Chapter 21
Planning and Assessment of Alveolar Bone Reconstruction for Dental Implants

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1. The Edentulous Residual Alveolar Ridge

Tooth loss leads to many challenges in order to restore the dentition for esthetics and function. These challenges range in complexity from simply selecting the appropriate type of prosthesis and supporting teeth (as with traditional prosthodontics) to more advanced, such as planning and performing therapies to maintain the residual alveolar bone or furthermore, to reshape or reconstruct the alveolar ridge with grafts in edentulous sites which have lost normal contours. The ultimate goal is directed towards compensating for tooth loss with dental implants. While shape and size of the residual alveolar ridge are important for function and esthetics in fixed and removable prosthetics, these become critical when dental implants are used to restore an edentulous space. In these circumstances, maintenance of the native bone or reconstruction of the atrophic jaw is mandatory.

The long-term success of dental implants relies on the fact that they must be embedded in a prosthetically driven location in structurally sound bone. As described in Chap. 19, adequate cortical and pericircumferential bone coverage around implants is of utmost importance. When this is compromised, the esthetic and biological osseointegrative success of the implant is guarded.

After tooth loss, the alveolar bone in the edentulous space undergoes progressive remodeling. In most cases, remodeling occurs slowly and gradually. Several factors have been identified as contributory to post-tooth extraction alveolar bone resorption, a term that includes all changes that may occur after tooth loss. These factors include the age of the individual, the extent of the deficient alveolar ridge (determined by the number of teeth extracted and the size
of the residual defects), the time elapsed since tooth loss, and the jaw (maxilla or mandible).

1.1. Evaluating and Intercepting Alveolar Bone Resorptive Patterns

When tooth replacement is considered using fixed or removable partial prosthetics, post tooth extraction alveolar bone resorption is expected, let alone bone reconstructive strategies considered. However, if tooth replacement by implant supported restorations are considered, implementing therapies to intercept and prevent alveolar bone loss either prior to or immediately after tooth extraction may delay resorption or alter resorptive patterns that may reduce the need for possible future therapeutic or surgical interventions.

The evaluation of the degree of atrophy for an established residual alveolar ridge in a partially or completely edentulous patient is necessary to classify the existing resorption and comprehend the available alveolar bone volume. As described in detail in Chap. 19, both qualitative and quantitative approaches are possible to characterize the morphology of the residual alveolar ridge defect. While the most extensive descriptive categorization has been proposed by Cawood and Howell (1988), the ITI SAC (International Team for Implantology Straightforward, Advanced and Complex) (Chen et al. 2009) system describing the bone defect in relation to surgical treatment plan implications has greater clinical application. In summary, alveolar bone volume is classified as: (1) Sufficient, (2) Deficient horizontally but allowing simultaneous augmentation, (3) Deficient horizontally requiring prior or bone augmentation, and, (4) Deficient vertically and/or horizontally, requiring prior bone augmentation.

In addition to classifying residual alveolar ridge morphology as to the amount of available bone volume (height and width) and potential need for osseous reconstruction, the clinician should consider the following questions:

- Is the site of interest present in a partially or completely edentulous location?
What is the quality of the alveolar bone in the sites under examination?

What is the alveolar ridge morphology?

What specific local bone deficiencies exist (compromised cortical plates, anatomic or cortical deficient concavities, etc.)?

What is the integrity of cortical plates, particularly at recent tooth extraction sites?

What is the degree of healing that has occurred at recent extraction sites?

After evaluating and classifying the residual alveolar ridge and taking specific considerations into account then decisions regarding the need for augmentation (based on the morphologic features of the alveolar bone), the type of augmentation procedure necessary, and the use of graft types most suitable for certain types of deficiencies can be made and the prognosis of a successful augmentation determined.

1.2. The Role of Cone-Beam Computed Tomography

Cone Beam Computed Tomography (CBCT) is the imaging modality of choice to evaluate, classify, and address specific clinical diagnostic concerns regarding the residual alveolar bone in an edentulous space and often for the periodic evaluation of any grafting procedure.

CBCT provides outstanding detail and anatomic accuracy necessary for the assessment of the osseous structures of the maxillofacial region and their anatomical boundaries. Potential osseous defects can be analyzed from all perspectives including volumetric three-dimensional (3D) representations of alveolar resorption patterns. The internal trabecular structure and quality of cancellous bone, and peripheral cortical thickness is readily discernible with CBCT. If the scan is performed with the patient’s dentition closed and the FOV extends to the teeth of the opposite dental arch, CBCT may also reveal the
available restorative space. More detailed analysis of the contribution of CBCT in the assessment of the alveolar bone is beyond the scope of this chapter (See Chap. 19).

2. Materials and Methods Used to Reconstruct the Residual Alveolar Ridge

2.1. Autogenous Grafts and Bone Substitutes (Allografts, Xenografts, and Alloplasts)

Thorough implant treatment planning should also consider the possibility of alveolar reconstructive options when deficiencies exist in the alveolar bone at prosthetically important sites. A variety of materials has been used for that goal. Autogenous bone remains the “gold standard” of grafting materials, and is still the only vehicle of true osteoinduction.

Allografts are tissue grafts originating from donors of the same species but different genotype and are mostly human cadaveric material. They possess some osteoinductive capability, and may be combined with BMPs (Bone Morphogenetic Proteins), rPDGF (recombinant platelet-derived growth factor), and other biomolecules that induce bone growth, that are native to the bone filler material or mixed with it.

Xenografts are grafts that originate from donors of a different species whereas alloplasts are minerals like hydroxyapatite, which are naturally present in bone. These graft materials are primarily vehicles of osteoconduction and creeping substitution-(Becker et al. 1994; van Steenberghe et al. 2000; Maréchal et al. 2005; Molly et al. 2006).

On CBCT images, autogenous bone and allograft materials will appear relatively hypodense, whereas a xenograft will appear hyperdense and generally possesses greater dimensional stability, which is one of its advantages. Functionally, the key to successful xenograft placement is vascularized bone, so a xenograft may be more stable as a scaffold. However, because the resorptive properties of these grafts are poor, they may be more prone to infection or react as
a foreign body. Their physical stabilizing property also helps preserve microarchitecture and prevent resorption once well incorporated.

Another class of bone grafting materials includes a reverse-phase putty-based combination of demineralized human bone matrix, naturally occurring growth factors, and BMPs that can be molded and packed into an irregularly shaped defect (Accell Connexus®, Keystone Dental, Burlington, MA, USA). This material may have a bone like appearance on CBCT (Figs. 21.1 and 21.2).

Choices of bone augmentation materials are driven by a combination of individual practitioner’s preference, appraisal of the available literature as well as objective clinical experience and results obtained with specific techniques and materials.

