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Age as compromising factor for implant insertion

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The long-term success of oral implants in partially edentulous cases (12, 17, 24) has encouraged clinicians to broaden the use of implants to young patients missing one or more teeth due to agenesis and/or trauma. When placing implants in a growing child, one should be aware that, because of the intimate bone apposition (osseointegration), which resembles ankylosis, these implants do not follow the spontaneous and continuous eruption of the natural dentition. Such implants may even disturb a normal development of the jawbones.

In order not to interfere with the growth of the jawbones, the installation of an implant should generally be postponed on average until after puberty or after the so-called growth spurt of the child. However, since temporary therapies (removable dentures, acid-etch bridges) are rather uncomfortable (because, respectively, of the removable character and incidence of fractures/loosening), patients and/or their parents often force the clinician to reduce the waiting time and to start the surgical intervention as soon as possible. Besides this, the risk of ongoing alveolar bone resorption after tooth extraction also encourages the clinician to insert the implant as soon as possible. At that moment the periodontist has to estimate whether the implant may interfere with a further development of the jawbones and/or whether the position of the implant in relation to the remaining teeth could be jeopardized due to further tooth eruption.

The risks for early implant placement are clinically well illustrated by the disharmony obtained when teeth become ankylosed during childhood (Fig. 1). Implants, like ankylosed teeth, do not take part in the further growth of the jaw bone and the alveolar process in particular. The latter has been nicely demonstrated by several studies in young pigs (26, 27). Clinically, radiologically and histologically, it appeared that implants do not follow the formation and development of the alveolar process. At some distance from the implants, the tissues developed normally, but in the immediate vicinity of the implants, further development was slowed down. The latter can lead to unesthetic and non-functional situations (loss of occlusal contact) together with periodontal complications (e.g. angular bony defect around neighboring tooth). The clinical relevance of these animal studies was confirmed by longitudinal observations (10 years) in young adolescents in whom missing teeth were replaced by implants, (27, 28) manifesting some unfavorable conditions (see later).

This chapter intends to give guidelines concerning the ideal timing for oral implant placement in the growing child, taking into account the further development of the jawbones and especially the ''continued'' eruptive movement of the teeth (even after reaching occlusal contact). The latter is unfortunately not limited to puberty (as generally believed) but can still reach significant dimensions even after the age of 18 years (13), especially in case of a deviant facial type (long *versus* short face). This has already previously been demonstrated when the increase of the gingival width with time was studied (1).

Growth of the jawbones

For ease of understanding, growth of the jaws is commonly discussed according to its direction of manifestation: transverse, anteroposterior (sagittal), and vertical. The growth of the mandible and the maxilla follows a distinct chronology, with a completion of the growth first in a transversal plane,

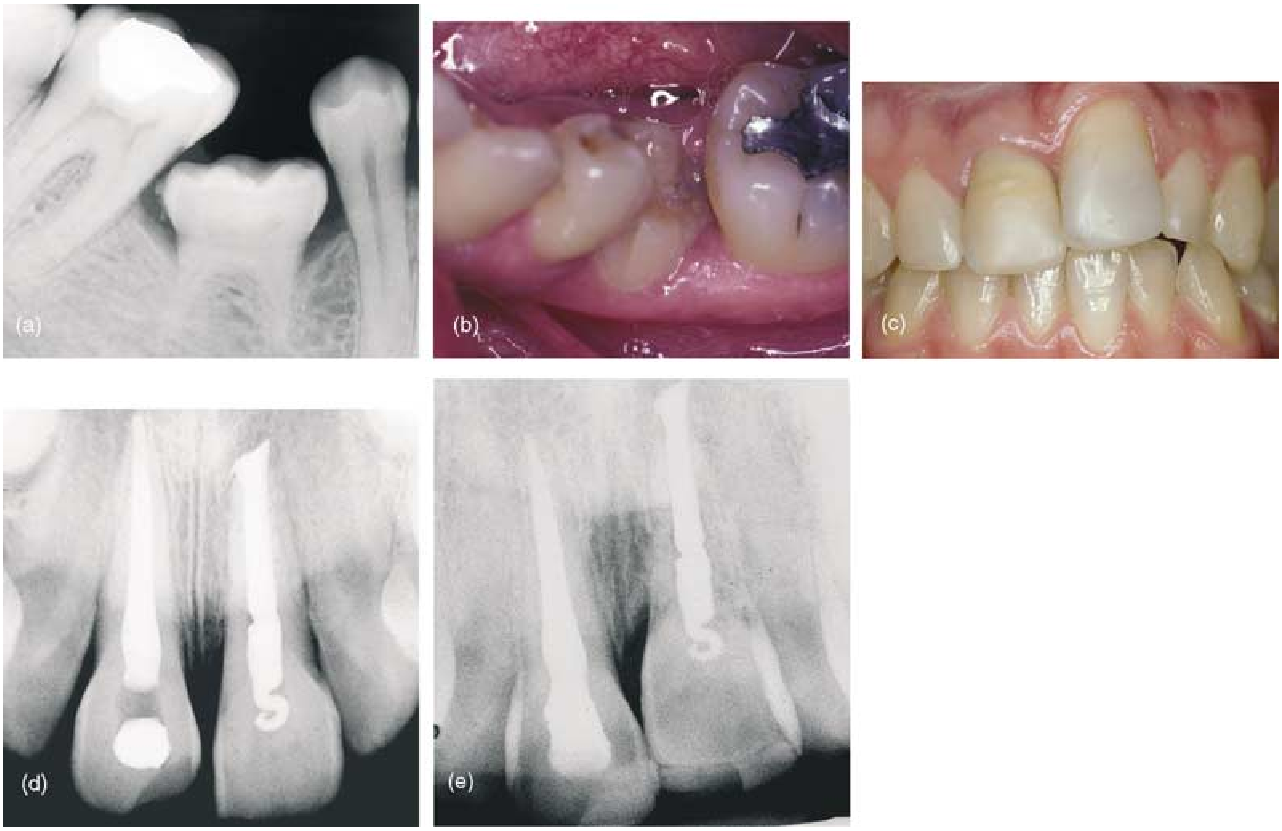

Fig. 1. Radiologic (a) and clinical (b) picture of an ankylosed primary molar, which came into infraocclusion because of the normal eruption of the neighboring elements. The crown of the primary tooth has almost completely disappeared under the gingiva, and the neighboring teeth are angulated. The radiograph shows how the bone has grown with the definitive teeth, but around the primary tooth the processus has remained at a lower level. Such anomalies can also appear in early implant placement. Radiologic picture (d) of a patient with a history of trauma at age 12 followed by endodontic treatment of 21 and an composite filling to reconstruct the corner of 11. Radiologic (e) and clinical (c) picture at age 17. Tooth 21 ankylosed and became shorter in relation to the neighboring teeth as seen on the pictures, even after trying to correct this difference with a composite filling.

