CHAPTER 8

The Fourth Dimension of 3D Surgical Alveolar Ridge Reconstruction: Bone and Soft Tissue Grafting to Compensate for Dynamic Craniofacial Changes Associated with Aging in Partially Edentulous Patients Influencing Placement Consideration for Osseointegrated Implants

Oded Bahat,[1] Richard Sullivan,[2] Fereidoun Daftary,[3] Ramin Mahallati,[3] and Peter S. Wöhrle[4]

[1]American Board of Periodontology, Beverly Hills, California, USA
[2]Clinical Technologies, Nobel Biocare North America, Yorba Linda, California, USA
[3]Center for Implant and Esthetic Dentistry, Beverly Hills, California, USA
[4]Newport Beach, California, USA

Introduction

It has recently been recognized that changes in the bones and soft tissues of the face are a normal dynamic phenomenon that continues throughout life [1–7]. Some of the changes are similar for the two sexes, and some are not. For example, in a study by Kahn and Shaw of the orbit involving three-dimensional computed tomography of 60 patients who were not edentulous [8], facial changes were demonstrable in all age groups. The changes in the bones of the face appear to begin earlier in female patients [8, 9] (Figure 8.1), although the exact age of onset, along with the magnitude and vectors of the changes, are variable and not predictable. Such three-dimensional changes in the position of teeth and associated hard and soft tissue relative to the static position of dental (oral) implants over the course of time can introduce both esthetic and functional compromises of the original implant in a restoration, with unintended consequences. These problems are discussed herein.

Changes associated with aging

The changes with aging arise from a number of sources. The increasingly common addition of body weight and the impact of gravity and sun exposure are obvious causes of facial change [4, 5]. Less obvious is normal redistribution of fullness as a result of fat atrophy or hypertrophy, alterations that contribute significantly to facial aging [6, 10]. Also important are histologic and microstructure changes such as reduction in skin elasticity [6, 11, 12] and loss of facial bone density [13]. Tooth wear may become prominent as a result of occlusal changes and shifting jaw relations [4, 5].

The numerous age-related changes in the maxilla and mandible can create several important alterations [3, 14–17]. Both bones grow downward and forward such that the face gets larger [4] and there is an increase in facial height both anteriorly and posteriorly, especially in the lower face, with an increase in the mandibular angle [3, 16, 17]. Confusingly, different studies have produced different results. For example, Shaw et al. [18] found that ramus height and mandibular body height both decreased significantly with age in both sexes, whereas the mandibular angle increased significantly. The extent of these changes differs in men and women [4, 19], with the posterior change being greater in men [20]. In males, there is downward growth of the ramus and autorotation of the mandible (Figure 8.2) [14, 15], whereas in females, an increase in the mandibular angle occurs (Figure 8.3) [3, 16, 17].

In both men and women, arch circumference and length decrease [4, 7], and the teeth drift mesially [11, 21], leading to tooth crowding, especially in the mandible [22]. In the sagittal plane of the posterior mandible, bony changes will result in lingual resorption and facial bone deposition. The intermolar distance increases (Figure 8.4) [12, 23–27].

In both sexes, the resorption pattern in the sagittal plane of the maxilla results in *facial (buccal) bone loss* (Figure 8.5) [14, 15]. In a female patient, the anterior maxilla exhibits downward growth with a lingual vector. This may cause earlier implant thread exposure [3, 17, 28]. In the male patient, on the other hand, the anterior maxilla exhibits only vertical downward growth (Figure 8.6a to d) [3, 17, 28]. In both the male and female populations, the orbital spaces enlarge [6, 8] and the chin changes in shape and degree of projection [6].

Several soft-tissue changes also occur with aging. The upper lip length increases [4] and its thickness decreases [19]. Maxillary incisor display declines, whereas mandibular incisor visibility increases as the bone rotates anteriorly in males and posteriorly

Vertical Alveolar Ridge Augmentation in Implant Dentistry: A Surgical Manual, First Edition. Edited by Len Tolstunov.

