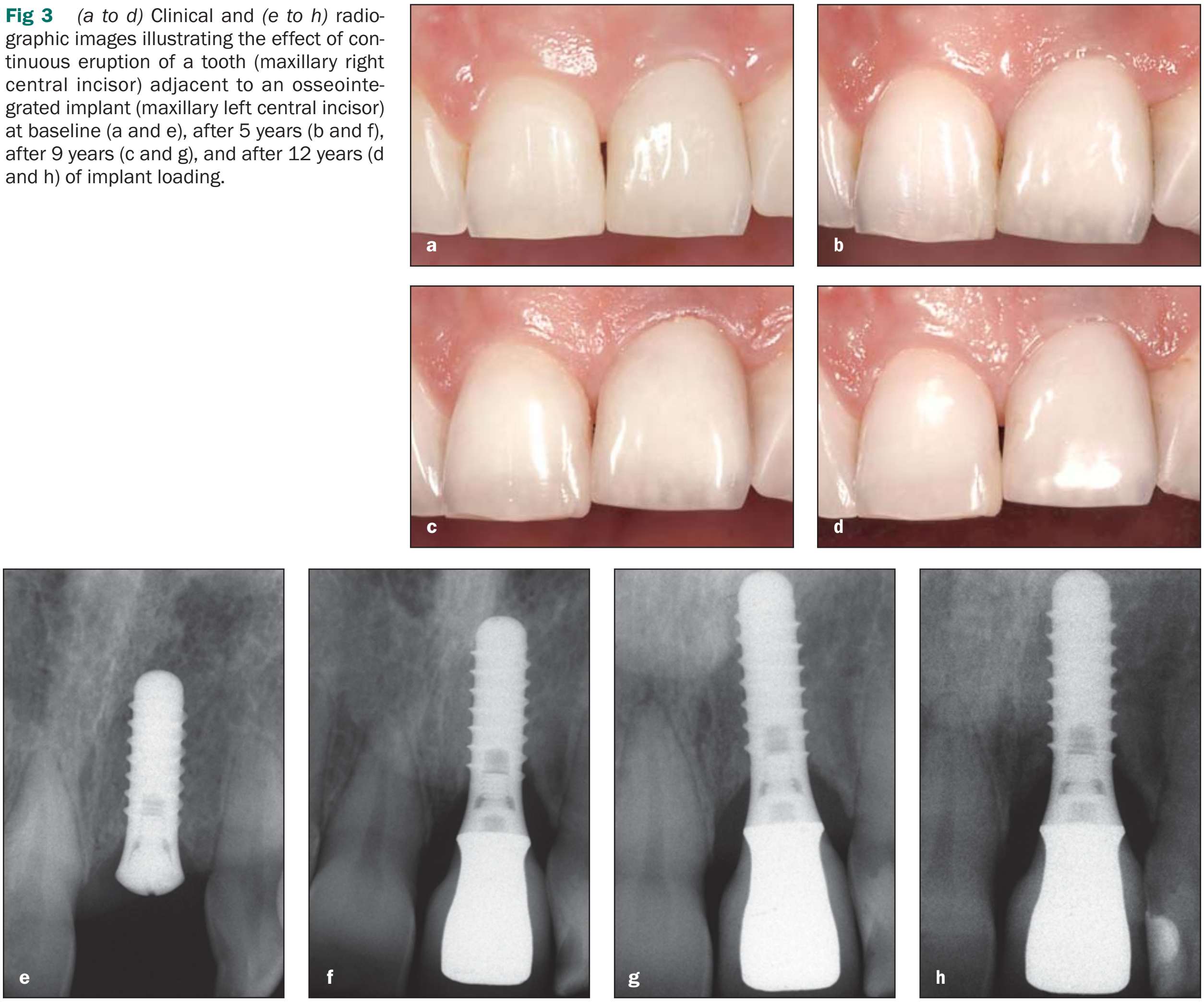


Fig 3 *(a to d)* Clinical and *(e to h)* radiographic images illustrating the effect of continuous eruption of a tooth (maxillary right central incisor) adjacent to an osseointegrated implant (maxillary left central incisor) at baseline (a and e), after 5 years (b and f), after 9 years (c and g), and after 12 years (d and h) of implant loading.

Bernard and coworkers followed the vertical changes of maxillary incisors adjacent to implants in a group of adolescents (mean age, 18.4 years; range, 15 to 20 years) and adults (mean age, 43.6 years; range, 40 to 55 years) for a mean period of 4 years.[12] All patients in the "young adult" group showed infraocclusion of the implant-supported crowns, with a vertical step between 0.1 and 1.65 mm. For the "mature adult" group, similar changes were observed, with infraocclusion ranging from 0.12 to 1.86 mm (Fig 3).

These literature reports on both ankylosed teeth and osseointegrated implants should draw the periodontologist or oral surgeon's attention during the planning phase to the changes in vertical and horizontal dimension between and within the jawbones to understand and prevent disharmony between implants and teeth.