Vital bone volume is an important consideration in guided bone regeneration (Buser 2009). A bone substitute material applied used in alveolar ridge preservation or reconstruction should resorb and remodel similarly to new bone to facilitate implant placement. Low substitution-rate or nonresorbable material such as an inorganic bone matrix xenograft (e.g., BioOss®, Geistlich Pharma North America, Inc., Princeton, NJ, USA) or alloplasts (e.g., Perio-glas®, Novabone, Jacksonville, FL, USA) may offer advantages in certain applications, such as in esthetic sites (Buser 2009). These materials control dimensional aspects of sites with high esthetic demand by adding structural support to underlying bone, in support of esthetically critical soft-tissue architecture (Buser 2009).

2.1.1. Tissue Engineering

Tissue engineering is the use of a combination of cells, engineering, materials, methods, and suitable biochemical and physicochemical factors to improve or replace biological functions. Tissue engineering involves the use of a scaffold for the formation of new viable tissue for a medical purpose. Its objective is the de novo bone formation by recapitulating fetal intramembranous bone growth. There are different ways for this to be accomplished:
• Use of biomolecules like protein-peptides where the therapeutic state of the art exists today, best exemplified by recombinant human bone morphogenetic protein 2 (rhBMP-2).
• Use of mitogens (proteins that induce cell division).
• Cell-based therapy. This includes the use of mesenchymal stem cells, such as those available from the iliac crest at the time of surgery for oncologic as well as oral and maxillofacial surgical procedures.
• Gene-based/RNA therapeutic strategies (Rios et al. 2011).
• Scaffold fabrication technology.
• Laser technology.

Most applicable techniques of tissue engineering in alveolar bone augmentation seem to be the utilization of molecules like rhBMP-2 or mitogens like platelet-rich plasma (PRP), plasma-rich growth factor (PRGF), platelet-rich fibrin (PRF), and platelet-derived growth factor (PDGF). These materials accelerate angiogenesis and favorable bone formation. Emerging regenerative approaches for periodontal reconstruction has been recently published by Cochran et al. (2015).

2.2. Graft Techniques

A number of osseoconductive surgical procedures have been designed to increase the amount of bone available locally without bone grafting (Table 21.1). Bone grafting has been used to maintain or reshape the atrophic alveolar bone and restore the dimensional morphology of the residual ridge. These along with proper bone quality are considered the foundations for successful implant placement. The use of osteoconductive materials such as growth factors, bone morphogenetic proteins, and cytokines have been tested in animal studies (Preti et al. 2007; Stadlinger et al. 2008).

<table>
<thead>
<tr>
<th>Table 21.1 Methods to reconstruct deficient alveolar ridges</th>
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<td>Category</td>
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<td>Local</td>
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<td>Surgical</td>
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<td>Procedures</td>
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<tr>
<td>Crestal split technique</td>
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<td>Guided bone regeneration (GBR)</td>
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<td>Distraction osteogenesis</td>
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**Bone Grafting Procedures**

| Autogenous | Cortical and cancellous bone grafting harvested from the same individual. Most common cortical harvesting sites include ribs, the iliac crest, ascending ramus, and mandibular symphysis. Cancellous harvesting mostly from iliac crest. | Cortical used to onlay large areas such as decreased vertical or horizontal alveolar ridges. Cancellous used to fill  
alveolar clefts and maxillary sinus floor augmentations. |
| Allografts | Non-vital osseous tissue harvested from one individual and transferred to another individual of the same species. There are three forms of allogeneic bone: <span class=""">Fresh frozen (not used now), freeze-dried and demineralized bone (FDBBM)</span>. Demineralized Bone Matrix (DBM) is incorporated into carriers such as collagen or selected polymers to form putties. | Freeze dried used to onlay areas or as a crib to retain autogenous bone graft. DBM is most commonly used in extraction sites to prevent ridge resorption, alveolar ridge reconstruction and bone expansion (e.g., sinus augmentation). |
| Xenografts | Skeletal tissue harvested from one species (mammalian bones such as bovine, porcine, equine or murine or fill defect or extraction site to preserve alveolar ridge. May require retentive |


<table>
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<tr>
<th>Alloplastic bone substitutes</th>
<th>Coral exoskeletons) transferred to the recipient site of another species. Usually powder</th>
<th>Structure (e.g., membrane, miniscrews)</th>
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<tbody>
<tr>
<td>Synthetic substances (hydroxyapatite, other ceramics and polymers)</td>
<td>Used as fillers and expanders often in association with autogenous bone grafts</td>
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2.2.1. Alveolar Bone Maintenance/Extraction Socket Preservation

After tooth extraction, the alveolar bone usually undergoes rapid morphologic changes after healing is established and present as resorption of the alveolar ridge. Various anatomic, metabolic, and functional factors affect the rate of resorption and final morphology of the alveolar process (Atwood 1957). Generally, the labial cortical plates are most affected and undergo resorption reducing bone volume and altering the buccal contour, resulting in the reduction of the alveolar bone width (Araujo et al. 2015a, b). This is most likely as a result of the reduced thickness of the cortical plate and the higher incidence of dehiscence associated with the tooth roots (Irinakis 2006). Bone volume reduction is principally caused by horizontal alveolar changes rather than a reduction in vertical height (Araujo et al. 2015a, b).

The time after tooth extraction is an important determinant of the residual ridge resorption rate. Most loss of tissue contour in the alveolus involving narrowing of the ridge occurs within the first 6 months after tooth extraction. These changes occur at a greater rate in the maxilla than the mandible (Araujo et al. 2015a, b) most likely due to the increased vascularity of the maxillary bone. At the completion of healing, alveolar bone height is often reduced as compared to pre-extraction levels (Irinakis 2006).

Understanding of the pattern of alveolar bone resorption underscores the need for atraumatic extraction and appreciation of the available strategies to preserve ridge volume overall (Araujo et al. 2015a, b). It is now acceptable practice that to arrest the effects of ridge resorption immediately after the removal of a tooth, the
fresh extraction socket should be treated with grafting material, a barrier membrane, or both (Isaella et al. 2003; Artzi et al. 2000). Araujo et al. (2014) proposed a ridge preservation strategy involving xenograft placement in fresh maxillary extraction sockets that resulted in a significant reduction in post-extraction hard tissue cross-sectional area on CBCT at 4 months (3%) versus a control (25%) (Figs. 21.1 and 21.2).

2.2.1.1. Value of CBCT Imaging

The role of CBCT is crucial in the initial assessment of the pre-extraction site for the periodic evaluation of the graft integration or maturation. CBCT is the only dental imaging modality that provides the detail necessary to assess the integrity of the facial and lingual/palatal cortical plates adjacent to the tooth to be extracted. Specifically, CBCT can provide information on the thickness of the cortical plates and risk of possible fracture, and presence of fenestrations or dehiscences that may compromise the cortical plates. Post-operatively CBCT provides useful information about the progress of integration of the graft, graft stability, and possible complications (Fig. 21.3).