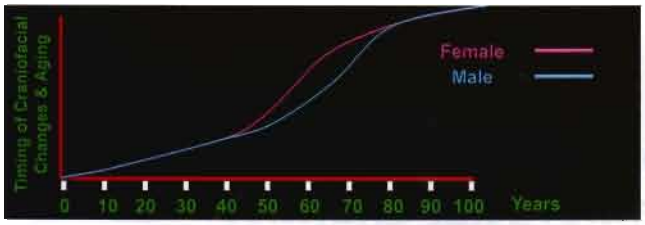

Figure 8.1 Generalized timing of facial and craniofacial aging in males and females. The onset occurs earlier in the female population.

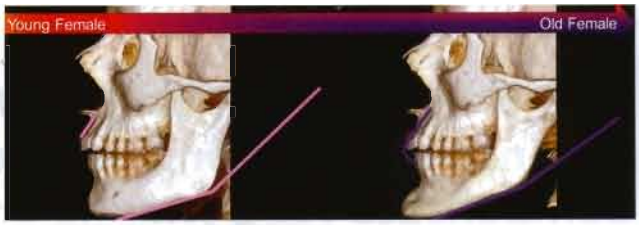

Figure 8.3 Illustrates the general changes in females, including increased mandibular angle and down-growth in lingual vector of the anterior maxilla.

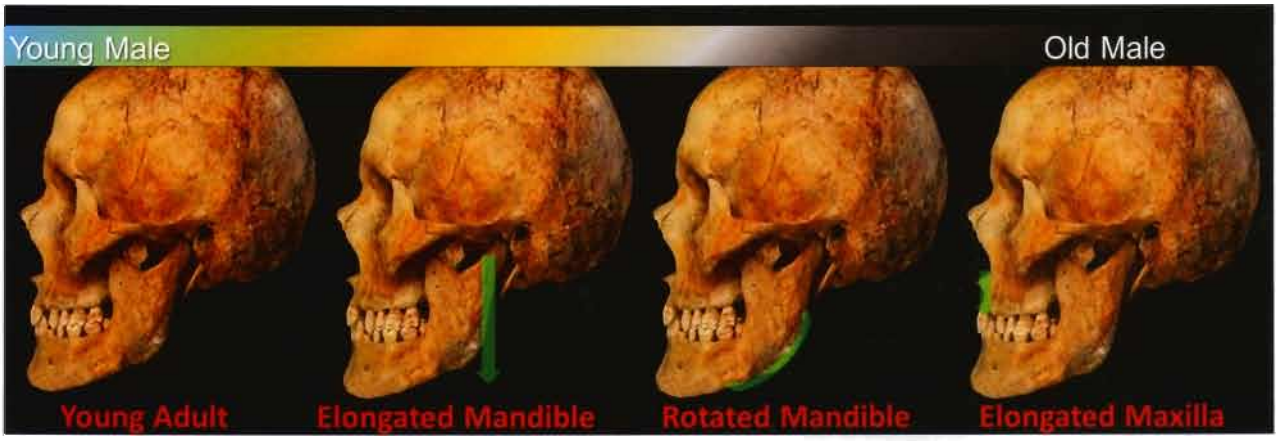

Figure 8.2 Illustrates the general changes in males, including elongation of the ramus, autorotation of the mandible and the down-growth in vector of the anterior maxilla.

in females [17]. The vermilion display of the lip declines, nearly disappearing in the old [6].

These vertical and horizontal changes are more pronounced in patients with short or long faces (Figure 8.7). Whereas all other structures are free to shift in three dimensions as a result, the true position of implants does not change, whereas the relative position of other structures may. Therefore, any implant to be placed in a short or long face may create greater asymmetry secondary to bone changes in the adjacent sites [19, 29, 30].

Figure 8.4 Illustrates increase in intermolar distance with lingual bone resorption and facial apposition.

Implant treatment planning to reduce adverse effects of the aging face

The challenge for treatment planning, therefore, is to consider and anticipate potential changes over time. This will necessitate application of a protocol that is time dependent and that will reduce the future adverse effects of implant placement in an aging face.