The placement of an implant should in principle be postponed until after puberty or after the so-called growth spurt of the child. However, since provisional prosthetic solutions such as removable partial dentures or acid-etched partial dentures are not always satisfactory, the parents or the children often insist on a surgical solution, even before bodily growth is finalized. Patients and families should be informed that the placement of implants before the completion of growth could jeopardize the long-term esthetic outcome, since the remaining changes in the growing alveolar process will not be followed by the implant. Moreover, continuous tooth eruption continues to take place after puberty and can lead to occlusal disharmony in some patients (Fig 3). Another interfering factor is alveolar bone resorption. Botticelli and coworkers found, via a re-entry procedure, that within 4 months of single tooth extraction, the buccolingual width of the alveolar crest can show resorption up to 3 mm (in other words a horizontal resorption of more than 40% of the entire width).[13] Similar observations were made by Schropp and coworkers, who registered a reduction of 50% of the ridge width after 12 months, of which two thirds occurred during the first 3 months of healing.[14] This horizontal resorption was accompanied by only minor changes in the vertical dimension. In some instances, delaying the placement of an endosseous implant may after a while render this treatment option impossible because of lack of sufficient bone volume related to its resorption. It remains questionable, however, whether such resorption can be prevented by immediate implant placement in the extraction socket. The resorption of alveolar bone occurs much more slowly in a space created orthodontically (at a rate of about 1% over 4 years) than in an extraction socket (about 34% over 5 years).[15]

The present review proposes guidelines for timely oral implant placement, taking into account the growth of the jawbones via displacement and remodeling. The displacement of the entire jaw bony complex via sutural growth will of course be followed by oral implants, so such growth does not create a major risk unless the prosthetic rehabilitation crosses the midline suture. Conversely, bone remodeling—the reshaping of bone by selective resorption in some areas of its surface and apposition/deposition in other areas—is not followed by implants and thus can jeopardize the long-term occlusal and esthetic outcome. Finally, continuous tooth eruption is not limited, as is often assumed, to puberty, but can continue even after the age of 18 years, especially in the case of a deviant facial type (long or short).

GROWTH OF THE JAWBONES

The growth of jawbones will be discussed according to direction of manifestation: transverse, sagittal, and vertical. Both the mandible and the maxilla follow a distinct chronology: growth is first completed in the transversal plane, then in the sagittal plane, and finally, only at a later stage, in the coronal plane. The growth of the mandible is closely associated with growth in stature, whereas growth of the maxilla is more associated with growth of the cranial structures. These associations have been made on the basis of longitudinal studies in which small experimental implants were placed in the jawbones and used as fixed reference points.[16,17] These studies were designed before the era of the use of oral osseointegrated implants.

Maxillary Growth

After the age of 7 years, the majority of the changes that occur in the maxilla are the result of remodeling.

Transverse Growth. The width of the anterior portion of the arch is completed prior to the adolescent growth spurt, but for the posterior portion increase in width is closely related to increasing jaw length. The width in the anterior portion increases mainly by growth at the midpalatal suture (*sutura palatina mediana*). Changes in the intercanine distance are minimal after the age of 10 (mean increase, 0.9 mm).[16] The increase of the intermolar distance is smaller than the sutural widening in this area (the latter is 3 times more in the posterior than in the anterior), which suggests an adaptation of the dental arch. In the more posterior areas, changes can occur until complete tooth eruption.

Implications. The placement of an implant in a central incisal position in a young patient (eg, 7 years) can lead to a diastema with the adjacent natural central incisor and a subsequent shifting of the midline to the implant side. Replacement of both central incisors prior to the end of transverse anterior growth could result in a diastema in between them. Case reports of implants placed in the anterior maxilla in patients as young as 9 years of age do not include mention of problems with growth in the transversal direction.[18,19] The midpalatal suture usually closes after puberty, around the age of 15 (but with large variation from 15 to 27 years). Thus, placement of a midpalatal implant as anchorage for orthodontic appliances can be planned for patients who are at least 15 years old.

Sagittal Growth. The maxilla increases in length because of both sutural growth and bone apposition at the maxillary tuberosity. The anterior part of the maxilla is relatively stable. However, when the maxilla follows the mandibular growth, up to 25% of this sutural growth is lost via jawbone resorption at the anterior site. The sagittal growth of the maxilla is closely associated with the growth in skeletal body height but stops earlier.

> *Implications.* Resorption in the anterior part of the maxilla could result in the gradual loss of bone on the labial side of an implant. In a case report that described the treatment of a 13-year-old boy and an 11.5-year-old girl, problems with labial fenestrations were noted as early as 11 months after placement in the girl and 19 months in the boy.[20] The problems increased in severity with growth.

Vertical Growth. Growth of the maxilla in a vertical direction occurs via displacement (sutural growth), remodeling, and continued eruption. The maxilla is displaced downward, away from the cranium, by growth in the orbits and by increases in the size of the nasal cavity and maxillary sinuses. This is the consequence of resorption of the nasal bone wall surfaces and of bone apposition on the palatal and alveolar surfaces. Vertical growth of the maxilla continues beyond the age at which transverse and sagittal growth cease. Usually adult levels of vertical growth are reached at 17 or 18 years for girls and somewhat later for boys.