Many different types of grafting materials are available for socket preservation. The imaging appearance of grafted sites on CBCT depends on its type, composition, and the time elapsed since the procedure was performed. Rarely are these features reported to the maxillofacial radiologist. Autografts often appear as osseous fragments, similar to the adjacent cortical bone. Some grafts consist of different sizes of granules and demonstrate a particulate hyperdense appearance, a heterogeneous conglomerate of medium to high opacity and attenuation within the defect (e.g., alloplasts such as hydroxyapatite-based Perioglas®) (Fig. 21.4). Others graft materials (e.g., xenografts composed of inorganic bone matrix) are smoother and show a more homogenous lower density appearance (e.g., BioOss®).

It is crucial for the clinician who seeks expert interpretive consultation to provide all relevant clinical information to facilitate assessment of the status of a bone graft.
While no standardized radiographic features have been defined to assess the success of a grafted site, some parameters are useful to consider when a socket preservation graft (or any graft) is evaluated with CBCT:

- Has the graft contributed in maintaining (preserving) the dimensional stability of the grafted site (extraction socket)? Specifically, has the alveolar bone maintained the initial shape and size after the grafting procedure?
- Is the grafted site homogenous in density and how does it compare to the surrounding native bone? Are any voids present or areas of density similar to that of soft tissue?
- Is there any part (or parts) of the graft which is separated from the main body of the graft?
- What is the contact interface of the graft to the surrounding bone (or extraction socket)? Is there a tight contact between the graft and the native bone or there are areas separated?
- In the case of a graft which has been placed to preserve a socket with a compromised buccal/lingual plate, has the graft achieved to establish a stable buccal/labial boundary? Does this maintain the natural contours of the bone with a smooth and rounded outline?

A successful socket preservation graft usually maintains the anatomical contours of the alveolar ridge even if dehiscences are present. These grafts are usually homogenous hyperdensity without any voids. Depending on the material used, some grafts may be of a somewhat lower density than that of the surrounding cancellous bone. If granulated, the grafting material granules should demonstrate even distribution without any soft tissue inter-dispersed. Finally, the graft should demonstrate a very tight contact with the extraction socket with no separation from inner aspect of the socket wall (lamina dura).

Socket preservation procedures involving grafting is fairly straightforward surgical procedure with a high success rate (Apostolopoulos and Darby 2016; Covani et al. 2014). Given the reliability of this procedure to maintain the
dimensional morphology of the alveolar ridge, it is likely that CBCT will be used more often for site assessment and graft evaluation prior to implant osteotomy.

2.2.2. Horizontal and Vertical Alveolar Ridge Augmentation

Restoring the anatomical contours of the severely atrophic alveolar crest of either the maxilla or mandible is challenging. The pattern of resorption in these situations is such that the alveolar ridges are no longer representative of the location of teeth. In fact, since the tooth-bearing bone is no longer present, the spatial relationship between existing teeth (in the partially dentate edentulous space) and the residual bone available for implant placement is markedly discordant. This implies that not only is there insufficient alveolar bone available to place a dental implant based on the occlusal considerations of the implant retained prosthesis, but also, pending on the extent and severity of resorption, there is most likely inadequate facial contours to provide soft tissue support (Figs. 21.5 and 21.6).

In partially dentate situations, the existing occlusal scheme determines the type and amount of reconstructive surgery necessary to restore a deficient alveolar ridge. In completely edentulous situations, the redesigned occlusal platform and scheme will dictate the location of implants and therefore the kind of ridge augmentation needed to facilitate implant positioning. Alveolar ridge augmentation may be necessary in the horizontal dimension to increase the width of the alveolar bone, in the vertical dimension to increase the height of the alveolar bone, or in both dimensions. The more extensive the grafting procedure, the more complex and challenging it becomes.

Several methods have been described for the augmentation of the bone height and/or width of the deficient alveolar ridge (Table 21.1). These include guided bone regeneration (GBR) with and without particulate grafting materials, alveolar ridge splitting, distraction osteogenesis, and the utilization of block “onlay” grafts. Both particulate and block grafts can be used for either horizontal or vertical augmentation.
2.2.2.1. Onlay Block Grafts

Donor sites for “onlay” grafts may be intraoral or extraoral from the patient themselves or from cadaveric donors (Toscano et al. 2010). The most common intraoral sources are the mandibular symphysis (chin region) and the anterior border of the ascending mandibular ramus whereas the most common extraoral sources include the iliac crest, parietal cranial bone (calvarium), tibial plateau and ribs (Indrontino and Valente 2016). Block grafts are not as widely used as particulate grafts which tend to vascularize more quickly and with the advent of tissue engineering techniques. Onlay grafts are commonly retained with narrow diameter, self-tapering fixation miniscrews (Figs. 21.7 and 21.8) Cortical-cancellous onlay grafts (e.g., symphysis) are preferred as the presence of the cancellous component facilitates faster vascular in growth after placement, faster integration (osteogenesis) and less potential resorption after healing (Hammack and Enneking 1960). When cortical grafts are used they may be fixated using a miniscrew with a “filler” of autogenous graft material (e.g., bone marrow). In this situation cortical bone is used for space maintenance and stability whereas the autogenous graft material is osseoinductive. Failure of this grafting technique may involve either the cortical onlay component or lack of osseoinductive “fill” of the autogenous graft (Fig. 21.9).

2.2.2.2. Particulate Grafts

Particulate grafts are more commonly used in dento-alveolar regenerative procedures because they are more easily vascularized and pose less morbidity for the patient. Small-particle autogenous grafts can be combined with cortico-cancellous allograft, xenograft, or tissue engineering, as with the use of BMP-2 (Mandelaris et al. 2015) and physically retained with biomembrane with or without miniscrew “tenting” technique (Figs. 21.10 and 21.11) or miniscrew retained metallic mesh (Figs. 21.12, 21.13, 21.14, and 21.15). The production of inexpensive biomodels can be used to preshape and prebend mesh, saving considerable intraoperative time (Figs. 21.16 and 21.17).
Despite the fact that CBCT imaging has markedly enhanced the three-dimensional assessment of bone for “onlay” grafts, no radiologic standardized criteria exist regarding the successful integration of these types of grafts. The large number and different types of grafting materials used, their different origin and properties, different forms (variability in size granules and consistence such as putty or paste), their different density and mechanism of action (e.g., scaffolding, osseoconduction, osseoinduction), and degree of maturation make it difficult to identify characteristic radiographic features that suggest success or failure. Although periodic radiologic assessment of an alveolar bone graft is not specifically contra-indicated (especially those applied to extensive areas of the ridge), conclusions should not be drawn about the integration or bone formation progress at early stages after surgery, especially if the post-operative progress is uneventful and without complications (Bornstein et al. 2014; Harris et al. 2012). Therefore, it is recommended that bone augmentation be evaluated by CBCT after the completion of bone maturation (4 months to 6 months for most graft materials). At that time, the anatomical contours of the deficient bone should have been reshaped, the graft is fairly homogenous in density and that the contact between the graft and the native bone is “tight” and continuous without any soft tissue undermining the graft (Figs. 21.18 and 21.19). These radiologic findings are highly suggestive of a successful ridge augmentation. However, ultimately, the successful grafting procedure is judged mostly by the end result determined clinically and at the time of implant osteotomy. This includes considerations of the stability of the graft, its homogeneous nature, gross appearance, and its density. A core biopsy of the graft, where the percentage of newly formed osseous tissue is calculated, appears to be a generally accepted objective method to assess true success.