Patients can be divided between those who present a high risk and those who present a low risk of significant later craniofacial changes (Table 8.1). The high-risk patient is one with a high smile line and considerable esthetic demands, a short or long face, rapid onset of aging, missing or thin facial or interseptal bone (Figure 8.8), a need for asymmetrical implant placement, thin soft tissue biotype, and highly scalloped soft tissue. The lower-risk patients are those with a low smile line, minimal esthetic expectations, a need for symmetrical implant placement, intact or thick facial and interproximal bone, thick soft tissue

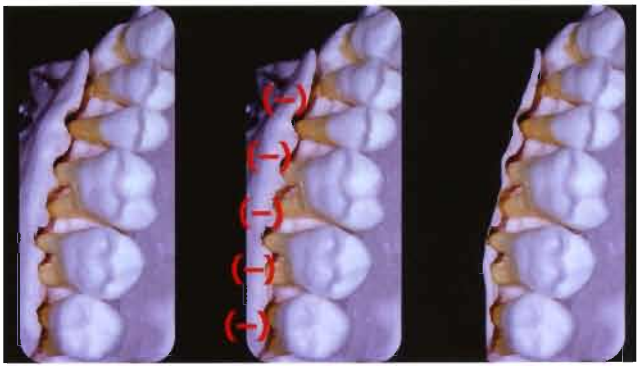

Figure 8.5 Illustrates posterior maxilla with bone resorption on the facial aspect associated with craniofacial aging.

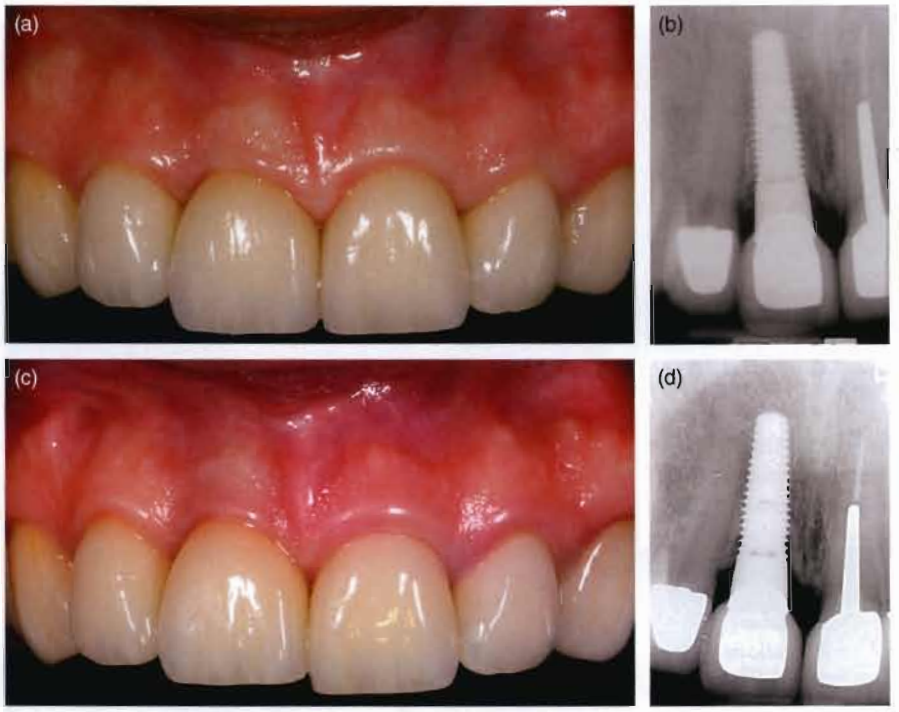

Figure 8.6 Illustrates changes in the anterior maxilla for a male patient aged 35. Images show 9 years post-operative. Continuous down-growth of the maxillary left central incisor with associated structures while the implant position remains the same (as an ankylosed unit).

Figure 8.7 Craniofacial variations between normal, long, and short skull anatomy.

biotype, soft tissue coronal to the adjacent dental unit, and flat soft tissue architecture.

The clinical decisions that must be made prior to treatment are described in the Table 8.2. They include selection of an appropriate implant macrostructure and microstructure (Figure 8.9a and b). Rough and smooth surfaces in the coronal third of the implant will react differently to bony changes. Overthinning of the bone and subsequent possible loss may cause an adverse reaction by the soft tissue to a rougher implant surface. A wide-diameter implant will be more susceptible to early exposure and detrimental results in a given ridge dimension. A clinical decision weighing implant strength, loading forces, the age of the patient, and the likelihood of earlier thread exposure is important. Similar decision making is valuable with regard to the apical third of the implant. Sharp threads and cutbacks increase the penetration and its sharpness. However, in areas of a high esthetic demand, where exaggerated vertical discrepancies occur with common thinning of the soft tissue, retrieval of the implant may be necessary. An extensive vertical asymmetry in the esthetic zone cannot be resolved by overextending the incisal

Table 8.1 Algorithm for risk factor.