then in a sagittal plane and only at a later stage in a vertical plane. It is important to realize that, in relation to implants, a displacement of the entire bony complex (via sutural growth) will be followed by oral implants, and as such does not create a major risk unless the prosthetic rehabilitation crosses the suture. However, bone remodeling (also termed drift and defined as the reshaping of bone by selective resorption in some areas of its surface and apposition/deposition in other areas) is not followed by implants. Bone changes in the maxilla after the age of 7 consist, for two-thirds, of remodeling, increasing significantly the risk concerning the final position of an implant.

For solitary implants and/or partial bridges on implants, the vertical growth by drift plays an especially important role (Figs 1 and 2). Theoretically, the implant apex could even perforate the floor of the nose and occupy a part of the *aperture piriformis* (see Fig. 4). Most of the data in this paper are derived from longitudinal studies, in which some small experimental implants in the jawbones have been used as fixed reference points (5, 13).

Growth of the maxilla

Transverse growth

The width of the anterior portion of the arch is completed prior to the adolescent growth spurt, but for the posterior portion, the width increase is closely tied to the increasing jaw length. The width in the anterior portion increases mainly by growth at the midpalatal suture (sutura palatina mediana), a growth that is 3 times larger in the first molar area than in the front (Fig. 3). The inter-canine distance will change only little after the age of 10 (0.9 mm; 5). Thus if a central incisor was replaced with an implant shortly after eruption, a diastema could

Fig. 2. Clinical record of a patient (30 years old) where a solitary crown on an implant was placed 5 years ago (position 11). Infraocclusion, which has developed because of further eruption of neighboring teeth, is already clinically noticeable (a). (b) An SFS patient showing a more palatal position of the implant over the years.

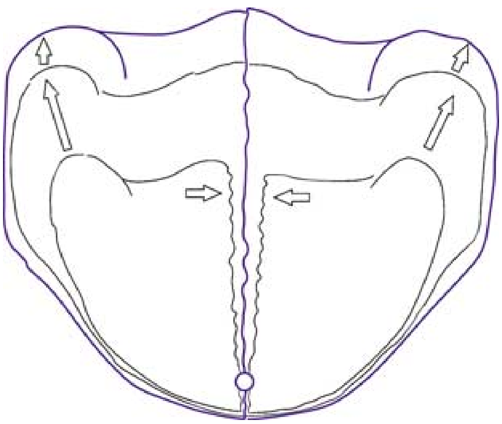

Fig. 3. Schematic image of growth in the horizontal plane of the maxilla. In transversal direction, growth proceeds mainly via the midpalatal suture. This increase is 3 times larger posteriorly than anteriorly, although the transversal increase in width between the posterior teeth is smaller as a result of adaptive changes within the dental arch. Length increase is caused by sutural growth and bone apposition at the tuberositas maxillaris; the frontal part of the maxilla base is rather stable. (Sources for this figure: Oesterle et al. (18)).

develop between the implant and the adjacent natural central incisor, resulting in 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 between them. The enlargement between the molars appears smaller than the sutural widening in this area, suggesting an adaptation of the dental arch. In the more posterior area, changes can occur until complete tooth eruption. In case reports (7, 16) of implants placed in the anterior maxilla as early as 9 years of age, no transverse problems have been reported; however, significant problems in the vertical dimension will overwhelm any transverse problem.

The midpalatal suture usually closes after puberty around the age of 15 (from 15 to 27 years). The latter should be kept in mind when planning the placement of a midpalatal implant as anchorage for orthodontic appliances.

Sagittal growth

The maxilla increases in length due to both sutural growth and bone apposition at the maxillary tuberosity (Fig. 3). The anterior part of the maxilla is rather stable. However, when the maxilla is displaced downward and forward during growth, up to 25% of the displacement is lost via resorption at the anterior site. The latter could result in an implant gradually losing labial bone. A case report of implants replacing a lateral incisor of a 13-year-old boy and an 11.5-year-old girl noted problems with labial fenestrations as early as 11 months after placement in the girl and 19 months in the boy, increasing in severity with growth (19). The sagittal growth of the maxilla is closely associated with the growth in skeletal body height, but stops earlier. The eruption of the third molars can be responsible for some changes afterwards, through a process of bone apposition.

Teeth have a spontaneous mesial drift. The lateral segment (canine to first molar) moves on average 5 mm mesially (between 10 and 21 years of age) but the maxillary 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 tooth migration''. Thus an implant in the lateral region could stop the mesial drift resulting in an asymmetric arch, while an implant in the frontal region cannot follow the teeth and will become relatively more palatal with time.

Vertical growth

The vertical growth in the maxilla (Fig. 4) occurs via both displacement (sutural growth) and drift. The maxilla is displaced downwards, away from the cranium, by growth in the orbits (eyes increase in size) and by increase in size of the nasal cavity and maxillary sinuses (by resorption on their nasal surface and by deposition of bone on their palatal and alveolar surfaces).