> *Implications.* To prevent complications in the vertical plane (especially related to remodeling), it may be advisable to delay implant placement until the age of 18 years.

Mandibular Growth

The timing of mandibular growth is similar but not identical to that of the maxilla. The mandible grows more in a sagittal plane than the maxilla during adolescence. This "differential jaw growth" converts the more convex child profile to the straighter adult profile. In girls, mandibular growth is nearly completed 2 to 3 years after menarche (usually at age 14 or 15), while for boys, growth can continue into the early 20s but usually reaches adult levels by age 18.

Transverse Growth. In the anterior region growth ceases very early. Almost no changes occur after eruption of the permanent canines because of early closure of the mandibular symphysis (in the first year of life) and the limited remodeling afterwards. In the premolar and molar regions, growth extends over a longer period through bone remodeling (bone apposition at the buccal site and resorption at the lingual site). Eruption of the permanent molars is accompanied by some transversal changes in the jaw dimensions, although these are restricted to a few millimeters.

> *Implications.* The width of the anterior portion of the arch is completed prior to the adolescent growth spurt. Since the posterior portion increases in width via remodeling (relative lateral movement), a molar or premolar implant placed in a young patient could be shifted into a lingual position.

Sagittal Growth. The sagittal growth of this jaw results from both endochondral growth at the condyle and remodeling of the mandibular ramus. The growth at the condyle increases the length of the mandible but has no direct impact on the mandibular corpus shape and thus on eventual implants. The corpus of the mandible itself lengthens in an anteroposterior direction, mainly through resorption at the ventral side of the ramus and bone apposition at the ramus's dorsal surface. The resulting increase of mandibular corpus length accommodates the eruption of the molars.

> *Implications.* The sagittal growth of the mandible has no impact on implant placement in children. The rotation of the mandible in the sagittal plane during growth must be considered.

Vertical Growth. The mandibular height increases by condylar growth and by bone apposition at the dentoalveolar complex (the latter especially during tooth eruption). When sequential cephalometric radiographs are superimposed for different stages of growth, it appears as though the mandible is growing downward and forward from the cranium. However, when small endosseous implants were placed as reference points in the mandible, the condylar process rather appeared to grow upward and backward, with little if any change at the chin.[21] A normal facial type shows only minor rotation of the mandible in a sagittal plane, but the 2 other facial types (short and long) show a remarkable rotation.[22,23] The relative change in position between maxillary and mandibular teeth caused by this rotation is corrected during tooth eruption via the so-called "dentoalveolar compensation mechanism" (defined as a system trying to maintain the normal intra-arch relationship).[24] As such, the rotational growth of the mandible significantly affects the anteroposterior and vertical eruption patterns, which are intimately connected.

Implications. The mandibular rotation in the sagittal plane during facial growth is important for implant placement because the variation in the compensatory amount and direction of incisor eruption could dramatically affect the relationship between an implant and an adjacent tooth, especially in the short and long face types. An implant will not make these compensatory position changes either vertically or labiolingually. An orthodontic colleague can help one define the facial type (long, normal, or short) involved.

MESIAL DRIFT OF TEETH IN THE MAXILLA AND MANDIBLE

Spontaneous mesial drift of teeth is well documented.[25] The lateral segment in the maxilla and mandible (canine to first molar) moves on average 5 mm mesially between 10 to 21 years of age. The incisors move only 2.5 mm buccally, causing a net loss in space, which could lead to crowding.

An implant does not take part in this "spontaneous mesial drift of teeth." Thus, an implant in the lateral region could stop the mesial drift, resulting in an asymmetric arch, while an implant in the anterior region cannot follow the teeth and will become relatively more lingually oriented with time.

Depending on the facial growth type and because of the further eruption of the teeth, vertical changes can still occur after puberty, though at a slower pace than during the active growth phase.

CONTINUOUS ERUPTION OF TEETH IN GENERAL

The continuous eruption of teeth, ie, after occlusal contact has been established, was evaluated on consecutive cephalometric radiographs properly superimposed via small endosseous implants as reference markers.[17] The average eruption reached 1.2 to 1.5 mm/y during the active growth phase, and was reduced to an annual 0.1 to 0.2 mm afterwards, even after the age of 18 years. Eruption between 9 and 25 years of the maxillary central incisors thus reached 6.0 mm, while a movement of 2.5 mm buccally could be observed. For the maxillary first molars, these values reached 8.0 and 3.0 mm, respectively. If one focuses on the timespan between 17 and 25 years of age, this movement is reduced to an average 1 and 0.5 mm for the incisors and 1.5 and 0.8 mm for the maxillary molars, respectively. Large interindividual variations were recorded, especially in short and long faces.