Reduced risk	High risk
Intact interproximal bone	Compromised blood supply
Intact facial bone	High esthetic demands
Thick soft tissue biotype	Short or long face
Soft tissue coronal to adjacent unit	Facial or interseptal bone missing
Flat soft tissue scallop	Thin biotype
	Highly scalloped periodontium

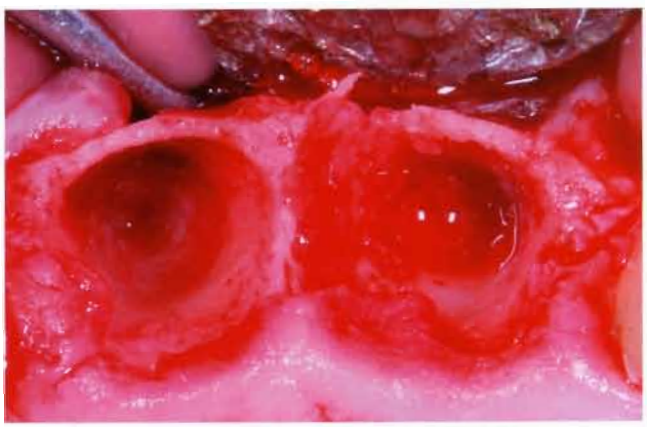

Figure 8.8 Occlusal view of the anterior maxilla after extraction illustrates thin interseptal and buccal bone, which may result in a complete loss of bone subsequent to dynamic changes during aging.

Table 8.2 Clinical decisions to be made.

Asymmetrical placement
Implant diameter
Implant macrostructure
Implant microstructure
Healed site or placement at time of removal of tooth or implant
Immediate versus delayed loading
Hard and soft tissue grafts: staging, approach and biomaterials
Mode of provisionalization

edge of the implant, as the disharmony of the gingival architecture will display unfavorable results. Removal of such an implant with a high penetrating capacity will result in a greater residual defect that will be more difficult to reconstruct and may create a residual defect on adjacent dental units (Figure 8.10).

A treatment plan should be created for modification of the conventional osteotomy in order to accommodate future bone and soft tissue changes. Those directional modifications may necessitate early decisions regarding the need for grafting and the appropriate graft materials. Variation of the conventional osteotomy is clinically challenging and admittedly not always possible. The general intention should be to accommodate future physiologic bony changes without compromising initial implant stability and the long-term esthetic and restorative outcome. This necessitates translation of the point of entry of the osteotomy to allow for increased dimension of bone and soft tissue in the area of highest risk (posterior maxilla and mandible) (Figures 8.11 and 8.12). The influence of craniofacial changes over time for the *posterior maxilla* have been shown to move the buccal plate and associated soft tissue toward the medial/palatal direction. While the necessity of optimal restorative support and emergence profile are a primary objective, sometimes flexibility allows more medial implant placement (Figure 8.11c and d) compared to more lateral placement (Figure 8.11a and b), thereby decreasing risk or at least prolonging any compromise that may be introduced by craniofacial changes over the long term. In the *posterior mandible*, the tendency for movement of bone is from medial to lateral.