As mentioned previously, this vertical growth 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. Afterwards, depending on the facial growth type (see later) and due to the continued eruption of the teeth, changes still might occur, though much slower than during the active growth phase. However, over decades it can still contribute to significant changes and as such it has an impact on the use of osseointegrated implants (2). Between 9 and 25 years of age, the maxillary incisors will move about 6 mm downwards and circa 2.5 mm buccally. The average eruption velocities reaches 1.2 to 1.5 mm/year during the active growth phase, and 0.1 to 0.2 mm/year afterwards, even after the age of 18 years (13). Ranly (22) calculated that an implant inserted in the anterior part of the maxilla at the age of 7, will 9 years later be located 10 mm more apically than the neighboring teeth. This assumption was confirmed by clinical observations (7, 14, 16) after placement of solitary implants at the average age of 12, showing a "relative" infraocclusion of 5 to 7 mm 4 years later, sometimes combined with a labial fenestration. In the molar region, similar changes were measured (29).

Growth of the mandible

The timing of the mandibular growth is similar but not identical to that of the maxilla. Where the former is more closely associated with growth in stature, the latter is more associated with growth of the cranial structures. This accounts for the greater amount of sagittal growth of the mandible than of the maxilla during adolescence. This "differential jaw growth" converts the more convex child profile to the

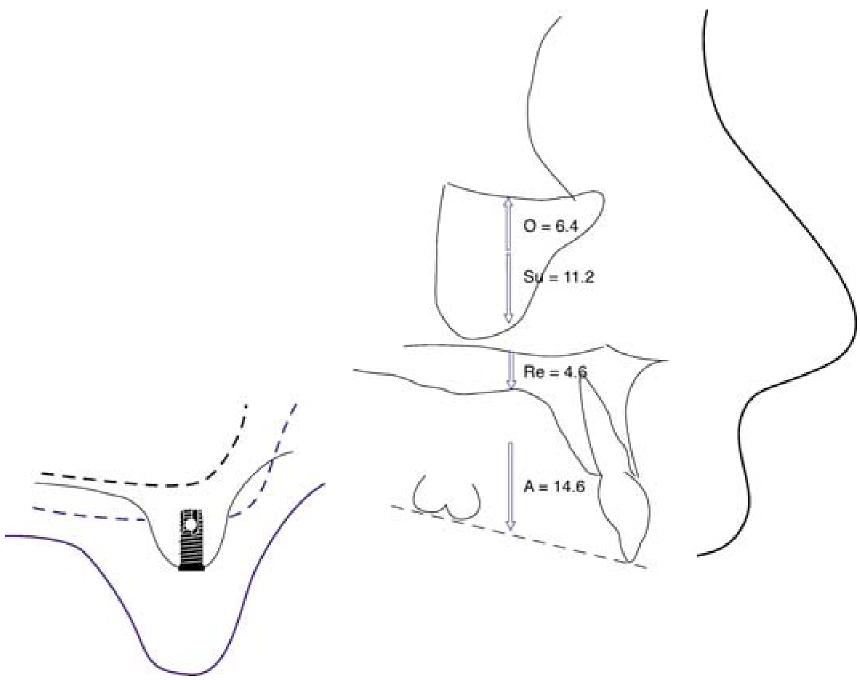

Fig. 4. Vertical development of the maxilla, from age 4 to adulthood, through both sutural and appositional growth of the dentoalveolar complex (combined with tooth eruption). Based on a study in which small implants were placed on several locations in the maxilla, the following was established: Sutural growth (Su) with an average of 11.2 mm (varying from 9.5 to 13 mm). Resorptive lowering (Re) of the nasal floor with an average of 4.6 mm associated with appositional growth at the palatal side of the maxilla. Appositional increase in alveolar height (A) with an average of 14.6 mm, varying from 9.5 to 21.0 mm. Bone apposition at the floor of the orbit (O) (based on drawings of Björk & Skieller (5), and Oesterle et al. (19)). Drawing in lower left of figure illustrates how an early placed implant (e.g. at the age of 5), can be found in the floor of the nose after puberty, while the permanent teeth have further grown down 15 mm.

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

Although the width of the anterior portion of the arch is completed prior to the adolescent growth spurt, the posterior portion of the jaw will increase in width, closely tied to the increasing jaw length. In the anterior region growth ceases very early (almost no changes after eruption of the permanent canines) because of a fast closure of the mandibular symphysis in the first year of life and the limited changes afterwards via remodeling (Fig. 5). In the premolar-molar region, growth extends over a larger period through a bone remodeling, characterized by a bone apposition at the buccal site and resorption at the lingual site. This relative lateral movement of the bone could eventually lead to a linguoposition of an implant in case of early installation. The eruption of the permanent molars is accompanied by some changes in the jaw, though restricted to a few millimeters.

Sagittal growth

The sagittal growth (Fig. 6) emanates from an endochondral growth at the condyle and a remodeling of the ramus of the mandible. The growth at the condyle extends the mandibular length, but has no direct impact on the mandibular corpus shape and thus on eventual implants. The corpus of the mandible itself prolongs in an anteroposterior direction mainly through resorption at the ventral site of the ramus and bone apposition at its dorsal surface. The resulting increase in mandibular corpus length as such accommodates the eruption of the first, second, and third molars. Impacted third molars are therefore a direct consequence of a lack of mandibular anterior-posterior body growth. In the mandibular arch, the teeth show the same tendency to migrate mesially as discussed previously for the maxilla.

Vertical growth

The mandibler bone height mainly increases by bone apposition at the dentoalveolar complex, especially during tooth eruption, and by the condylar growth (Fig. 6). When sequential cephalometric radiographs are superimposed for different stages of growth, it

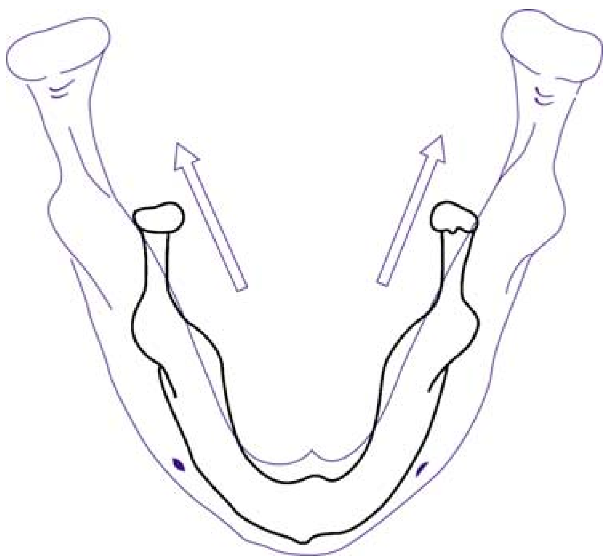

Fig. 5. Horizontal growth of the mandible. The anterior region shows little change, while the premolar–molar region moves laterally through bone remodeling (vestibular bone apposition, lingual resorption). In anteroposterior direction, the mandible mainly grows through condylar growth and an increase in length of the corpus through resorption at the ventral side of the ramus and bone apposition at the dorsal side. (Based on drawings of Enlow (9) and Oesterle et al. (19)).

