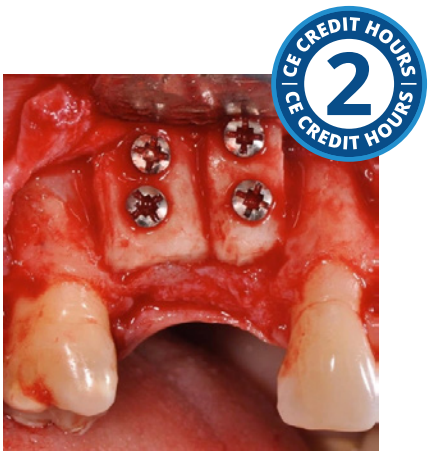
Alveolar Ridge Preservation and Augmentation for Optimal Implant Placement



Course Author(s): Lavanya Rajendran, DMD, MDSc; Sejal Thacker, DDS, MDSc
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Conflict of Interest Disclosure Statement

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Short Description

This course outlines needs and modes of bone preservation and augmentation to facilitate optimum 3-dimensional implant placement.

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Overview

This course outlines needs and modes of bone preservation and augmentation to facilitate optimum 3-dimensional implant placement. The authors will walk you through the process of bone modeling following extraction, alveolar ridge preservation, types of ridge deficiencies, alveolar ridge augmentation techniques, complications, prognosis and maintenance of augmented sites.

Learning Objectives

Upon completion of this course, the dental professional should be able to:

- Understand in brief the biology behind bone modeling following extraction and resorption.
- Identify and classify bone defects in edentulous sites.
- Describe the eligibility for bone grafting and select the appropriate modality of treatment for the same.
- Explain the steps involved in executing bone augmentation procedures.
- Discuss the risks and complications of bone augmentation.
- Explain the long-term prognosis of procedures described.

Introduction

Extraction of teeth triggers a cascade of biologic events, mediated by both the local inflammatory response that follows the surgical intervention and the deprivation of masticatory stimulation of the periodontium. This elicits an alteration of the homeostasis and structural integrity of the periodontal tissues. As a consequence, a physiologic process of disuse atrophy characterized by an intense resorption of the alveolar bone and a partial invagination of the mucosa takes place following tooth extraction. Bone modeling, that ensues, results in horizontal and vertical ridge reduction.[1,2]

Implant therapy for rehabilitation of edentulous patients is a common treatment modality. For its long-term success, comprehensive treatment planning and precise technical execution are fundamental necessities. One of the prime essentials for implant osseointegration is adequate bone volume in three dimensions. Considering the above mentioned biologic phenomenon of bone modeling following extraction, alveolar ridge preservation (ARP) and augmentation to preserve or gain bone volume form an integral part of implant therapy.

This course focuses on natural events that follow extraction, modes of ARP, evaluation of an edentulous site for implant therapy and various surgical options available for ridge augmentation.

Patient Selection

All of the clinical procedures explained below are surgical interventions and the outcomes are directly related to not only clinical skills and expertise, but also to appropriate patient selection. Some examples of relative contraindications to such interventions include a medically compromised patient with conditions such as neuropsychiatric disorders and severe bleeding disorders, and patients with a history of radiation therapy, intravenous bisphosphonate therapy, uncontrolled diabetes and heavy smoking to name a few.[3] These systemic contraindications

may be relative or absolute depending on the severity of the disease and the ability of the team, including the patient's physician, to manage the condition.

As a general rule patient's dental compliance, periodontal stability, caries control, restorability and prognosis of remaining teeth should be assessed and addressed as needed before performing any grafting procedure. Deep probing depths in patients with uncontrolled periodontal disease or high plaque / bleeding on probing scores in patients who are non-compliant with oral hygiene instructions can result in poor healing post surgically and complications such as infections, graft exposure and loss of native bone.

In fact, poor oral hygiene, history of periodontal disease, smoking, uncontrolled diabetes and patient's non-compliance with maintenance regimen are all proven risk factors for peri-implant mucositis and peri-implantitis.[4-6] Hence, these patients are not eligible candidates for grafting and dental implant therapy.

Clinicians should be cognizant of systemic and local contraindications and be selective of patients receiving grafting and implant surgeries to avoid mishaps.