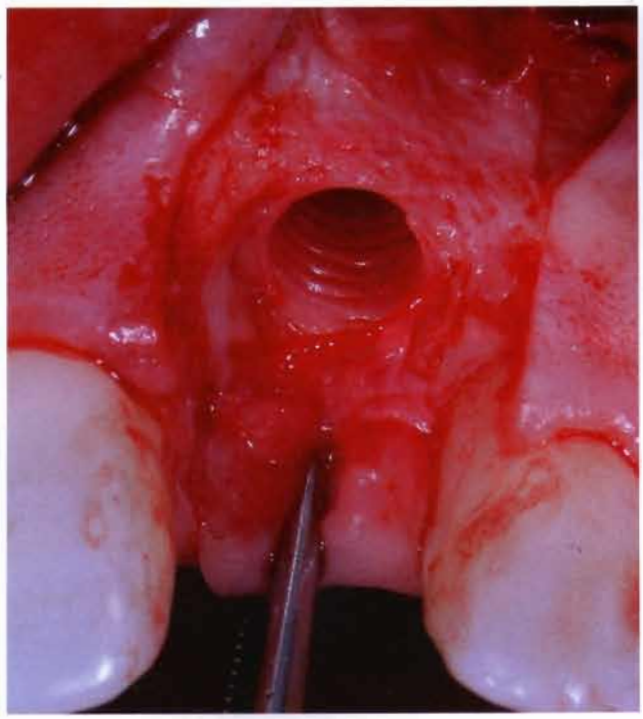

Figure 8.10 Residual defect subsequent to implant removal in the anterior maxilla in a patient with a high smile line. Adjacent anterior maxillary teeth with associate structures in the esthetic zone have continued in a down and lingual vector of movement with age. The implant acted as an ankylosed unit and has not changed its position, eventually residing in the infraocclusion relative to adjacent natural teeth.

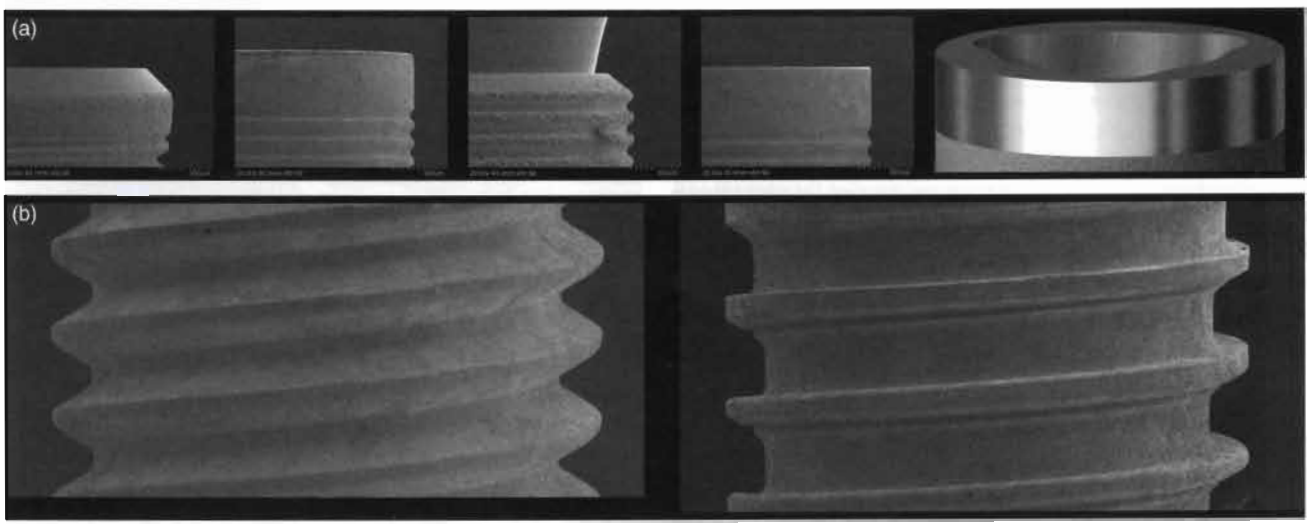

Figure 8.9 (**a**) Implant macrostructure considerations today include variations in abutment emergence or platform shift as well as the degree and extension of surface texture roughness. (**b**) Implant thread geometry may be either rounded or squared, its significance is not known to thinning of buccal bone, and potential thread exposure secondary to physiologic bone changes can become a clinical concern for soft tissue.

Figure 8.11 The influence of craniofacial changes over time for the posterior maxilla have been shown to move the buccal plate and associated soft tissue toward the medial or lateral direction. While the necessity of optimal restorative support and emergence profile are a primary objective, sometimes flexibility allows more medial implant placement **(c, d)** compared to more lateral placement **(a, b)**, thereby decreasing risk or at least prolonging any compromise that may be introduced by craniofacial changes over the long term.