Ranly calculated that an implant placed in the anterior part of the maxilla at the age of 7 years would be located 10 mm more apically than the adjacent teeth 9 years later.[26] This assumption was confirmed by clinical observations after the placement of solitary implants at the average age of 12 years, which should a "relative" infraocclusion of 5 to 7 mm 4 years later, sometimes combined with a labial fenestration.[18,19,27] Similar changes were measured in the molar region.[28]

Changes in the dentoalveolar complex during adulthood were studied by Tallgren and Solow in a cross-sectional study calculating the average dentoalveolar height in women 20 to 29, 30 to 49, and 50 to 81 years of age.[29] From this study the following observations were made:

- The average dentoalveolar height in the 2 latter groups was similar.
- The average dentoalveolar height in the 2 latter groups was significantly higher both in maxilla and mandible (1.5 to 2 mm) than in the 20-to-29 group.
- Lower facial height in women increased 3 to 3.5 mm with age. This was associated with an "opening" of the mandible (ie, an increase in mandibular inclination).

A longitudinal cephalometric study confirmed this increase in anterior face height. Patients between 25 and 45 years showed a 1.6 mm increase wherefrom about 1 mm was related to continuous eruption of the maxillary incisors.[30] Aging women tend to get a longer face, with more probability for infraocclusion of an implant in the anterior, while men tend to grow more in the posterior regions.[31,32]

In 2006, Fudalej and coworkers evaluated the timing of growth cessation in a sample of 300 postorthodontic patients (unpublished data). The sample had a male:female ratio of about 50:50. The dental records of these patients were reviewed for an extended period of time following orthodontic appliance removal. The sample was stratified, so completion of orthodontic treatment occurred when the patients were in their mid-teens to mid-twenties. Then, for each patient, lateral cephalometric radiographs were evaluated and superimposed at least 10 years after the completion of orthodontic treatment. By evaluating this stratified cross-sectional sample using longitudinal statistics, the authors were able to determine the point at which vertical growth ceased on average in males and females. Vertical growth was assessed as the distance from nasion to menton. When this distance did not increase, it was assumed that vertical skeletal growth had ceased and therefore that space for tooth eruption would not be available. In females, the age at which growth of the facial skeleton ceases vertical development is shortly after 17 years of age on average. The vertical change from nasion to menton ceases at slightly more than 20 years of age on average in males. However, these are averages, and large deviations were observed. The clinician must use superimposed cephalometric radiographs to accurately assess the cessation of vertical growth for each specific patient.

Implications. Placing implants in a growing child will mostly lead to occlusal disharmony of several millimeters after a few years. Thus, this should be limited to specific indications such as multiple anodontias, often associated with congenital growth deviations. Then provisional prosthetic superstructures should be used, since multiple replacements must be considered. Even in adults the ongoing tooth eruption can lead to differential occlusal heights, but more limited, which often can be dealt with by prosthetic adaptations.

DEVIATING FACIAL TYPES: SHORT AND LONG FACE SYNDROMES

The population can be divided into normal, short, or long facial types. These can best be observed by looking at the lateral profile of a person. Each of these facial types has its own "program" for development of the jawbones. Even when adulthood is reached, these distinct facial types keep developing in different ways. The short facial type is also described as a horizontal grower, a forward rotator (refering to rotation of the mandible), and/or a skeletal deep bite. Synonyms for the long type are: vertical grower, backward rotator, and/or skeletal open bite. The facial types are characterized by a cluster of morphologic features and can therefore be referred to as short face syndrome (SFS) and long face syndrome (LFS).

Essential Characteristics of SFS and LFS

The main differences between long and short facial types are schematically visualized in Fig 4.[22,23] The facial proportion index (FPI) helps to differentiate between a normal face and the SFS and LFS cases. This index is calculated by subtracting AUFH from ALFH, where AUFH is the distance from anterior nasal spine (ANS) to nasion (N) and ALFH is the distance from the same spine to the menton (Me). Both values are expressed as a percentage of the anterior total facial height (ATFH), distance from N to Me.

This value is around 10 for a normal face, with an ALFH of 55% and an AUFH of 45%. SFS is characterized by a small FPI (< 10), whereas this value exceeds 10 for patients with LFS. Other important differences can be obtained on a cephalometric radiograph. SFS is characterized by a smaller angle between the sella-nasion line (SN line) and the mandibular plane (this angle is 32 degrees for a normal face). The SN line represents the anterior cranial base (this is a line through the center of the sella tursica [s] and nasion), while the mandibular plane (MP) is the line through the menton and gonion. For LFS, the angle is > 32 degrees). The gonial angle (formed by the intersection of a line tangent to the posterior border of the ramus and the mandibular plane) is relatively small for patients with SFS (about 110 degrees) compared to the normal situation (125 degrees), and certainly compared to patients with LFS, where values of about 129 degrees are found.