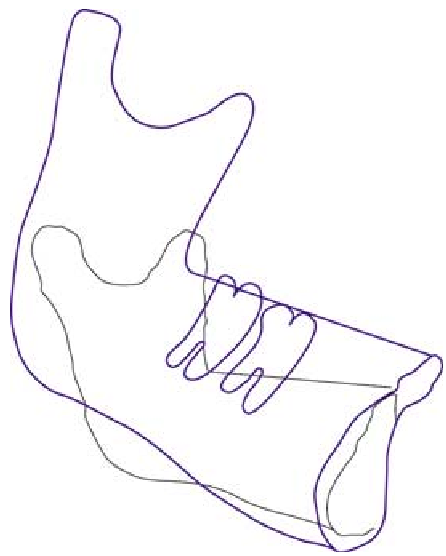

Fig. 6. The growth at the condyle causes a lengthening of the mandible, but this has no direct impact on possible implants. The height of the mandible increases mainly through bone apposition at the dentoalveolar complex, especially during the tooth eruption phase and the growth at the condyle. The latter makes the *corpus mandibulae* undergo a limited rotation. Superposition was performed based on the small implants placed in the *corpus mandibulae.* (Source: Björk & Skieller (6)).

appears as though the mandible is growing downward and forward from the cranium, but it is actually growing upward and backward, with little if any increase at the chin. Especially in this growth, significant differences have been reported between different facial growth types (short and long faces). With a normal facial type there is a minor rotation of the mandible in a sagittal plane. The two other growth types show a remarkable rotation. The dentoalveolar compensation mechanism normally comes into operation. It is defined as a system trying to maintain the normal intra-arch relationship. It occurs when eruption proceeds normally and there are no functional deviations (23).

The rotational growth of the mandible significantly affects the anteroposterior and vertical eruption patterns, which are thus intimately connected. This rotation is important for implant insertion because the variation in compensatory amount and direction of incisor eruption could dramatically affect the relationship of an implant to an adjacent tooth. The implant cannot make compensatory position changes either vertically or labiolingually.

Deviating facial types: the short and the long face syndrome

So far, growth has been described based on the average or mean growth as occurs in a large sample of individuals. The confounding factor is that, when these mean or average data are applied to the individual, they may miss the predictive mark considerably if the individual is at one end of the normal range. From an esthetic point of view, the population can generally be divided into normal, short or long facial types. Within these facial types, the development of the jawbones differs strongly. Even when adulthood is reached, the distinct facial types keep developing in different ways, showing phenomena that might jeopardize the placement of implants even after puberty. Therefore it is essential to recognize these facial types and to remember their most relevant differences.

In the orthodontic literature, the short facial type is also described as: horizontal grower, forward rotator (mandible) and/or skeletal deep bite. Synonyms for the long type are: vertical grower, backward rotator and/or skeletal open bite. Since these types distinguish themselves by a group of features it is better to talk about syndromes: the short face syndrome (SFS) and the long face syndrome (LFS). From now on, we will utilize the terms SFS and LFS.

The most essential characteristics of SFS and LFS

The main differences between both facial types are schematically visualized in Fig. 7. The facial proportion index helps to differentiate between a normal face and the SFS and LFS cases. This index is calculated by subtraction of the anterior upper facial height (AUFH = distance anterior nasal spine (*ans*) to nasion (*N*)) from the anterior lower facial height (ALFH = distance from the same spine to menton (M_e) in which both values are expressed as a percentage of the anterior total facial height (ATFH = distance from *N* to M_e). This value is around 10 for a normal face, since ALFH is 55% and AUFH is 45%. An SFS is characterized by a small facial proportion index (FPI < 10), whereas this value clearly exceeds 10 for an LFS. Other important differences can be obtained on a cephalometric radiograph. An SFS is characterized by a smaller angle between the sella–nasion line, representing the anterior cranial base, (SN line through the center of the sella tursica (*S*) and nasion) and the mandibular plane (MP, the line through the menton and gonion) than the angle for a normal face (which is 32°). For an LFS, this angle is obviously larger (>32°). 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 an SFS (circa 110°) compared to the normal situation (125°) and certainly compared to the LFS, where values of about 129° are found.

The following clinical features can also be helpful to differentiate. An SFS 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 is characterized by a heightened lower facial half, hump on the nose, a less obvious chin point, a chin 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. 7).

Important growth differences in relation to the normal facial type

The maxilla

The SFS group exhibits more growth in the transverse direction (1.5 mm versus 0.3 mm for the LFS) at the midpalatal fissura because of later closure. Also, the