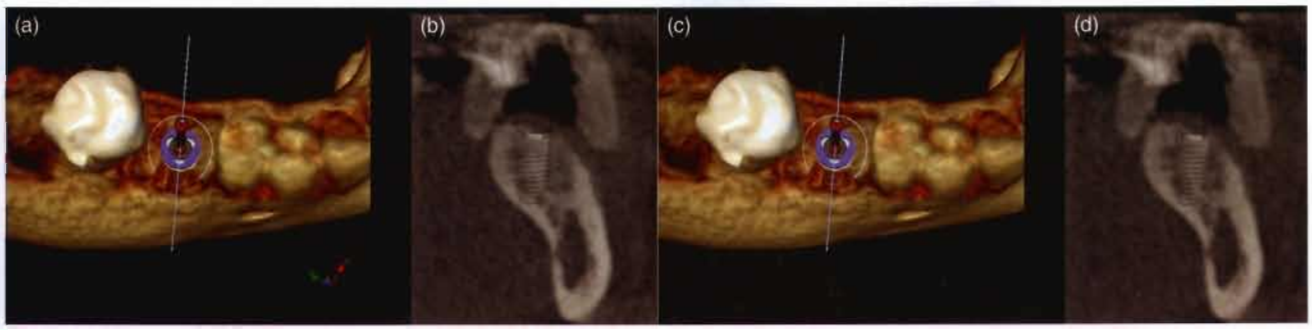

Figure 8.12 In the posterior mandible, the tendency for movement of bone is from medial to lateral. Placement of implants toward the lingual **(a, b)** could result in eventual lingual thread exposure even though restoratively ideal. Positioning the implants in the lower jaw more laterally **(c, d)** while still fulfilling restorative requirements provides an additional safeguard anticipating any craniofacial shifting.

Placement of implants toward the lingual (Figure 8.12a and b) could result in eventual lingual thread exposure, even though restoratively ideal. Positioning the implants in the lower jaw more laterally (Figure 8.12c and d) while still fulfilling restorative requirements provides an additional safeguard anticipating any craniofacial shifting. These modifications may result in thread exposure intraoperatively on the opposite side, which may necessitate grafting.

The selection of grafting material deserves further attention. Once grafting has been successful, the graft will respond in a way similar to the local anatomy, undergoing the same craniofacial changes. Therefore, alteration in grafting techniques and materials may be needed for a single tooth replacement in the anterior zone (Figure 8.13a and b) or a complete reconstruction of a deficient ridge (Figure 8.14a to e). The facial aspect may be at risk of resorption and may benefit from xenografts or allografts as facial layering.

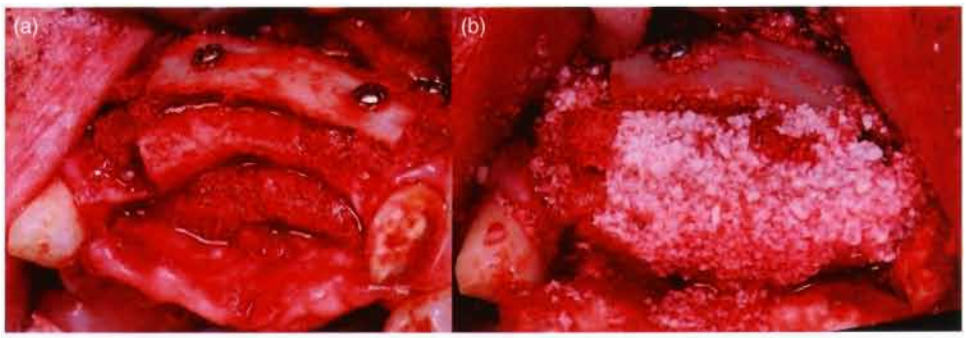

Figure 8.13 **(a)** Facial and lingual grafting with autogenous bone to reconstruct the anterior maxilla. Once vascularization occurs and implants are placed, the graft will respond to craniofacial growth in a similar fashion to the normal alveolus with possible threads exposure. **(b)** Addition of non-resorbable graft material will result in fibrous tissue that may mask exposed threads.