Furthermore, an SFS patient shows an enlarged nasiolabial angle, a well-developed chin point, a concave profile with retro-position of the lips, thin curly lips, a deep plica labiomentalis, and usually a broad nose and "a toothless look" when smiling. An LFS patient is characterized by a heightened lower facial half; a lump on the nose; a less obvious chin point; a chin positioned down- and backward; a convex profile; an enlarged interlabial distance, often with tooth-exposition; a small nose and small nostrils; and finally, a "gingival smile" (Fig 4).

Important Growth Variations in Relation to the Normal Facial Type

The Maxilla. Maxillary growth is more pronounced for those with SFS in the transverse direction (1.5 mm, versus 0.3 mm for the LFS), since the midpalatal fissure closes later. In the case of a narrow maxilla (which occurs often with LFS), the alveolar process grows more in height (21 mm), while in the case of a wide jaw (which occurs often with SFS), there is less increase in height (9.5 mm).[17] The direction of growth of the maxilla will also differ in the 2 facial types (Fig 5). The dentoalveolar complex will compensate and thus follow the mandibular rotation in relation to the cranial base (SN line). This rotation proceeds forward in SFS adolescents and backward in LFS ones.

Implication. Implants placed in the maxillary anterior region will eventually become more palatal compared to the natural dentition, especially in the SFS face type. Indeed, in the maxilla the tooth movement in the horizontal plane is large. With the LFS type, the increased vertical movement of the natural dentition could result in disharmony for oral implants.