Bone Modeling Following Extraction

The healing of an extraction socket has been evaluated in multiple animal and human studies.[8-11] Extraction of the tooth results in formation of a socket that soon fills in with a blood clot. A provisional matrix replaces the coagulum, in about 7 days. This matrix forms a framework for woven bone that is formed between 14-30 days post extraction. Organization of woven bone, increase in marrow spaces and remodeling eventually results in lamellar appearance of the bone.[9]

These histologic events in an extraction socket are accompanied by changes in residual ridge dimensions. The inner surface of the alveolus is almost consistently lined with bundle bone. Thus, following tooth removal, this bundle bone is lost together with proportions of adjacent socket wall. This modeling results in substantial diminution of the edentulous ridge.[12] Van der Weijden et al, in a systematic review showed a mean clinical mid buccal height loss of 1.67 mm and a reduction in width of about 3.87 mm.[13] Approximately two thirds of these dimensional changes occur in the first 3 months after the extraction of the tooth.[10]

Alveolar Ridge Preservation/Socket Grafting

In an attempt to attenuate the resorptive events that follow tooth loss and to minimize the need for ancillary ridge augmentation procedures, ARP (also known as socket grafting) is performed immediately following extraction of the tooth. The need for ARP increases when the socket walls are thin or missing after extraction.[14] Facial wall thickness of ≤1 mm is a critical factor associated with the extent of bone resorption seen following extraction of single rooted teeth. Thin walled phenotypes in a novel 3d analysis by Chappuis and colleagues[15] displayed pronounced vertical resorption with a median bone loss of 7.5 mm, as compared with thick wall phenotypes which decreased by only 1.1 mm.

A variety of bio material and barrier membrane usage in the socket have been shown to successfully help minimize volumetric shrinkage that follows extraction.[1] Biomaterials that are commonly used for this purpose include autogenous blood derived products, xenografts (animal derived), allografts (human derived) and alloplasts (synthetic substitutes). Some examples of barrier elements include xenogenic collagenous membranes and autogenous blood products. Depending on the graft material used a healing time of 4-6 months will be required before re-entry for implant placement to allow for adequate vital bone formation and graft integration.[16]

A recent systematic review critically evaluated the available evidence on the effect of different modalities of alveolar ridge preservation (ARP) as compared to tooth extraction alone. They concluded, based on their systematic review and meta-analysis, that ARP via socket grafting as compared to tooth extraction alone, prevents horizontal (M=1.99 mm; 95% CI 1.54-2.44; p<0.00001), vertical mid buccal (M=1.72

mm; 95% CI 0.96-2.48; p<0.00001) and vertical mid lingual (M=1.16 mm; 95% CI 0.81-1.52; p<0.00001) bone resorption. The application of particulate xenogenic or allogenic materials covered with absorbable collagen membrane or sponge was associated with most favorable outcomes in terms of horizontal ridge preservation.[1] A randomized controlled trial by Avila-Ortiz showed that additional bone augmentation to facilitate implant placement in a prosthetically acceptable position was deemed necessary in 48.1% non-grafted extraction sites versus only 11.5% of ARP sites.[17] Furthermore, sites that receive ARP exhibit no difference compared with sites that underwent unassisted socket healing in terms of implant loss or success.[18] The cost effectiveness and the possibility of post operative adverse events such as infections, extravasation of bone graft particles, membrane exfoliation should be considered while performing ARP. Besides, clinicians should be aware of that ARP can greatly reduce but not eliminate the need for additional bone grafting at the time of implant placement.[19]

Evaluation of an Edentulous Site

A patient that presents with an edentulous site planned for implant therapy needs a thorough clinical and radiographic evaluation to determine adequacy of bone in 3 dimensions to facilitate placement of an implant in a prosthetically driven position, to provide predictable osseointegration and long-term successful outcomes. Visual examination, intraoral palpation of the edentulous site, measurement of the inter arch restorative space, two dimensional radiographs and CBCT scan analysis are all tools that will help assess the bone volume.