3. Maxillary Sinus Elevation and Grafting (MSEG)

For almost 30 years MSEG has been the mainstay of implant-directed maxillary reconstruction in situations in the posterior maxilla with inadequate bone height
The sinus lift technique was first described by Boyne and James (1980) as a combination of a lateral window osteotomy followed by elevation of the floor of the maxillary sinus and insertion of a bone like graft material.

Two surgical approaches can be used either to simply raise the sinus lining or to additionally introduce bone regenerative material under the Schneiderian membrane.

### 3.1. Techniques

- **Lateral Window Approach (LWA).** The technique is essentially a lateral antrostomy which involves the creation of a rectangular osseous window through the lateral wall of the maxillary sinus which is elevated as a hinge superiorly (Tatum 1986). Careful elevation of the mucoperiosteum of the maxillary sinus (Schneiderian membrane) is performed creating a soft tissue pocket below which bone augmentation material is compacted (Fig. 21.20). The amount of bone augmentation material placed depends on the amount of existing residual ridge resorption of the edentulous space and the length of the planned implant. This technique is usually performed for multiple implant sites. Various modifications of the technique have been reported without the creation of a bony hinge, and implants are either placed simultaneously or in a delayed procedure following bony remodeling of the augmentative material (Bornstein et al. 2008).

- **Trans-Alveolar Osteotomy (TAO).** A more conservative approach is a trans-alveolar osteotomy which uses osteotomes through the crestal bone to raise the Schneiderian membrane and perform a ridge expansion osteotomy superiorly (Summers 1994). In general, xenograft particulate graft materials are more compatible with this approach, because of their greater visibility. This technique is usually performed for a single implant site, however variations
include crestal core elevation (Toffler 2001), and the localized management of the sinus floor (Fig. 21.21) (Bruschi et al. 1998).

Survival rates for implants placed using either of these procedures are greater than 90% (Del Fabbro et al. 2004); however, presurgical- and sometimes postsurgical radiographic evaluation of the maxillary sinus is advisable (Tyndall et al. 2012).

3.2. Presurgical CBCT Assessment

Assessment of the maxillary sinus condition with consideration of the integrity of Schneiderian membrane prior to MSEG is important to minimize possible post-operative complications. Even in maxillary sinuses with absent signs of disease (e.g., mucosal thickening), minor post-operative sequelae are expected as MSEG surgical procedures may impair physiological maxillary drainage into the middle meatus by inducing transient inflammatory peri-ostial swelling or other mechanisms predisposing to acute maxillary sinusitis. However, sinus mucosa most often recovers well after MSEG surgery, with a prompt return to normal homeostasis, especially if sinus drainage is good (Stammberger 1986; Jensen et al. 1998; Timmenga et al. 2003).

Compared to panoramic radiography, CBCT imaging provides a significantly higher detection rate of sinus mucosal hypertrophy with a concomitant increase in surgical confidence and a significantly better prediction of complications (Caciut et al. 2013).

3.2.1. Surgical Considerations

- **Access.** The site for the access osteotomy should be approximately 3–4 mm above the apical base of the maxillary sinus through the buccal plate. This ensures optimal access for proper elevation of the Schneiderian membrane from the medial wall of the sinus.

- **Buccal cortical plate.** Adequate buccal cortical plate should be available to allow dissection of the inferior aspect of the membrane from the floor of the maxillary sinus and to elevate it upward to
create a space in the floor of the sinus for the bone-graft material. Cross-section or coronal CBCT imaging provides location specific measurements to optimize this access.

- **Schneiderian Membrane Thickness.** In both techniques, a possible major complication is perforation of the Schneiderian membrane during the surgical procedure. Perforation increases the possible side effects of graft loss, infection that causes disruption of sinus function, and even implant survival (Viña-Almunia et al. 2009). Ideally the sinus should be disease free or have minimal mucosal thickening (<3 mm), which would potentially compromise vascularity and healing. Assessment of sinus membrane thickness prior to MSEG provides a potential index of perforation. For both the LWA (Lin et al. 2015) and TAO (Wen et al. 2014) techniques, lowest perforation rates occur when the membrane thickness as measured on CBCT images is 1–1.5 mm and higher when membranes are thicker (≥2 mm) or thinner (<1 mm).

- **Local anatomy.** Intraosseous canals containing arterial vessels such as in the lateral antral wall (posterior superior alveolar) and on the palatal aspect of the maxillary canine should be identified so that they are avoided during surgery (Mardinger et al. 2007). Compared to CBCT imaging, panoramic radiography is unable to detect these canals and underscores the mesio-distal distance of available bone in the upper premolar region (mean 2.9 mm, range 0.1–7.5 mm). (Temmerman et al. 2011).

- **Patency of the maxillary sinus ostia.** In addition, any condition that could lead to obstruction of the ostium and therefore drainage of the maxillary sinus may be a possible contraindication to the procedure. The ostia should be patent (Fig. 21.22); however, localized mucosal thickening of the ostium and concha bullosa (pneumatized inferior turbinate) should be noted. While mucosal thickening of the inferior medial or lateral wall of the maxillary sinus associated with chronic
sinusitis is not a contraindication to the procedure, careful consideration should be given to situations in which elevation of a thickened mucosa will lead to a mechanical obstruction of the ostium (Figs. 21.23 and 21.24).

3.2.2. Clinical Contraindications

From the otolaryngologist’s (Pignataro et al. 2008; Torretta et al. 2013) and maxillofacial surgeon’s (Ozyuvaci et al. 2005) perspectives, many common anatomical alterations, such as mild nasal septal deviation, small concha bullosa or paradoxical middle turbinate not associated with history or evidence of sinus disease are not contraindications to MSEG. However, it is important to identify maxillary sinus conditions that are treatable and potentially reversible from those that are irreversible and are likely to jeopardize a successful outcome and need management or surgical treatment prior to MSEG.