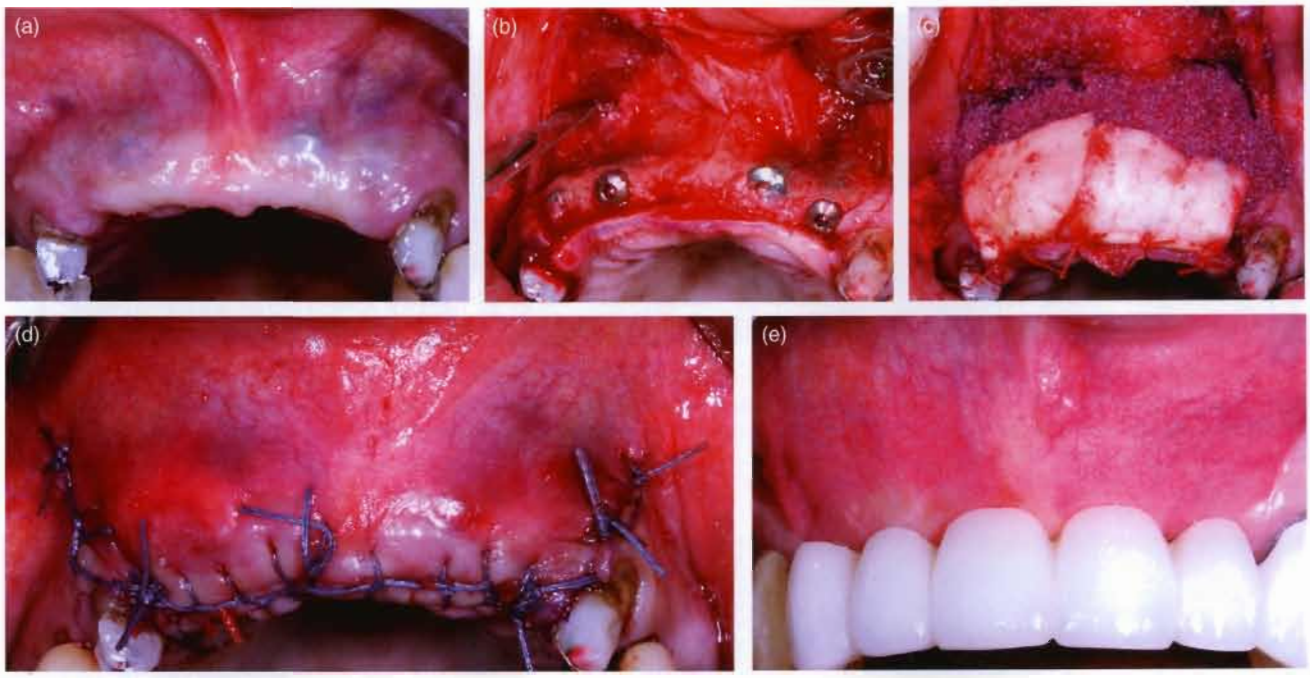

Figure 8.14 **(a)** Anterior maxilla in an adult female patient showing exposure and thinning of bone and soft tissue over previously placed implants due to down-growth in the lingual vector of the alveolus. **(b)** Flaps elevated and bone exposed. **(c)** Grafting crestally with Symbios non-resorbable OsteoGraf LD-300 and overlayed with Biohorizon AlloDerm. The AlloDerm is stabilized with resorbable sutures. **(d)** Flap advanced and closed primarily. **(e)** Two months post-operatively. Anterior maxilla reconstructed to compensate for facial resorption.

Summary

Clinical challenges of implant placement in adult patients have not been addressed adequately. Although infraocclusion, open contacts adjacent to implant restorations, thread exposure, and such have been discussed, a systematic approach for pre-treatment and intra-operative changes have to be included in order to compensate for the changes with time. The adult face undergoes normal dynamic physiologic aging, which results in diminished bone volume and structural changes over both teeth and implants. Those cumulative factors cannot be avoided. However, with proper care, its esthetic and functional impact on implant reconstruction can be diminished (Table 8.3).

Table 8.3 Clinical risks and conclusions.

Craniofacial changes continue throughout adult life
Onset differs in the two sexes
Informed consent that takes account of changes with time is necessary
Risks differ among patients (e.g., patients with high smile lines and significant esthetic demands will create greater difficulties)
Pre-operative analysis and protocol should be modified as appropriate
Asymmetrical implant placement creates a higher risk than symmetrical placement
Site recovery is challenging, especially in the esthetic zone