The amount of bone required in mesio-distal, bucco-lingual and apico-coronal dimension varies depending on the tooth type, number of missing teeth and the prosthetic plan. General guidelines for required bone quantity in an edentulous site are as follows:

1. **Mesiodistal dimension** – A strong correlation exists between bone loss at adjacent teeth and the teeth – implant horizontal distance. With decreasing distance, bone loss increases. A safe distance of about 1.5 mm is, hence, recommended between implant and adjacent teeth.[20] However, this lateral spacing is recommended to be at least 3 mm when an implant is placed in the esthetic zone to create harmonious emergence profile and soft tissue fill in the papillary areas.[21] When two adjacent implants are placed, an inter-implant distance of at least 3 mm is critical to maintain crestal bone levels.[20]

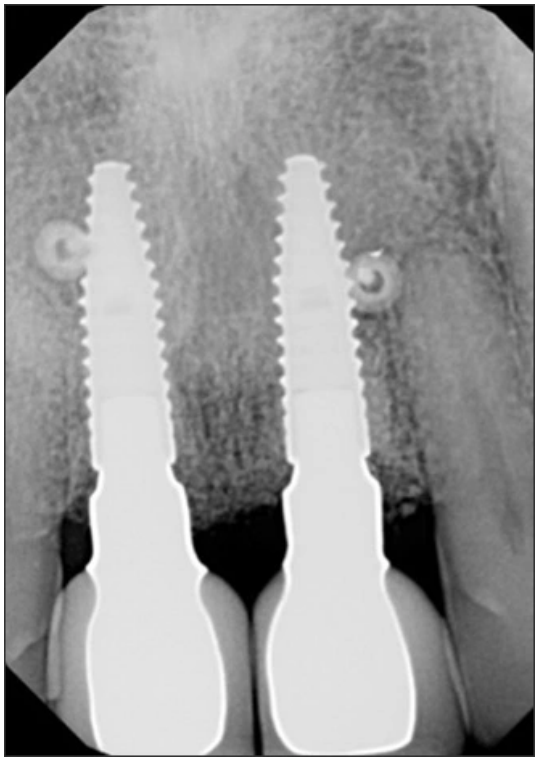
2. **Bucco-lingual** – The adequacy of bone in the bucco-lingual dimension will determine implant selection and need for bone grafting. Though bone volume in this dimension can be gauged clinically, for definitive assessment a 3-dimensional cone beam scan is recommended. A buccal wall thickness of 1.8 - 2 mm facial to the implant is necessary to prevent bone loss, gingival recession and help with long-term stability.[23,24]

3. **Apico-coronal** – The vertical bone height available for implant placement can be restricted by anatomic structures such as nasal floor, maxillary sinus, mental foramen and inferior alveolar nerve. Radiographic assessment using either a 2-dimensional or 3-dimensional radiograph will be required to determine length of implant, need for sinus augmentation and vertical ridge augmentation. A safe distance of at least 2 mm from vital structures such as mental foramen and the inferior alveolar nerve canal is paramount to prevent damage to these vital structures and sensory dysfunction.[25]

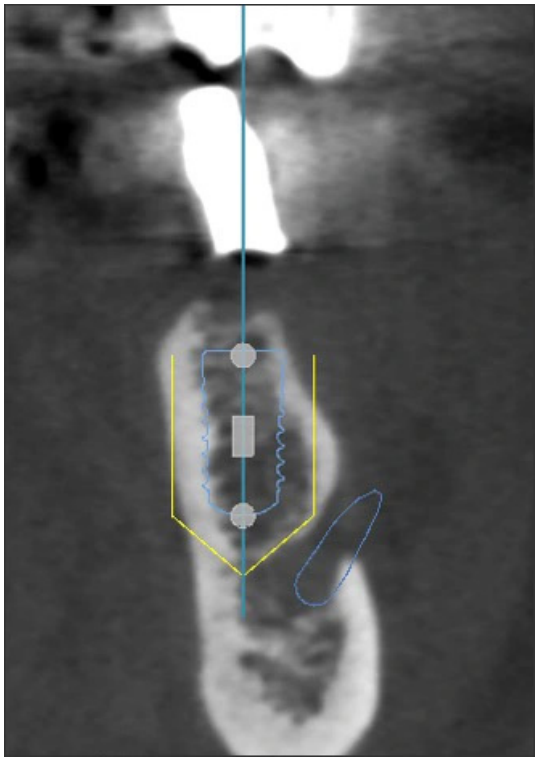
Planning Ridge Augmentation Based on Edentulous Site Evaluation

An edentulous site planned for implant therapy, once evaluated clinically and radiographically, can be classified using one of the many published classifications. This will help the clinician decide on whether the site can be grafted simultaneously during implant surgery or a staged approach should be implemented. Below is one such example of a classifications system, proposed by Benic et al,