3.2.2.1. Relative Contraindications

Many conditions are present in the maxillary sinuses that are a low risk for MSEG related complications. Many are anatomic in nature, potentially compromising sinus ventilation, whereas others are pathologies, presumably reversible either pharmacologically (e.g., by the use of preoperative topical steroid therapy or nasal irrigants) or by functional endoscopic sinus surgery (FESS) before MSEG. These include:

- Conditions impairing the maxillary sinus drainage pathways. Nasal septal deviation, paradoxical bending of the middle turbinate, and concha bullosa.
- Inflammatory conditions. Allergic rhinitis.
- Conditions causing mild luminal opacification (less than 1/3rd to ½ luminal opacification. Presence of polypoidal mucosal thickening, CRS, or retention pseudocysts (Kara et al. 2010) on the floor or walls that, with elevation, are unlikely to obstruct the maxillary ostia.
3.2.2.2. Absolute Contraindications

Conditions that require treatment prior to MSEG procedures include any condition that occludes the ostia or has the potential to occlude the ostia including:

- Patients with ARS.
- Conditions causing moderate to severe luminal opacification (greater than 1/3rd to ½ luminal opacification. Presence of polypoidal mucosal thickening, CRS$_2$ or retention pseudocysts (Kara et al. 2010) on the floor or walls that, with elevation, are likely to obstruct the maxillary ostia.
- Suspected benign or malignant sinonasal neoplasms.
- Concomitant presence of odontogenic pathology. Odontogenic cysts, tumors, or periapical infections of odontogenic origin.

3.2.3. Graft Simulation

Because of the variability of the maxillary sinus volume, software measurements on CBCT panoramic and cross-sectional imaging can provide potential volume estimates of the graft material to be used. This guards against the possibility of overfilling the maxillary sinus and occluding the ostium.

Some software allows addition of solid material into either cross-sectional or panoramic images (Fig. 21.25). This is most commonly performed to simulate bone augmentation in the maxillary sinus associated with a sinus lift procedure. This is applied by either designating the confines within which the material is to be added or simply painted in successive axial or cross-sectional contiguous frames. Qualitative dimensions both linearly and volumetrically can be derived from these simulations to assist pre-operatively in defining the limits of bone harvest material or amount of synthetic bone that is needed to bone placement to ensure against over- and under-filling (Fig. 21.26).

3.3. Postoperative Radiographic Patterns

Evaluation of the results of the sinus augmentation procedure 6 months to 8 months after placement of the graft material and prior to implant placement is
advisable to confirm the presence of adequate bone. Graft material has a porous structure and gains radiodensity on CBCT as osseointegration and osteogenesis progresses. CBCT radiographic imaging appearance appearances of the post-surgical MSEG maxillary sinus depends on the technique used and degree of condensation of graft material.

- **TAO.** The osteotome technique results in a small, dome-shaped homogeneous dense radiodensity arising from the base of the sinus floor adjacent to the apical portion of the implant- (Fig. 21.27).

- **LWA.**

  - *Globular, well-condensed, homogeneous, particulate hyper-dense mass.* A hyperdense mass juxtaposed the potential dental osteotomy site in the edentulous alveolar region exhibiting excellent adaptation to the floor and walls (Fig. 21.28). This finding suggests well-condensed bone augmentation material with optimal osseointductive effect. There may be mild to moderate mucosal thickening immediately superior to the graft material. Primary dental implant stability (achievable insertion torque) is likely optimal.

  - *Irregular heterogeneous particulate hyper-dense mass with irregular areas of soft tissue/fluid hypodensity.* Incomplete or partial condensation of the bone augmentation material adjacent to the potential dental osteotomy site suggests a poorly condensed host graft material with compromised osteogenic potential and possible bone microbial contamination (Fig. 21.29). Adaptation to the floor and walls is intermittent. Bone volume and primary dental implant stability may be less than optimal.

  - *Diffuse particulate hyper-dense aggregates within soft tissue/fluid hypodensity.* Incomplete or partial condensation of the bone augmentation material adjacent spread out over the floor or within the lumen of the maxillary sinus with poor adaptation to the floor and walls (Figs. 21.30 and 21.22). Bone volume is likely inadequate
for dental implant placement and primary dental stability is expected to be poor (Fig. 21.31).

- **Completely dispersed or displaced hyperdense mass within soft tissue/fluid hypodensity.** Lack of bone augmentation with minimal accumulation adjacent the potential dental osteotomy site (Fig. 21.32). Completely detached hyperdense mass “floating” within soft tissue/fluid or scattered particulate hyperdensities throughout the sinus indicate lack of bone augmentation material condensation and integration.

- **Loss of integrity or collapse of the lateral wall.** Lack of stability of the graft material, infection, or biomembrane collapse due to external forces can result in physical displacement of the graft material further into the maxillary sinus lumen and loss of desired morphology of the residual alveolar ridge (Fig. 21.33).

### 3.3.1. Long-Term Changes in Graft Volume

Few studies have evaluated the stability of the height and volume of the bone graft over the long term (Forum et al. 1998; Hallman et al. 2002; Hatano et al. 2004; Harris et al. 2012; Baciut et al. 2013; McCrea 2014; Kim et al. 2014). Reports generally indicate that MSEG bone graft height is progressively lost post-operatively and, in some instances, may even resorb to the level of the original sinus height. Most resorption usually occurs within the first 3 years after the bone graft. Average bone height loss is approximately 3.2 mm (Kim et al. 2014) or up to 32% volumetric loss after almost 3 years post-operatively. Type of graft material (e.g., autogenous bone±bone substitute), surgical method (LWA or TOA) and stages of surgery (one- vs. two-stage surgery) and residual alveolar bone height may all influence total resorption and resorption rates (Peng et al. 2013).

### 4. Immediate Implant Placement

Immediate implant placement (IIP) and restorative provisionalization for single maxillary anterior failing teeth is a Complex SAC procedure (Dawson and Chen
2009) with high success rates if specific clinical guidelines are adopted. These include the maintenance of intact labial cortical bone, absence of adjacent infection, the use of adjunctive soft and hard tissue graft material and planning the positioning of the implant to achieve primary stability by engaging the palatal aspect of the socket and bone 4–5 mm apical to the base of the socket. In addition, a buccal gap is desired of at least 2 mm facial to the implant which helps in determining the implant width to be used. A pre-surgical CBCT is very important in determining the feasibility of IIP by assessing root length, sagittal root position (SRP), and the morphology of the residual alveolar housing (Levine et al. 2014a, b, c; Chung et al. 2011; Tsuda et al. 2011).