References

1 Behrents RG: *Growth in the Aging Craniofacial Skeleton* [monographs 17 and 18]. University of Michigan, Ann Arbor, MI, 1985.
2 Bishara SE, Treder JE, Jakobsen JR: Facial and dental changes in adulthood. *Am J Orthod Dentofac Orthop* 1994;**106**:175–186.
3 Forsberg CM: Facial morphology and aging: a longitudinal cephalometric investigation in young adults. *Eur J Orthod* 1979;**1**:15–23.
4 Oesterle LJ, Cronin RJ: Adult growth, aging, and the single-tooth implant. *Int J Oral Maxillofac Surg* 2000;**15**:252–260.
5 Albert AM, Ricanek K, Patterson E: A review of the literature on the aging adult skull and face: implications for forensic science research and applications. *Forensic Sci Int* 2007;**172**:1–9.
6 Coleman SR: The anatomy of the aging face: volume loss and changes in 3-dimensional topography. *Aesthet Surg J* 2006; (Suppl): S4–S9.
7 Shaw RB, Katzel EB, Koltz P, et al: Aging of the facial skeleton: aesthetic implications and rejuvenation strategies. *Plast Reconstr Surg* 2011;**127**:374–383.
8 Kahn DM, Shaw RB: Aging of the bony orbit: a three-dimensional computed tomographic study. *Aesthet Surg J* 2008;**28**:258–264.
9 Doual JM, Ferri J, Laude M: The influence of senescence on craniofacial and cervical morphology in humans. *Surg Radiol Anat* 1997;**19**:175–183.
10 Donofrio LM: Fat distribution: a morphologic study of the aging face. *Dermatol Surg* 2000;**26**:1107–1111.
11 Clauser LC, Tieghi R, Galiè M, Carinci F: Structural fat grafting: facial volumetric restoration in complex reconstructive surgery. *J Craniofac Surg* 2011;**22**:1695–1701.
12 Little JW: Volumentric perceptions in midfacial aging with altered priorities for rejuventation. *Plast Recon Surg* 2000;**105**:252–266.
13 Shaw RB JR, Katzel EB, Koltz PF, et al: Facial bone density: effects of aging and impact on facial rejuvenation. *Aesthet Surg J* 2012;**32**:937–942.
14 Carmichael RP, Sandor GK: Dental implants, growth of the jaws, and determination of skeletal maturity. *Atlas Oral Maxillofac Surg Clin North Am* 2008;**16**:1–9.
15 Enlow DH: *Handbook of Facial Growth*. WB Saunders, Philadelphia, PA, 1990.
16 Tallgren A, Solow B: Age differences in adult dentoalveolar heights. *Eur J Orthod* 1991;**13**:149–156.

17 West KS, McNamara JA: Changes in the craniofacial complex from adolescence to midadulthood: a cephalometric study. *Am J Orthod Dentofac Orthop* 1999;**115**:521–532.
18 Shaw RB, Katzel EB, Koltz PF, et al: Aging of the mandible and its aesthetic implications. *Plast Recon Surg* 2010;**125**:332–342.
19 Bondevik O: Growth changes in the cranial base and the face: a longitudinal cephalometric study of linear and angular changes in adult Norwegians. *Eur J Orthod* 1995;**17**:525–532.
20 Op Heij DG, Opdebeeck H, van Steenberghe D, et al: Facial development, continuous tooth eruption, and mesial drift as compromising factors for implant placement. *Int J Oral Maxillofac Implants* 2006;**21**:867–878.
21 Björk A: Variations in the growth pattern of the human mandible: a longitudinal radiographic study by the implant method. *J Dent Res* 1963;**42**:400–411.
22 Bishara SE, Treder JE, Damon P, Olsen M: Changes in the dental arches and dentition between 25 and 45 years of age. *Angle Orthod* 1996;**66**:417–422.
23 Bondevik O: Changes in occlusion between 23 and 34 years. *Angle Orthod* 1998;**68**:75–80.
24 Enlow DH: The "V" principle. *Am J Orthod* 1984;**85**:96.
25 Enlow DH: A study of the post-natal growth and remodeling of bone. *Am J Anat* 1962;**110**:79–101.
26 Enlow DH: A morphogenetic analysis of facial growth. *Am J Orthod* 1966;**52**:283–299.
27 Enlow DH, Harris DB: A study of the postnatal growth of the human mandible. *Am J Orthod* 1964;**50**:25–50.
28 Sarnas KV, Solow B: Early adult changes in the skeletal and soft-tissue profile. *Eur J Orthod* 1980;**2**:1–12.
29 Opdebeeck H, Bell WH: The short face syndrome. *Am J Orthod* 1978;73:499–511.
30 Opdebeeck H, Bell WH, Eisenfeld J, Mishelevich D: Comparative study between the SFS and LFS rotation as a possible morphogenetic mechanism. *Am J Orthod* 1978;**74**:509–521.