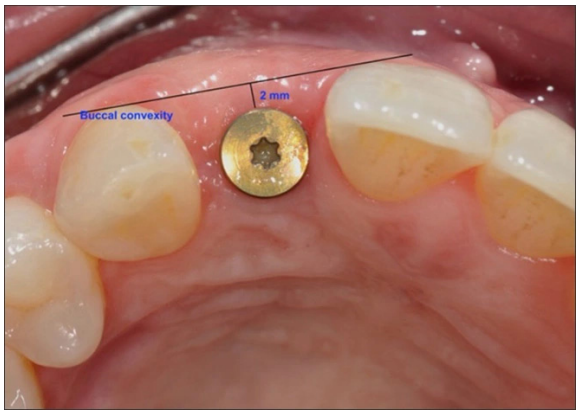
Figure 1.



A. Mesiodistal distance implant and tooth at least 1.5 mm and inter-implant distance 3 mm.



B. Implant planning with 2 mm distance from mental foramen.



C. Implant placed with 1.5 - 2 mm of buccal bone.

for implant planning of an edentulous site.[26] The proposed treatment recommendations, though, should be considered in lieu of other factors such as bone quality, anatomic limitations, patient factors and clinician's expertise.

One other simplistic way of classifying edentulous ridges is the one suggested by Seibert et al.[27] in 1983:

- **Class I** – buccolingual loss of tissue with normal apico-coronal height
- **Class II** – apico-coronal loss of tissue with normal buccolingual ridge width
- **Class III** – combination type defects (loss of both height and width)

Treatment Decisions Based on Defect Classification

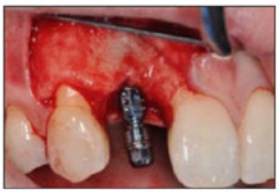
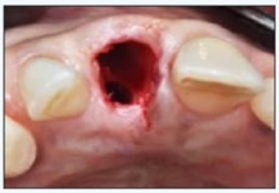
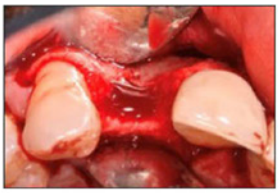
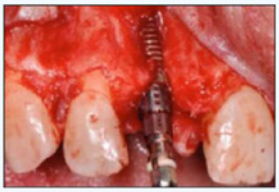
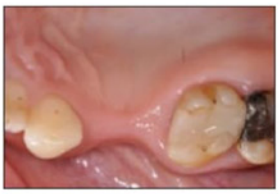
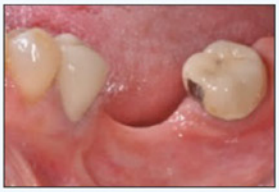
Methods of Bone Augmentation

The previously mentioned evaluations and tools will help the clinician determine need for grafting. Various alveolar bone augmentation techniques are available to facilitate these grafting needs. These techniques can be broadly classified as additive techniques and modification of the existing bone volume. The key to long-term stability of the graft and success of implant therapy lies in the clinicians understanding of the indications and limitations of each of these techniques.

Additive Techniques

These involve addition of bone outside the existing native bone envelope. Common examples of additive techniques include:

Table 1.

Bone Defect	Description		Proposed Treatment Recommendations
Class 0		Site with ridge contour deficit and sufficient bone volume for standard implant placement	• Simultaneous implant placement • GBR with resorbable membrane and particulate graft
Class 1		Intra-alveolar defect between the implant surface and intact bone walls (limited to situations where immediate implant placement is performed)	In esthetically sensitive site: • Use bone substitute into the intra-alveolar defect and over the buccal bone wall and coverage with resorbable membrane In esthetically non sensitive site when the horizontal defect dimension is >1-2 mm: • Application of bone substitute into the intra-alveolar defect and coverage with resorbable membrane
Class 2		Peri-implant dehiscence, in which the volume stability of the area to be augmented is provided by the adjacent bone walls	• Simultaneous implant placement • GBR with resorbable membrane and particulate graft
Class 3		Peri-implant dehiscence, in which the volume stability of the area to be augmented is not provided by the adjacent bone walls	• Simultaneous implant placement • Use of rigid barrier membrane such as ePTFE along with particulate bone substitute for GBR
Class 4		Horizontal ridge defect requiring bone augmentation before implant placement	• Staged implant placement • Augmentation with any of the following methods: 1. Autogenous bone blocks 2. ePTFE or Titanium mesh with particulate bone substitute 3. Distraction osteogenesis 4. Ridge split techniques
Class 5		Vertical ridge defect requiring bone augmentation before implant placement	• Staged implant placement: 1. Autogenous bone blocks 2. ePTFE or Titanium mesh with particulate bone substitute 3. Distraction osteogenesis