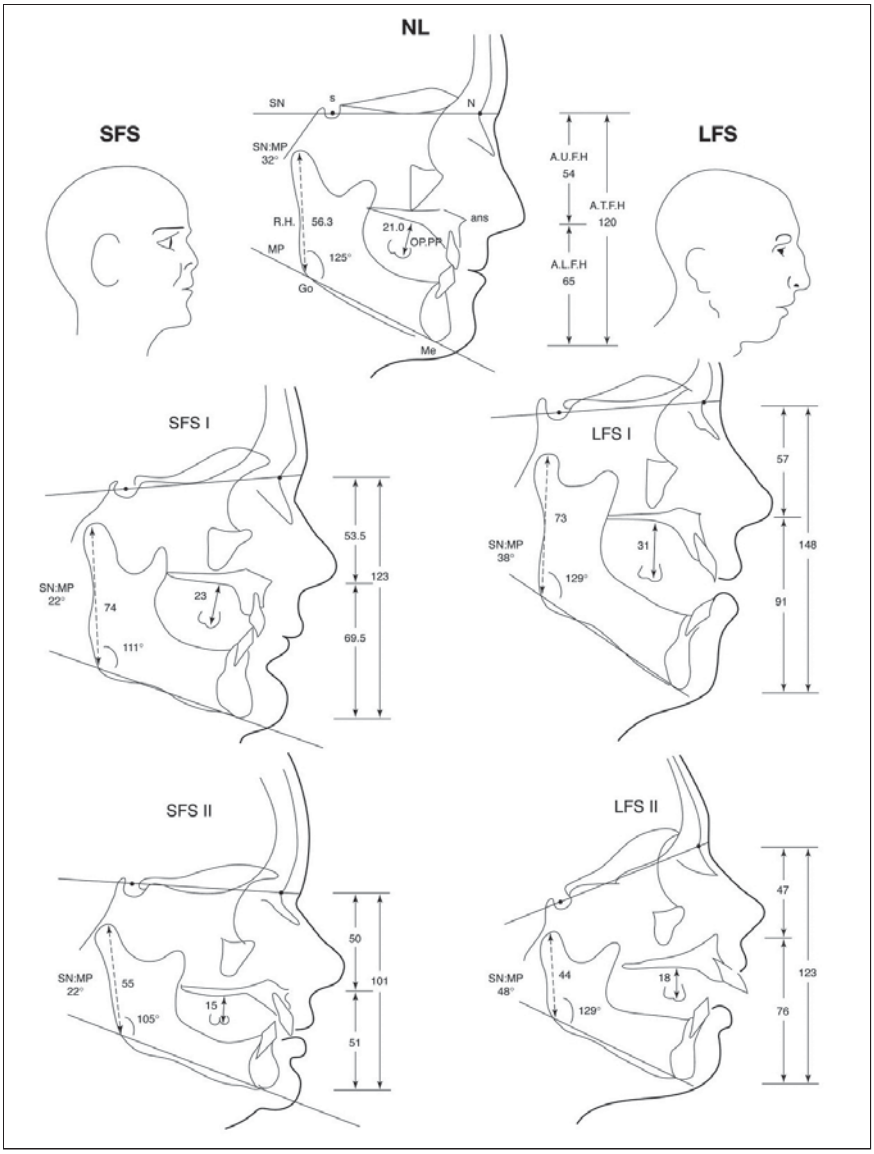


Fig 4 Schematic image of a "normal face" (NL), drawings of children exemplifying SFS and LFS, and cephalometric analyses of children exemplifying 2 subtypes of SFS and 2 of LFS. The cephalometric analyses were limited to the following characteristics: ATFH = anterior total facial height (the distance between the nasion [n] and the menton [Me; lowest point on the symphysis]); ALFH = anterior lower facial height (the distance between the anterior nasal spine [ANS] and Me); AUFH = anterior upper facial height (the distance between the nasion and ANS); SN = the line through the center of the sella tursica (s) and N; MP = the line through Me and the gonion (Go), which represents the plane passing through the mandibular borders; SN:MP = the mandibular plane angle formed by the intersection of SN and a line between Go and gnathion (GoGn); RH = the length of the ramus (the distance from the head of the condyle to Go); OP-PP: the distance between the mesiobuccal cusp of the first molar and the lower border of the palatal plane along the long axis of the first molar. SFS I is characterized by a long ramus, a slightly reduced SN:MP ratio, and normal posterior maxillary height. SFS II is characterized by a short ramus, a slightly reduced SN:MP ratio, and reduced posterior maxillary height (vertical maxillary deficiency). Patients with LFS I have a rather long ramus, increased OP-PP distance (vertical maxillary excess), and a moderately increased SN:MP angle. Those with LFS II have a short, sometimes extremely short, ramus, a normal OP-PP distance, and an increased SN:MP angle.[22,23] Measurements given in millimeters.

The Mandible. In the mandible, facial type mainly plays a role in growth in the sagittal and vertical planes. The growth of the mandible for an SFS face and an LFS face between the ages of 4 and 19 years is graphically illustrated in Fig 6. For the SFS type, the mandibular teeth move upward in a buccal direction. For the LFS type, the teeth move up but more lingually.

Implication. In SFS types, implants in the anterior area will end more lingual in comparison to the natural dentition because of the great mesial drift. In LFS types, implants in the mandibular anterior will become too labial because teeth gradually rise lingually. Implants in SFS children and adolescents are at risk for infraocclusion in the premolar region because of the above-average vertical growth in this area. In LFS children and adolescents, there is considerable risk of infraocclusion in the frontal area.

Continuous Tooth Eruption. With an SFS child (forward rotator), the vertical eruption of the central incisors is not very obvious and ceases quickly (at about 13 years), but these teeth show forward tipping (especially from 13 to 25 years) to compensate for the continuing forward growth of the mandible, while the sagittal growth of the maxilla is already slowing down and even seems to get shorter vertically (Figs 5 and 6). An LFS child (backward rotator), on the other hand, shows a large and prolonged vertical eruption (even until 25 years), combined with a backward movement most obvious at the age of 15 years to compensate for the cessation of growth in the maxilla. Between the ages of 15 and 25 years, the vertical tooth movement in an LFS face can amount to 5 mm, a distance difficult to overcome with implants (Figs 5 and 6).

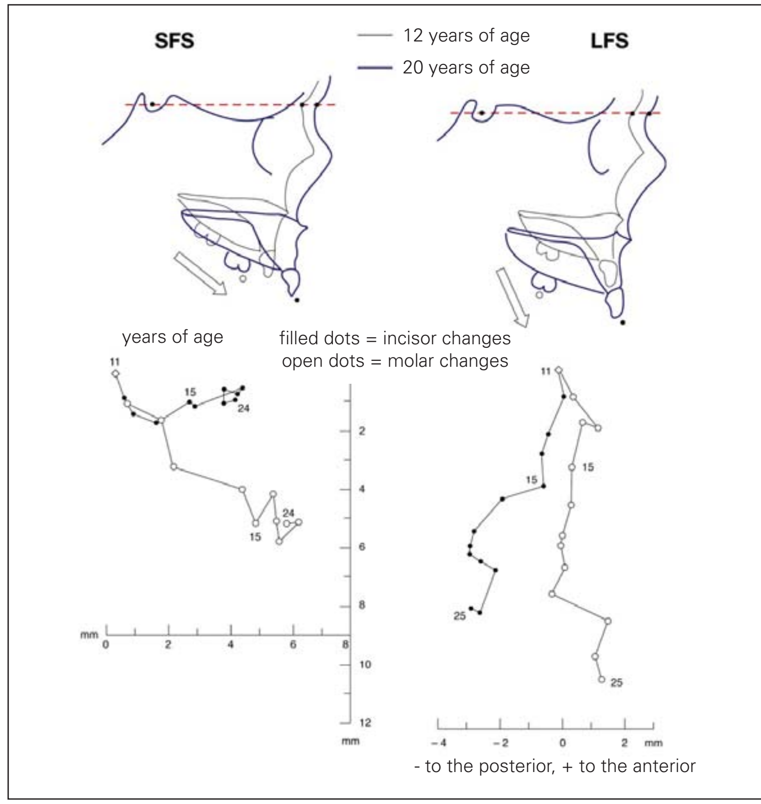


Fig 5 Direction of growth of the maxilla and continuous eruption of the maxillary central incisor and first molar (partially to follow the rotation of the mandible) for SFS and LFS types, respectively. In an SFS face, the rotation proceeds anteriorly, while in an LFS face, the mandible is rotated posteriorly. Cephalometric views at the ages of 12 and 20 years were superposed on the SN line. The shift in position of the central incisor and the first molar is shown in detail in the lower half of the figure (observations with intermission > 1 year and < 2 years). For these observations, a reference line was created in the corpus maxillae and in the zygoma for the superpositioning of consecutive encephalograms, guaranteeing that the changes illustrate the remodeling of the alveolar process. Sources for this figure: Björk[35] and Iseri and Solow.[17]