4.1. Sagittal Root Position

Assessment and classification of SRP of maxillary anterior teeth (Table 21.2) (Kan et al. 2013) prior to IIP and restorative provisionalization is a valuable aid in team communication and treatment planning. Most anterior teeth at all sites present with a Class I SRP and are most favorable locations for IIP because they present with a considerable amount of bone present on the palatal aspect and potentially allow minimal intrusion on the labial plate. At sites with teeth presenting with Class III SRP, implant stability relies mostly on engagement of the labial cortical bone. In these situations, there is more labial bone remodeling and a greater incidence of labial dehiscence and fenestration. When teeth are centered within the alveolus (Class II), bone volume is usually reduced compared to Class I and III sites. For Class II sites, labial bone grafting may need to be considered and adequate alveolar bone beyond the socket base (up to 5 mm) necessary to ensure primary implant stability. Approximately one out of every ten maxillary anterior tooth sites demonstrate the most unfavorable SRP, Class IV where the tooth occupies the entire bone volume. Often these sites are considered to be a contraindication for IIP and need adjunctive bone grafting procedures (Kan et al. 2013).
Table 21.2 Classification and frequency distribution of sagittal root position of anterior teeth on cross-sectional CBCT Images (Kan et al. 2013)

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
<th>Maxillary tooth position</th>
<th>Overall frequency distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Root is positioned against the labial cortical plate (Figs. 21.34 and 21.35)</td>
<td>86.5%</td>
<td>81%</td>
</tr>
<tr>
<td>II</td>
<td>Root is centered in the middle of the alveolar housing with or without engaging either the labial or palatal cortical plates at the apical third.</td>
<td>5%</td>
<td>6.5%</td>
</tr>
<tr>
<td>III</td>
<td>The root is positioned against the palatal cortical plate</td>
<td>0.5%</td>
<td>0.7%</td>
</tr>
<tr>
<td>IV</td>
<td>At least 2/3rd of the root engages both the labial and palatal cortical plates.</td>
<td>8%</td>
<td>11.7%</td>
</tr>
</tbody>
</table>

CI central incisor, LI lateral incisor, C canine

Based on reviews of the limited studies in the literature (Levine et al. 2014a, b, c) and general consensus (Morton et al. 2014), ideally a minimum of 2 mm of buccal bone wall (and preferably more than 2 mm) is necessary in the anterior maxilla once the implant osteotomy has been prepared in a healed site to ensure proper soft tissue support and to avoid resorption of the buccal bone wall following restoration. If this bone volume is not present clinically then contour augmentation (contour grafting) is recommended to create this adequate zone facial to the implant (Jensen et al. 2014). If soft tissue thickness is not adequate (<2 mm) considerations to augment should also be determined (Kan et al. 2009; Yoshino et al. 2014; Puisys et al. 2015).

5. Implant Removal and Alveolar Reconstruction

While the long-term prognosis of dental implants is excellent, they may need to be removed for various reasons including early or late failure of osseointegration, fracture or initial inappropriate three-dimensional placement resulting in poor
esthetics (Figs. 21.36, 21.37, and 21.38). While trephines, burs, piezoelectric devices, and various forceps have been used, these techniques often result in defects in bone. More and more commonly implant removal systems (e.g., Neobiotech NEO FR fixture remover, Neobiotech USA, Los Angeles, CA, USA) that act to derotate the implant by application of reverse torque are being used, especially for integrated implants. Often graft procedures are required to reconstruct bone loss from the surgical retrieval procedure or due to inadequate bone. Mean survival rate for implant replacement at the second attempt has been reported to be 89% with a range from 71 to 95% (Zhou et al. 2016).

References


Braut V, Bornstein MM, Belser U, Buser D (2011) Thickness of the anterior maxillary facial bone wall-a retrospective radiographic study using cone beam computed


Levine, RA, Manji A, Faucher J, Fava PL. (2014c) Use of titanium mesh in implant site development for restorative-driven implant placement: case


Molly L, Quirynen M, Michiels K, van Steenberghge D (2006) Comparison between jaw bone augmentation by means of a stiff occlusive titanium membrane or an


Fig. 2.1 Sequence of intraoral clinical photographs demonstrating the use of Accell Connexus® as an allograft graft material for the ridge preservation after removal of the mandibular right second molar. Appearance of socket immediately after tooth extraction, with graft material inserted (b), with placement of a resorbable biomembrane (c), and after soft tissue closure (d).

Fig. 2.2 Sagittal (a), axial (b), and cross-sectional (c) CBCT images of the mandibular right second molar extraction site in the patient in Fig. 2.1 24 h after tooth removal and insertion of graft material. Note that the grafting material used shows minimal density and may not be identifiable unless reported by the clinician to the radiologist. Corresponding sagittal (d), axial (e), and cross-sectional (f) images 4 months after tooth extraction and simultaneous grafting procedure. At this time there is only subtle differences in the imaging appearance of the extraction socket with relatively increased hyperdensity. This appearance suggests successful osteoinductive capacity. Unless the type of the procedure, grafting material, and time interval post-surgery are known, it is almost impossible to draw conclusions about the healing process and progress of integration.

Fig. 2.3 Cropped right (a) and left (b) panoramic and corresponding cross-sectional right (c) and left (d) CBCT images of the mandibular first molar region for two patients 6 months post-operatively demonstrating successfully integrated socket grafts. Note the relative differences in hyperdensity of the graft indicating different material used at each site. Note the intimate contact...
interface between the graft material and the intramedullary cancellous bone

Fig. 2.4 Reformatted panoramic (a) and serial cross-sectional (b) (CBCT images) of two socket grafts in the areas of the mandibular left premolars. The panoramic also demonstrates a patient who has undergone orthognathic surgery in the mandible where fixation plates are present bilaterally. The grafting material used is granulated and of high density. Note the fairly homogenous appearance and the close contact with the extraction socket, indicating a satisfactory fill of the socket

Fig. 2.5 Reformatted panoramic (a), axial (b), and cross-sectional (c) CBCT images of a socket graft in the region the left mandibular first molar. Note the wide, low density zone surrounding the graft (arrows). This zone may indicate a layer of soft tissue proliferating between the graft and the socket raising concerns about its stability and integration. This appearance should be correlated to clinical history and surgical timeline. Naturally, this needs to be verified by surgical exploration

Fig. 2.6 Reformatted cropped panoramic image (a) and CBCT cross-sectional images (b) of a socket preservation graft in the area of the right mandibular first molar. Note the thin low density separation between the graft material and alveolar bone, the void inside the graft which seems to be reducing the superior extent of the graft and dispersing fragments or granules of the graft towards the crest. This appearance is suggestive of graft failure
Fig. 2.7 Reformatted panoramic (a) and serial cross-sectional (b) CBCT images of the anterior mandible showing a cortical, hyperdense, onlay block graft stabilized to the labial aspect of alveolar ridge with a fixation miniscrew. The contact of the graft to mandibular bone is satisfactory and the graft has increased the thickness of the bone towards the crest.

Fig. 2.8 Sequential 1 mm thickness cross-sectional CBCT images at 2 mm intervals (a) and a reference reformatted panoramic image (b) of the left mandible showing use of both particulate graft (left second premolar region) and miniscrew fixated, block onlay graft (first molar region) material throughout the edentulous space in the region of the left mandibular premolar and first molar. Both techniques increase or restore the horizontal bone volume necessary for implant placement.