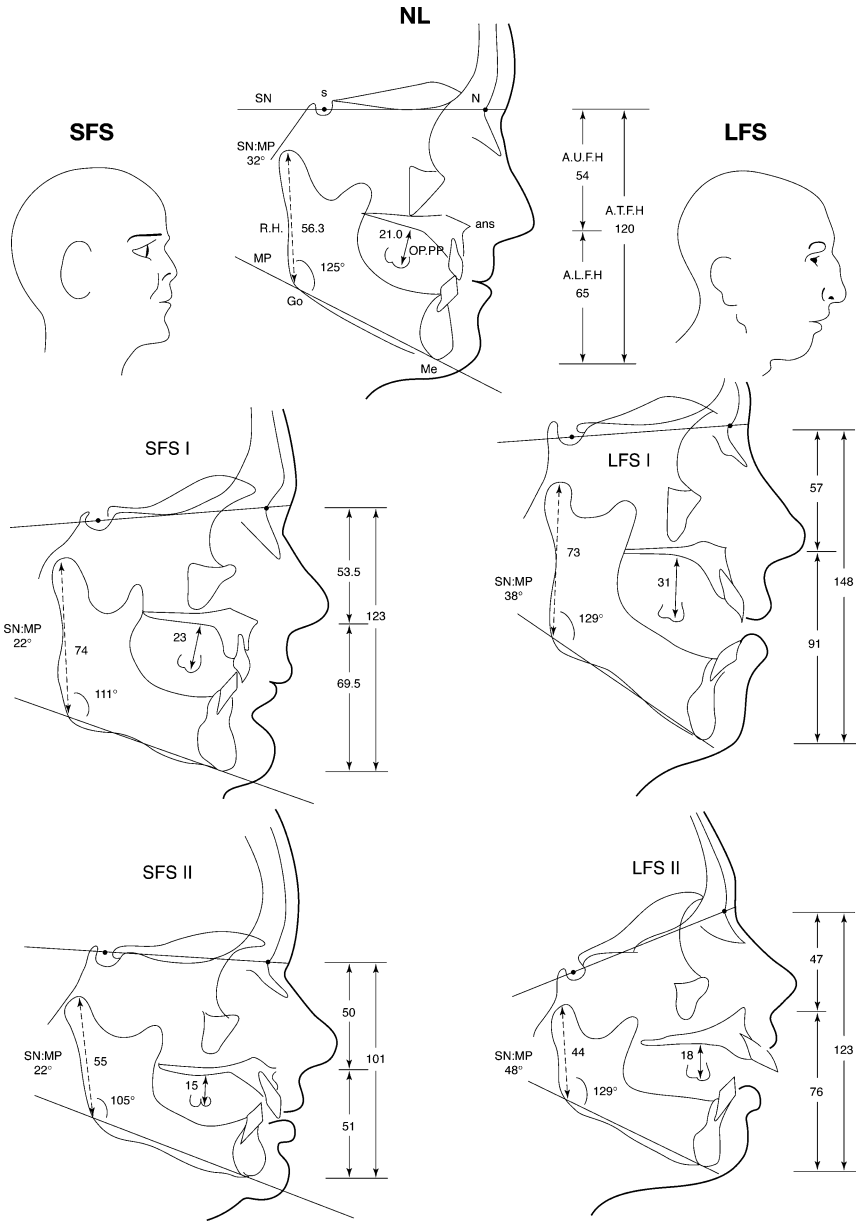

Fig. 7. Schematic image of a "normal face" (NL), drawing of the "short face syndrome" (SFS) together with a cephalometric analysis of two children exemplifying the two subtypes within this facial type and for the "long face syndrome" (LFS). The cephalometry limits itself to the following characteristics: ATFH: the "anterior total facial height" (distance between the nasion (N) and the menton (M_e = lowest point on the symphysis); ALFH: the "anterior lower facial height" (distance between the anterior nasal spine (ans) and menton (M_e)); AUFH: the "anterior upper facial height" (distance between ans and N); SN: the line through the center of the *sella tursica* (s) and the nasion; MP: the line through the point M_e and G_o representing the plane passing through the mandibular borders. SN : MP: mandibular plane angle, formed by the intersection of SN and G_oG_n; RH: the length of the ramus (the distance from the head of the condyle to G_o); OP–PP: the distance between the mesiobuccal cusp of the first molars and the lower border of the palatal plane along the long axis of 6. Special characteristics: SFS subtype I: *long ramus*, slightly reduced SN : MP, normal posterior maxillary height. SFS subtype II: short ramus, SN : MP slightly reduced, reduced posterior maxillary height (vertical *maxillary deficiency*). LFS subtype I: rather long ramus, increased OP–PP distance (*vertical maxillary excess*), moderate increase in SN : MP angle. LFS subtype II: *short and even extremely short ramus*, normal OP-PP distance, increased SN : MP angle. (Sources for this figure: Opdebeeck (20, 21)).

appositional growth in height of the alveolar process shows a large variation according to the study of Björk & Skieller (9.5–21 mm) and is negatively correlated to the transversal sutural growth: in other words, in the case of a narrow maxilla (as often in an LFS) the alveolar process grows more in height, while in the case of a wide jaw (as SFS) there is far less increase in height (13). In comparison to the