RECOMMENDATIONS BY ANATOMIC LOCATION

Anterior Maxilla

Vertical growth in this area exceeds growth in other dimensions and continues to a later age. Implant placement during childhood and young adulthood may necessitate repeated lengthening of the transgingival part of the implant or its prosthetic superstructure. This renders the endosseous-supraosseous ratio less favorable from a biomechanical viewpoint. Since the midpalatal suture only closes at puberty or even later in cases of SFS, maxillary transverse skeletal growth can also have an adverse effect on implants placed before its closure. Implant placement should thus be delayed until skeletal growth is completed. Modulation of these principles according to facial type should also be taken into consideration.

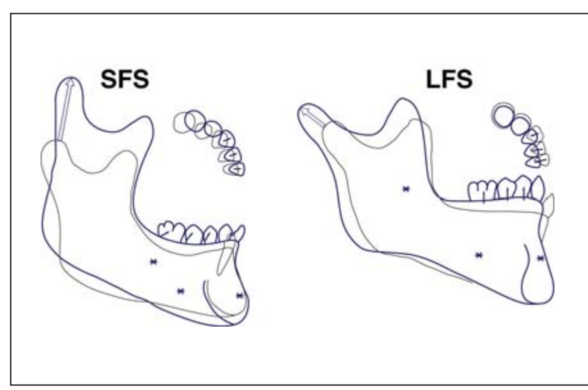


Fig 6 Graphic illustration of mandibular growth (through bone resorption and apposition, at the lower border of the mandible, the dentoalveolar complex, and the condyle) for an SFS individual and an LFS individual between the ages of 4 and 19 years. To monitor this growth, small implants (markers) were placed in the mandible for superimposition. Based on drawings of Björk and Skieller.[36]

Posterior Maxilla

Large variations exist in the amount and direction of both sagittal and vertical growth, and the unpredictability of the growth pattern adds to the difficulty of deciding when it is safe to place implants in this area. Since the vertical growth occurs by apposition on the alveolar aspect and resorption on the nasal or maxillary sinus area, an implant placed early could become submerged occlusally and penetrate the sinusal or nasal cavity. Prosthetic connections that cross the midline will interfere with the transverse growth. In partial edentulism, implant infraocclusion may lead to long-term esthetic problems for the implant and periodontal damage around the adjacent teeth. Implant placement can only be recommended after cessation of growth. However, implant placement in the anodontic child could be considered under well-planned conditions, despite the risk of problems because of the appositional and resorptive pattern of the posterior maxillary growth.

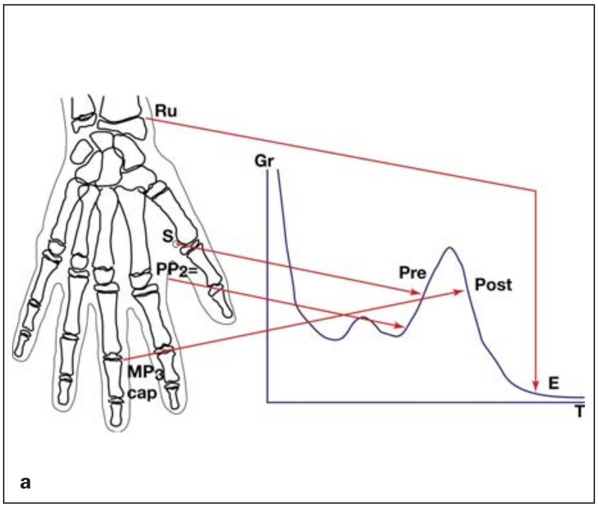
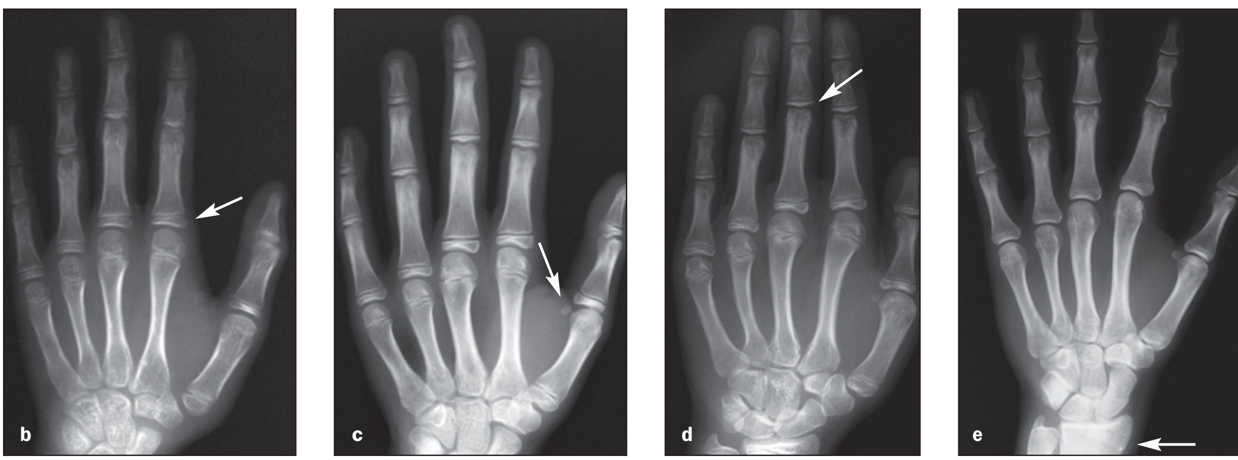