Fig. 2.9 Reformatted panoramic (a) and serial cross-sectional 1 mm thickness and 1 mm intervals (b) CBCT images showing the 5-month post-operative imaging appearance of the left maxillary anterior region. The patient presents with an extensive history of left facial trauma due to a baseball with root canal therapy and ultimate loss of the left maxillary left central and then lateral incisor teeth. Initially particulate bone grafting was performed which failed. Most recently a tibia graft was performed to reconstruct the edentulous alveolar defect. There is a single labial miniscrew present supporting a well-defined onlay graft; however, a hypodense uniform void is present between the graft material and labial surface of the existing alveolar ridge with multiple small irregular osseous curvilinear
fragments intermittently dispersed within the alveolar soft tissues on the labial and palatal aspects adjacent to the graft and residual ridge. The imaging appearance is consistent with inadequate integration of the graft.

Fig. 2.10 Reformatted panoramic (a), serial 1 mm thick cross-sectional (b) images and virtual implant simulation on cross-sectional image of and edentulous maxillary right lateral incisor region showing a deficiency in alveolar bone width necessary for implant placement. Corresponding reformatted panoramic (d), serial 1 mm thick cross-sectional (e) images and virtual implant simulation on cross-sectional image 6 months after screw retained autogenous graft with bioreabsorbable membrane. Note the marked increase in alveolar bone width adequate for dental implant placement and excellent adaptation of graft material to the buccal cortical plate.

Fig. 2.11 Sequential 1 mm thickness cross-sectional CBCT images at 2 mm intervals (a) and a reference reformatted panoramic image (b) showing and extensive particulate graft extending through the edentulous space in the region of the left mandibular premolar and first molar. Note that there are two buccally inclined miniscrews used to provide support for a biomembrane (tenting) under which a well-consolidated homogeneous hyperdensity is closely adhered to the buccal cortical plate posteriorly and labial bone defect adjacent the area of the mental foramen. This graft increases the horizontal bone volume necessary for implant placement.

Fig. 2.12 Clinical photograph of extensive labial and cancellous defect at the site of the left maxillary lateral incisor arising from a
failed graft/implant (a). In fact, only the plate cortical plate was intact. Clinical photograph of the defect immediately after grafting with rh-BMP-2 and cancellous allograft combination therapy (b). Subsequently, a titanium mesh was used to maintain space and provide stability for wound healing. Cross-sectional CBCT image (c) of the grafted site 9 months post-operatively; note the newly formed bone marrow suggesting successful de novo bone formation.

Fig. 2.13 Reformatted panoramic (a) and serial cross-sectional CBCT (b) images of the maxillary anterior edentulous region showing a mature alveolar ridge on lay grafted site with cancellous bone formation underneath a titanium mesh applied on the labial aspect of the alveolar ridge to maintain the graft. Note the initial bone thickness (dotted line) and the intimate contact interface between the graft and the residual bone (arrows). The alveolar ridge width is almost doubled after the procedure.

Fig. 2.14 Reformatted panoramic (a) and serial cross-sectional CBCT ((b), (c), and (d)) images of the maxillary left posterior edentulous bounded region showing the initial appearance of the grafted site with underneath a titanium mesh fixated with mini-screws on both the labial and palatal aspects of the alveolar ridge to maintain the graft. The graft is designed to increase both alveolar residual ridge height and width.

Fig. 2.15 Reformatted panoramic (a) and serial cross-sectional CBCT ((b), (c), and (d)) images of the mandibular right posterior edentulous free-end region showing the initial appearance of the grafted site underneath two “X”-shaped, mini-screw fixated...
titanium barriers. The graft is designed to increase both alveolar residual ridge height and width.

Fig. 2.16 Clinical intraoral photograph (a) of a large combined vertical and horizontal defect in the anterior mandible with a compromised labial cortical plate. A mandibular biomodel was printed using CBCT pre-surgical data and a titanium mesh pre-sculptured to the desired shape of the alveolus (b). The defect was reconstructed with tissue engineering combination therapy (rhBMP-2+ cancellous allograft) (c) which was secured in place by fixating the custom preformed titanium mesh with miniscrews (d).

Fig. 2.17 Immediately post-operative cross-sectional (a) and reformatted panoramic (b) CBCT images of the patient in Fig. 2.16. Note the minimal density of the graft underneath the titanium mesh.

Fig. 2.18 5-month post-operative reformatted panoramic (b) and serial cross-sectional (a) CBCT images of the patient with an extensive resorbable biomembrane, mini-screw fixated particulate graft on the buccal aspect of the mandibular right posterior free-end edentulous region increasing the horizontal width of the residual alveolar ridge. Note the homogenous density of the graft, intimate contact between the graft and the native bone and well-defined supero-buccal alveolar crest, all features indicative of a successful horizontal augmentation procedure.

Fig. 2.19 7-month post-operative reformatted panoramic (a) and serial cross-sectional CBCT images of the maxillary right anterior region to assess the integration of a mandibular symphysis.
particulate autograft which was reshaped to match the anatomy of the alveolar crest. The margin of the native bone and the size of the defect are clearly seen; however, there is no separation evident. This was considered a successful grafting procedure although there was a small gap on the palatal aspect (arrow).

Fig. 2.20 Post-operative sagittal (a), coronal (b), and axial (c) CBCT images of a LWA MSEG procedure homogeneous consolidation of hyperdense bone graft material adjacent to the maxillary right second premolar edentulous space now restored with a dental implant. A localized defect in the lateral cortical plate of the maxillary sinus (arrows) corresponds to the antrostomy site.

Moderate concomitant mucosal thickening is present; however, this is not near the right ostia.

Fig. 2.21 6-month post-operative reformatted panoramic (a) and serial cross-sectional CBCT images of the left posterior maxillary bounded edentulous region where simultaneous sinus bone grafting was required in conjunction with immediate post-extraction socket bone grafting. This illustrates the concomitant use of the TAO approach associated with the extraction and localized, more extensive sinus floor management adjacent the edentulous space required using the LWA.

Fig. 2.22 Serial coronal cross-sectional CBCT images (a) showing patent right primary maxillary sinus ostia (PMO) and uncinate process (UP) with mild mucosal thickening of the floor of the maxillary sinus. Additional coronal image of another patient (b) showing accessory maxillary ostia (AMO). 9 AMO have been
reported to occur in the lateral wall of the nasal fossa from 22.5% up to 401% and should not be confused with PMO (Alyea 1936; Myerson 1958; Walter et al. 1976; Stammberger and Kennedy 1995; Kumar et al. 2001).

Fig. 2.23 Axial (a) and para-sagittal (b) CBCT images of the left partially edentulous maxilla showing a local endo-sinus condition with severe swelling of the mucosa at the level of the apically involved premolar. Note that there is an intra-sinus osteoma anteriorly arising from the floor of the maxillary sinus, most probably associated with a history of previous tooth extraction.