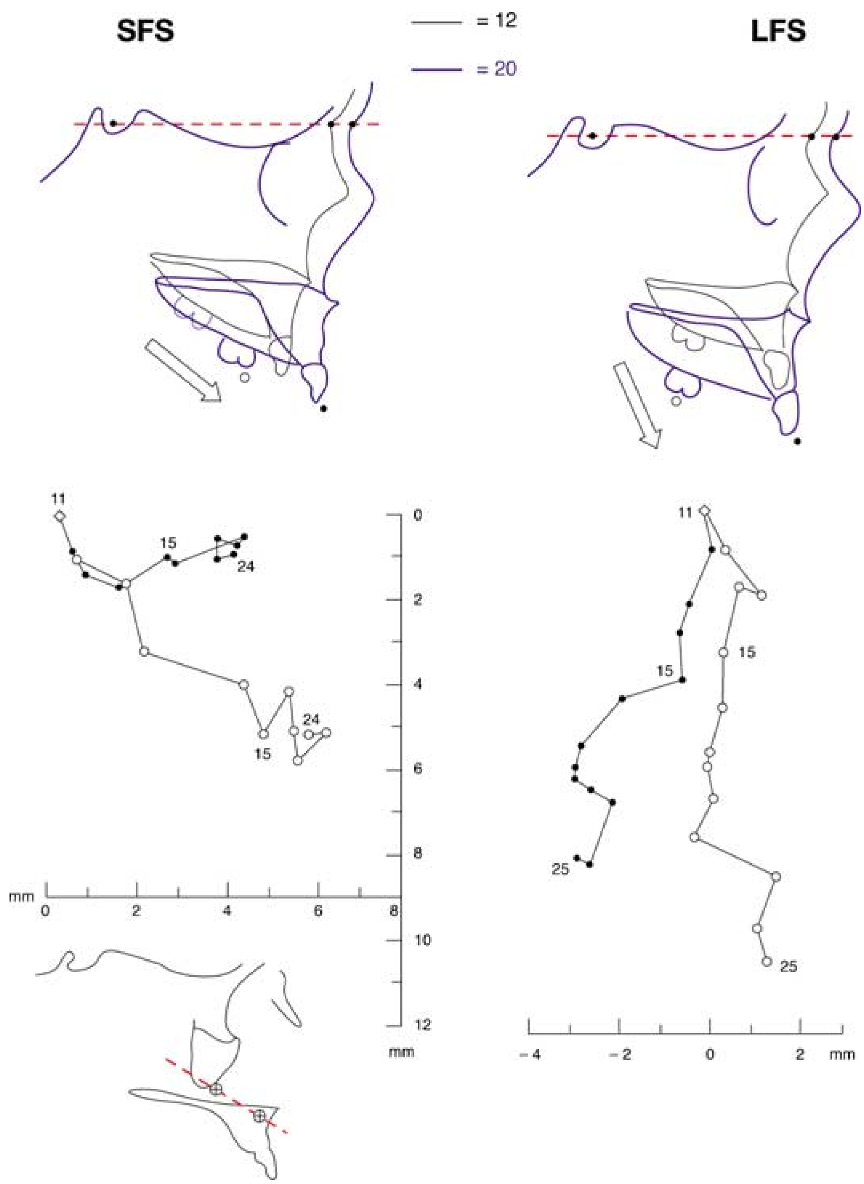

Fig. 8. Growth direction of the maxilla + movement of the teeth trying to follow the rotation of the mandible, as it occurs in SFS and LFS types. With an SFS person, this rotation proceeds rather to the anterior, while an LFS rotates rather posteriorly. The cephalometric views at the age of 12 and 20 were superposed on the SN line. The shift in position of the central incisor and the first molar for two adolescents of the SFS and LFS group 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 formed by two implants in the corpus maxillae and the zygomatic bone (insert left below) for superposition, guaranteeing that the changes illustrate the remodeling of the processus alveolaris. (Sources for this figure: Björk (4), and Iseri & Solow (13)).

normal face, the growth direction of the maxilla will also differ in the two facial types (Fig. 8). Moreover, the dentoalveolar complex of the maxilla will undergo some rotation in relation to the cranial base (SN line), since the teeth try to follow the rotating mandible through the dentoalveolar compensation mechanism. This rotation proceeds forward in SFS adolescents and more backward in LFS types. Since in the maxilla the tooth movement in horizontal direction is large for the short facial types, implants in the front will eventually find themselves more palatal compared to the natural dentition. With the LFS type it is especially the increased vertical movement of the natural dentition which could be risky.

The mandible

In the mandible, the facial type mainly plays its role in the sagittal and vertical plane. Figure 9 shows

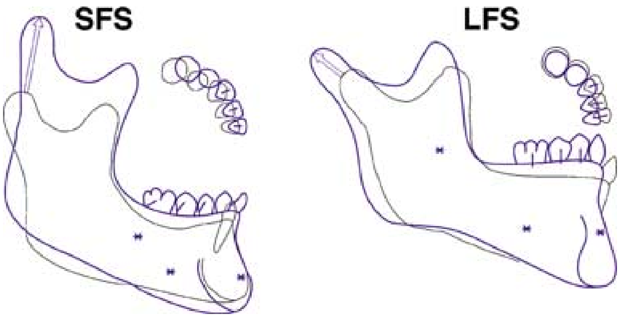

Fig. 9. Graphic illustration of the growth of the mandible (through bone resorption and apposition, at the lower border, the dentoalveolar complex and the condyle) for an SFS and LFS between the ages of 4 and 19 years. To monitor this growth, small implants (markers) were placed in the mandible for superposition. (Based on drawings of Björk & Skieller (6)).

graphically the growth of the mandible for an SFS and LFS between the ages of 4 and 19 years. Because there is a great mesial drift in the SFS types, implants in the front will end up more lingual in comparison to the natural dentition. In LFS types the mandibular frontal elements will gradually rise lingually, so that implants in this area will, in turn, end too vestibularly. SFS children and adolescents show above average vertical growth in the premolar/molar area, which could lead to infraocclusion of an implant there. LFS children and adolescents, on the other hand, show more vertical growth in the anterior area, increasing the risk of infraocclusion of an early installed implant.

Changes in dentoalveolar complex, before and after puberty

Since changes in the dentoalveolar complex are of particular importance for the functional/esthetic outcome of implants, a study by Iseri & Solow (13) deserves special attention. They examined the eruption of permanent maxillary central incisors and first molars after they had reached contact with their antagonists. In 14 young girls (aged 9 years) with divergent facial growth types, several small implants were placed as reference points (markers). Consecutive cephalometric radiographs were superimposed via these markers to study further eruption of the teeth. The teeth showed a ''prolonged or continued eruption'' even after occlusion was obtained. The average movement (between 9 and 25 years) of the central maxillary incisor was 6.0 mm in the caudal direction and 2.5 mm in the ventral direction. For the maxillary first molars these movements were 8.0 and 3.0 mm, respectively. Between 17 and 25 years of age, these values were on the average 1 mm and 0.5 mm for the incisors, and 1.5 and 0.8 mm for the maxillary molars, respectively. These movements showed, however, a very large interindividual variation, also dependent on the facial type (Fig. 8). With an SFS child (forward rotator) the vertical eruption of the central incisors is less obvious and ceases early (at about 13 years); but these teeth show more 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 seem to get shorter vertically. An LFS person (backward rotator) shows a large and prolonged vertical eruption (even until 25 years), combined with a backward movement most obvious at the age of 15 to compensate for the ceased growth in the maxilla while the mandible keeps on developing. Between the ages of 15 and 25 years the vertical tooth movement in an LFS can amount to 5 mm, a distance difficult to overcome with implants.