Fig 7 *(a)* Schematic representation of growth velocity (Gr) over time (T). *(b)* When the growth disk has the same width as the proximal phalanx of the second finger (PP2), the child is in the early stage of the growth spurt. *(c)* The sesamoid bone (S) of the thumb usually begins to calcify during the accelerating phase of the pubertal growth spurt (Pre). Since a substantial amount of growth is ahead, this is an inappropriate time to place an implant. *(d)* Capping of the middle phalanx of the third finger (MP3cap) usually occurs after the maximum growth velocity has passed (beyond the peak of the growth curve) and indicates a deceleration of the pubertal growth spurt (Post). This correlates with the approximate onset of menstruation in girls and deepening of the voice in boys. Since most pubertal growth has been completed, consideration of implant placement can begin. However, since the exact length and rate of growth are still unknown, some risks still exist. *(e)* When the epiphysis of the radius fuses and forms a bony union with the diaphysis (Ru), adult levels of skeletal growth have been attained, and no further increase in statural height can be expected (end of growth, E). The best and safest time to place a solitary implant adjacent to teeth is when the final indicator, radial epiphyseal closure, has occurred.



Anterior Mandible

The symphyseal area causes the least problems with implant placement, since the mandibular symphysis is closed in early childhood, and sagittal growth primarily occurs in the posterior part of the mandible. In partially edentulous patients, however, the early use of implants in this area can be contraindicated because of significant compensatory changes in the dentoalveolar complex during growth.

Posterior Mandible

In the posterior mandible, large amounts of transverse, sagittal, and vertical growth occur. As the mandible undergoes rotational growth, significant changes occur in both the alveolus and the lower border of the mandible. Such changes are largely influenced by the facial growth type. A conservative approach in the posterior mandible dictates that implants should not be placed until skeletal growth is completed. Progressive infraocclusion of the implant precludes the early placement of implants in these areas. A lack of reports of early implant use in the edentulous posterior mandible renders the formulation of recommendations impossible.

PROPER AGE FOR IMPLANT PLACEMENT

During a consensus meeting in 1995 it was decided that it is preferable to postpone implant placement until craniofacial/skeletal growth is complete, especially in partially edentulous cases.[33] It should be noted that the age at which growth is complete varies widely.[33] It is commonly observed that the growth spurt is expected to occur at 12 years for girls and at 14 years for boys; however, the age at which it occurs can vary by as much as 6 years. Thus, when a clinician plans the use of oral implants in a child, the problematic age period extends from 9 to 15 years for girls and 11 to 17 for boys.[34] If one adds to this the variability observed among face types (SFS and LFS show significant changes up to the age of 25 years), even longer periods should be taken into consideration. The chronologic age is thus certainly not sufficient to estimate growth cessation. A clinician should rely on a reliable evaluation of growth by:

- Superimposing tracings of cephalometric radiographs taken at least 6 months apart.
- Waiting until no growth changes take place for 1 year. However, the time required and the radiation involved are drawbacks.
- Evaluating bodily growth in length annually for 2 years to make sure that annual growth is less than 0.5 cm/y. Again, a time-consuming assessment.
- Observing changes of dental positions within the arch, such as the eruption of the second molar.

Another method is evaluation of the skeletal age on the basis of a radiograph of the wrist of the least used hand to observe to what degree the growth plates are closed (Fig 7).[37] This parameter is accurate but needs regularly repeated radiographs until the proper age is reached. Hand-wrist radiograph indicators can be used to place a patient in a general area of the growth curve shown in Fig 7a. In patients with severe anodontia or oligodontia in the anterior mandible it is possible to place implants even before the pubertal growth spurt. Only limited changes related to growth occur in this area after the age of 5 to 6 years, especially when teeth are not present.

SUMMARY

It is evident that jaw growth may compromise the outcome of oral rehabilitation using implant-supported prostheses even if the implants are successfully integrated. Lack of proper occlusion and unesthetic situations can occur, especially in the anterior region. The timeframe for the development of the alveolar process can vary widely, especially in the case of long or short facial types. The risks posed by continuous tooth eruption in adulthood should also be considered. Too often, only the growing child and adolescent are considered challenges.

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