Fig. 2.24 Reformatted panoramic (a), coronal (b), and axial (c) CBCT images of a completely edentulous maxilla with a radiographic template inserted during the scan (notice the multiple radiopaque markers). There is soft tissue opacification occupying approximately 2/3rds of the left maxillary sinus with an irregular surface consistent with chronic sinusitis. This patient was scheduled for bilateral sinus augmentation procedure; however, as addition of bone graft material would most probably elevate the soft tissue material to occlude the left ostium, the procedure was delayed until after resolution of the condition.

Fig. 2.25 Cross-sectional CBCT image (a) superimposed with a virtual implant (pink) and prosthetic emergence profile (yellow) positioned in the left posterior region in a severely atrophic completely edentulous maxilla (Dentsply Implants, Leuven, Belgium). Corresponding cross-sectional (b) and volumetric rendered (c) images with virtual sinus grafting material (green)
Fig. 21.26 Screen capture of completely edentulous maxilla with radiographic template showing simulated virtual placement of multiple implants. The most posterior implants bilaterally are positioned into the anterior recess of the maxillary sinus. The red and blue volumes indicate anticipated bone graft material required for successful sinus lift and bone augmentation procedure.

Fig. 21.27 Reformatted panoramic (a) and serial 1 mm thick cross-sectional CBCT images (b) of a successful maxillary sinus osteotome technique associated with an endosseous dental implant placed in the maxillary left second premolar previous tooth position.

Fig. 21.28 Cropped reformatted panoramic (a), axial (b), and right ((c) — small dashed) cross-sectional images demonstrating globular, well-condensed, homogeneous, particulate hyper-dense mass with minimal superimposed mucosal thickening. This represents the optimal post-operative radiographic appearance of MSEG procedures.

Fig. 21.29 Thin section (10 mm) reformatted panoramic (a), coronal (b), and axial (c) CBCT images of a 52-year-old female with a completely edentulous maxilla reporting failure and recent removal of a dental implant in the left posterior region. The images demonstrate variable heterogeneity and intermittent condensation of the hyperdense particulate bone graft material adjacent the floor of the left maxillary sinus with a hypodense alveolar defect related to the removal of a dental implant. Note: the images visualize a scanning prosthesis fabricated by adding barium sulfate to the traditional methylmethacrylate.
Fig. 21.30 Pre-operative reformatted panoramic (a) and right ((b)—small dashed) and left ((c)—heavy dashed) cross-sectional images demonstrating clear, normal maxillary sinus bilaterally.

Fig. 21.31 Post-operative reformatted panoramic (a) and right ((b)—small dashed) and left ((c)—heavy dashed) cross-sectional images of the same patient as shown in Fig. 21.30 demonstrating bilateral post-operative acute sinusitis. Some consolidation of the graft material occurs in the anterior recess; however, the bulk of the material shows diffuse particulate hyperdense aggregates within soft tissue/fluid hypodensity.

Fig. 21.32 Reconstructed panoramic (a), axial (b), and sequential cross-sectional (c) images demonstrating completely detached hyper-dense bone graft material mass “floating” within soft tissue/fluid with minimal accumulation adjacent the proposed implant site suggestive of a lack of bone augmentation material condensation and integration.

Fig. 21.33 Reformatted panoramic (a) and serial cross-sectional (b) CBCT images of the right maxillary free-end edentulous region demonstrating extensive anterior mesh retained graft reconstruction in the premolar, canine, and incisor region and a MSEG in the molar region. The cross-sectional images demonstrate localized medial displacement of the graft material and creation of a regional void or “pocket” within the graft volume.

Fig. 21.34 Clinical intraoral photograph (a), reformatted panoramic (b) and cross-sectional (b) CBCT images in a female with a chief complaint of poor esthetics associated with root canal filled.
maxillary left central incisor. The patient presents with an excessive gingival display and poor esthetics and altered passive eruption of the anterior teeth (Levine and McGuire 1997). The left central incisor is to be removed and an implant immediately inserted. The maxillary left central incisor demonstrates a Type I sagittal root position (Kan et al. 2013). This tooth was extracted and an implant immediately inserted with guided bone regeneration procedure used to fill the buccal gap along with connective tissue grafting under the buccal gap for “perio biotype conversion” (Kan et al. 2011). The implant together with all anterior teeth were subsequently restored with fixed prostheses.

Fig. 21.35 Reformatted panoramic (a) and cross-sectional (b) CBCT images of the maxillary right central in a 58-year-old female which is to be removed and an implant immediately inserted. This tooth demonstrates generalized pericircumferential periodontal ligament space widening and, in the panoramic projection, appears that there is separation between the distal aspect of the tooth and the root canal material highly suggestive of vertical root fracture. The maxillary right central incisor demonstrates a Type I sagittal root position (Kan et al. 2013). Note that there is marked reduction in the width of the alveolus in the apical region associated with the presence of a prominent buccal concavity and the nasopalatine fossa.

Fig. 21.36 Implant removal and alveolar reconstruction of the left maxillary lateral incisor site for 50-year-old female whose implant was placed too far labially with multiple soft tissue procedures attempted to correct for poor esthetics. Initial intraoral presentation
of implant (a) and subsequent implant retrieval (b) and immediate post-operative CBCT cross-sectional image (c) demonstrate large osseous vertical and horizontal alveolar deficiency. After healing (d) the site was re-entered and Gem-21 (Luitpold Pharmaceuticals, Inc., Shirley, NY, USA), a highly purified recombinant human platelet-derived growth factor (rhPDGF-BB) with an osteoconductive matrix (beta tricalcium phosphate, β-TCP) with Puros cortical bone graft (Zimmer Dental, Inc., Carlsbad, CA, USA) was secured using a titanium mesh (DePuy Synthes, West Chester, PA, USA) fixated using miniscrews (e). 5-month post-op intraoral (g) and reformatted panoramic (h) and cross-sectional CBCT image (i) shows substantial reconstruction of the alveolus in both height and width with Type IV bone. Analysis on the cross-sectional image (i) shows adequate bone volume for implant placement.

Fig. 21.37 Intraoral clinical photograph (a) and corresponding cross-sectional CBCT image of a right maxillary implant placed outside (labial) to the available bone volume. Removal of the abutment and adjacent crowns on the right posterior premolar and molars reveals the excessive labial location of the implant (c). The implant was removed, the cortical bone bed prepared and Osteocel (human adult stem cell; Nuvasive®, Inc.) graft was secured using Synthes mesh which was retained using miniscrews (d) (Levine and McAllister 2016)

Fig. 21.38 CBCT imaging 6-months post GBR of the patient identified in Fig. 21.37. Reformatted panoramic (a) with site reference (orange vertical line) and corresponding cross-sectional
image (b) at the second premolar region and reformatted panoramic (c) with site reference (orange vertical line) and corresponding cross-sectional image (d) at the first premolar region. Measurements confirm establishment of adequate bone volume for insertion of implant in correct prosthetically driven location