The changes in the dentoalveolar complex at a later age were also studied by Tallgren & Solow (25) who compared the average dentoalveolar height of 191 women divided into three age groups (A: 20–29 years; B: 30–49 years and C: 50–81 years) in a cross-sectional study. The following observations were made:

- the average dentoalveolar height in groups B and C was significantly higher than group A, both in maxillary and mandible (1.5–2 mm); the differences between B and C were negligible, and
- the mandibular facial height in women increased 3–3.5 mm with age, and was associated with an increase in mandible inclination (i.e. the opening of the mandible with a smaller increase in the posterior area than anterior).

This continuous increase in dentoalveolar height until middle life generally causes no major changes in the natural occlusion. Implants will, however, gradually go into infraocclusion because of this change, though these rather small changes can easily be countered. We should realize that the above-mentioned study only included normal facial types; in SFS or LFS persons more significant observations are to be expected. Other long-term studies (2, 3) indicated that a women when aging tend to get a longer face, with more probability for infraocclusion of an implant in the front, while men tend to growth more posteriorly.

Relative movement of an implant after puberty

Besides animal studies (26, 27), the clinical relevance of the previously stated risks for early implant placement was illustrated by longitudinal observations (3 and 10 years) in partially edentulous adolescents rehabilitated with implants (27, 28). The group consisted of 15 adolescents (8 boys, 7 girls) with a total of 27 implants (19 in the maxilla and 8 in the mandible). The average age at installation was 15 years and 4 months (varying from 13 to 19 years).

The data after 3 years showed a clear correlation between body length growth on one hand and the extent of implant infraocclusion on the other hand. In the four adolescents with the highest growth in length (6–18 cm over 3 years) the six implants (maxillary incisors region) showed an infraocclusion ranging from 0.8 to 1.6 mm within 3 years.

Although no further growth in length could be measured from the 4^{th} year on, and no further craniofacial alterations arose, the relative infraocclusion of the implants further increased. This ongoing infraocclusion reached a mean of 0.5 mm over the remaining 7 years (standard deviation of 0.6 mm). During the entire 10 years of observation, the total infraocclusion extended over a mean of 1.0 mm, ranging from 0.1 to 2.2 mm. The authors hypothesized that this infraocclusion around the implant was also the cause of a simultaneous bone loss around the neighboring teeth (28). During this follow-up study significant changes could also be noticed in the vestibulo-oral relationship between implants and neighboring teeth. Such observations support the previously described growth patterns of jawbones.

How to avoid compromising implant outcome by choosing a proper insertion age: Consensus report

There exists no such thing as optimal chronologic age for implant insertion. In the case of severe anodontia or oligodontia in the mandible the possibility or necessity exists to place implants even before the pubertal growth spurt, since in this patient group few growth changes occur in the anterior region after the age of 5–6 years, especially because of the absence of teeth. For the maxilla it is suggested to wait until after the growth spurt (15). However, as indicated above, major jawbone changes occur afterwards, dependent of the facial type, even after the age of 18 or 20.

During a consensus meeting in 1995 (15) it was decided that implant placement, especially in partially edentulous cases, preferably should be postponed until the end of the craniofacial/skeletal growth. One should, however, realize that the growth of children has a wide range. The growth spurt is expected to occur for girls at ca. 12 years and for boys at 14 years. Apart from this difference between sexes, the individual variation within one gender, which could be up to 6 years, should be taken into account (meaning 9–15 years for girls and 11–17 for boys; 11). The chronologic age is thus not sufficient to estimate growth cessation. More reliable standards are: superimposing tracings of serial cephalometric radiographs taken at least 6 months apart, a follow-up of the growth in length during at least 2 years (waiting for a growth below 0.5 cm/year), the change in dental position (i.e. eruption of the second molar), and/or an evaluation of the skeletal age (analysis of radiograph of wrist of the least used hand) (Fig. 10). It even is advisable to determine growth cessation through a combination of several methods (10).

Although superimposing tracings of serial cephalometric radiographs (waiting until no growth change is seen over a period of 1 year) is probably the most reliable, it requires a lot of time (and irradiation) and may unnecessarily delay implant insertion.

Skeletal growth status can be appraised fairly accurately by comparing a conventional radiograph of the hand and wrist against a standardized atlas of hand and wrist bone development (Fig. 10).

It is also advisable to take the growth pattern (SFS or LFS) into consideration.

Recommendations by area (15)

Anterior maxilla

This is probably the most risky site for early implantation due to the amount, the direction, and the unpredictability of growth in this area, especially in the presence of adjacent natural teeth. The vertical growth in this area exceeds the growth in other dimensions and continues to a later age. Premature implant placement can necessitate a repeated lengthening of the transgingival or transmucosal part of the implant, resulting in a poor implant–prosthesis

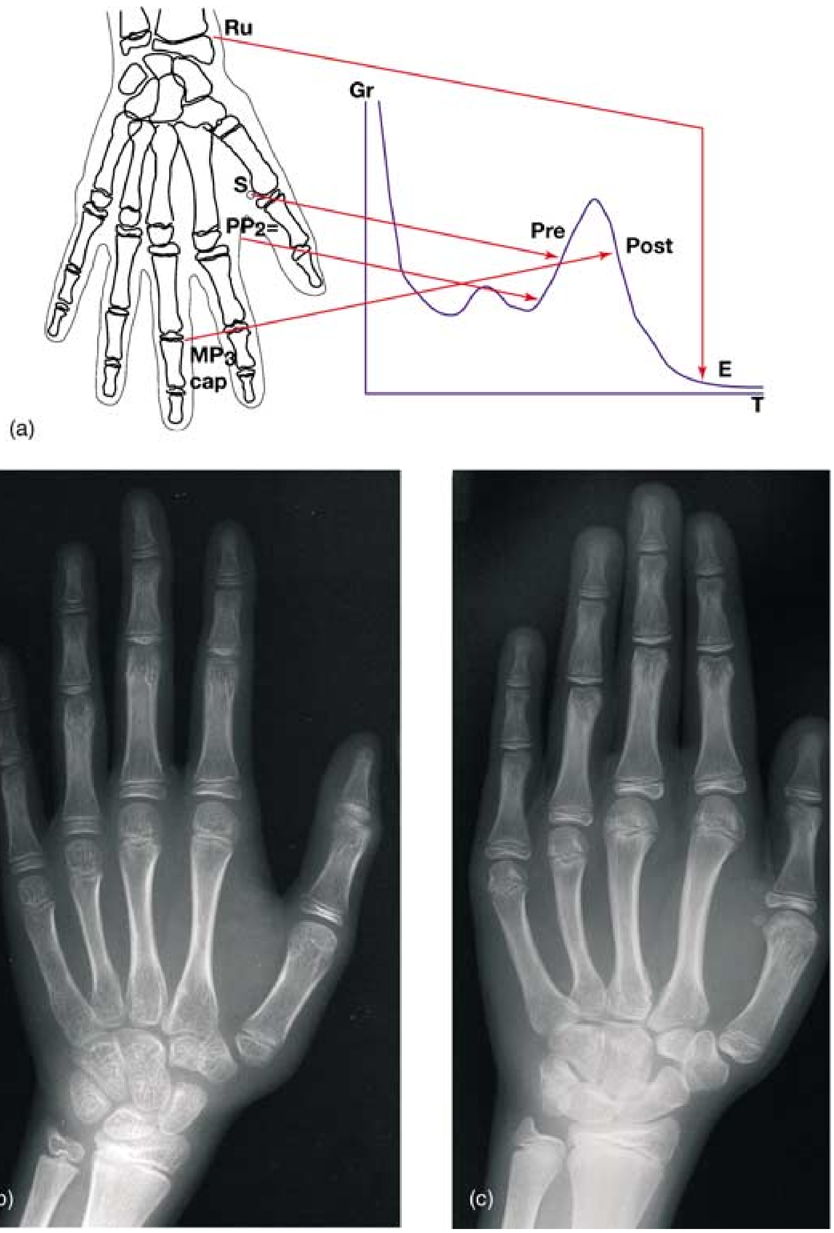

Fig. 10. (a) Schematic representation of growth (Gr) in time (T). The chart shows a decelerating rate of growth from birth into childhood, a small increase in growth rate during childhood (prepubertal growth spurt); a large increase during adolescence (pubertal growth spurt) followed by a decreased rate until adulthood. Hand–wrist radiograph indicators can be used to place a patient in the general area of the growth curve. The sesamoid bone (S) of the thumb usually begins to calcify during the accelerating phase of the pubertal growth spurt (prepuberty PRE). Since a substantial amount of growth still remains, this is an inappropriate time to place an implant. Capping of the middle phalanges of the third finger (MP_3cap) 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-puberty 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. 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 he 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. The changes afterwards are small and easier to compensate, but the SFS and LFS cases should receive special attention. For the fully or partially anodontic patient with natural teeth far from the implant site, consideration of skeletal maturity may not be as important since there are no erupting, compensating adjacent teeth. (Based on Cronin & Oesterle (8)). (b) Wrist of a child. PP2 = growth is at a very early stage. (c) Wrist of a child. Mpcap = indicates that maximum growth velocity has passed, but sketetal growth has not yet finished and continued eruption of the teeth is still possible.

ratio and adverse load magnification. Since the mid-palatal suture remains open up to puberty, maxillary transverse skeletal growth can also have an adverse effect on implants placed too early and vice versa. On a long-term basis, early placement can even adversely affect adjacent natural teeth. The best strategy is to delay implant insertion until after skeletal growth has completed. The significant differences between facial types should also be taken into consideration.

Posterior maxilla

The maxillary posterior area presents a similar problem. Large variations exist in the amount and direction of both sagittal and vertical growth, and the unpredictability of the growth pattern only adds to the difficulty. Since the vertical growth occurs by apposition on the alveolar aspect and resorption on the nasal or maxillary sinus area, an early inserted implant can become submerged occlusally and exposed apically because of resorption of bone in the maxillary sinus/floor of the nose. A transpalatal prosthetic connector will interfere with the transverse growth and must be avoided at too early an age. The combination of teeth and implants presents the worst prognosis due to implant infraocclusion and its long-term effects on both the implant and the adjacent teeth. It is therefore recommended to delay an implant placement until after cessation of growth. Implants in the anodontic child may also be problematic because of the appositional and resorptive pattern of the posterior maxilla.

Anterior mandible

The main transverse and sagittal growth is completed relatively early in this area (the mandibular symphysis is closed in early childhood and the sagittal growth of this jaw primarily occurs in the posterior part of the mandible). Though long-term treatment results are lacking, this area seems to hold the greatest potential for early use of an implant-supported prosthesis. The use of early implants in combination with natural teeth in this area is, however, not advisable due to the significant compensatory change in the dentition in this area 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 mandibular border, largely influenced by the facial growth type. Progressive infraocclusion of the implant and harm to adjacent teeth preclude the early placement of implants in these areas. A conservative approach in the posterior mandible dictates that implants should not be placed until skeletal growth is completed. A lack of reports of early implant use in the edentulous posterior mandible renders the formulation of recommendations impossible.

Summary

It is evident that jaw growth may be very compromising for oral implants. Nevertheless, more and more, implants are placed in adolescents. Especially after trauma of an maxillary incisor one could question what the minimum age of a patient should be before placing a solitary implant. Because of the osseointegrated character of implants – the base for their success – they behave as an ankylosed element and do not follow the further evolution of the jawbones and certainly not of the alveolar process. This could lead to unesthetic situations, especially in the front region (e.g. a ''relative'' infraocclusion or labioversion). This chapter describes the growth of the jawbones and hence attempts to reach some directives to determine the ideal age for implant placement. Most attention is given to the large variation in the development of the alveolar process, especially between facial types (short versus long face). Finally, the development of the alveolar process after the age of 20 is analyzed in detail. The latter highlights further changes that might jeopardize the outcome of implants.

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