Adapted from Benic et al, Periodontology; 2000.[26]

1. Guided Bone Regeneration (GBR)
2. GBR with Particulate Graft
3. Block Bone Grafts

GBR involves the incorporation of barrier membranes in the treatment of alveolar ridge defects. The membrane separates the bone defect from the overlying soft tissue. This allows the defect space to be repopulated with new blood vessels and osteogenic cells, which differentiate to form osteoblasts and are responsible for forming new bone. Desirable properties of membranes include biocompatibility, cell-occlusion properties, space-maintaining capability, ease of manipulation, and minimal susceptibility to complications.[26]

Table 2 details the various types of membranes available as well as their advantages and disadvantages.

Table 2.

	Non Resorbable	Resorbable	
		Natural	Synthetic
	e-PTFE (Expanded polytetrafluorethylene) d-PTFE (Dense polytetrafluorethylene) Titanium Foil Micro titanium mesh	Native collagen Cross-linked collagen Freeze-dried fascia lata Freeze-dried dura mater	Polyglactin Polyurethane Polyactic acid Polyglycolic acid Polyactic acid/Polyglycolic acid copolymers Polyethylene
Advantages	• Good mechanical stability • Excellent biocompatibility • Rigidity is suitable for space maintenance, wound stability, and successful bone regeneration • Plasticity, allows for bending, contouring and adaptation to any defect morphology	• Decreased patient morbidity • No need for second surgery to remove membrane • Lower rate of exposure • Simplified surgical procedure • Has hydrophilic properties which allows it to adhere to bone well once saturated with blood	
Disadvantages	• Increase risk of exposure • Increased risk of infection after exposure • Increased risk of soft tissue ingrowth • Fixation screws/tacks necessary to hold membrane in place • Second surgery necessary for removal • Technique-sensitive	• Uncontrolled duration of barrier function • Need for tenting screws to avoid collapse • Micromovement of membrane leads to movement of graft material and disruption of blood clot	

Adapted from Benic et al, Periodontology; 2000[26] and Soldatos et al, Quintessence International; 2016.[28]

Both resorbable and non-resorbable membranes have shown to facilitate adequate bone gain in minimal to moderate sized horizontal defects. However, the rigidity of non-resorbable membranes becomes beneficial when one desires vertical augmentation or when significant horizontal gain is needed in non-contained edentulous ridges. Animal[29] and human[30] studies have shown an average vertical gain of 1.82 mm and 2.2 mm, respectively, with the sole use of non-resorbable e-PTFE membrane. The supplemental use of bone grafting materials along with membranes, can significantly increase the amount of bone gained following augmentation.[31]

GBR with Particulate Graft involves addition of particulate grafting material to assist with bone formation in GBR procedures. These grafts serve as space maintainers to prevent the membrane from collapsing or act as a scaffold, and/or stimulate bone growth. Based on their functional properties, they can be classified as osteogenic, osteoconductive or osteoinductive in nature.[32] Osteogenic grafts allow formation of new bone from living cells that are transplanted within the graft. Osteoconductive grafts assist in the formation of a 3D scaffold which allows cells to migrate for ingrowth of blood vessels and osteoprogenitor cells. Osteoinductive grafts help recruitment of osteoprogenitor cells which are the precursors to osteoblasts, thus resulting in de-novo bone formation.

The origin, examples, and properties of the particulate grafts are detailed in the Table 3.

GBR with particulate graft can be used to graft horizontal defects or vertical defects or combination defects requiring bone gain in multiple dimensions. Systematic review and meta-analysis by Sanz et al,[33] showed superior bone width gain of 5.68 mm with a combination of particulate xenograft, particulate autogenous graft and bio-absorbable membrane.[33] A vertical bone height gain of as high as 8 mm has been documented when e-PTFE membranes when used with particulate grafts.[31] These combination techniques can be used not only during staged approaches but also simultaneously during implant placement when there are Class I, II, III defects (as explained in Table 1). The fact that this technique can be used in multiple case scenarios and is, unlike autogenous grafts, not limited by donor site anatomy, makes it fairly popular among clinicians.

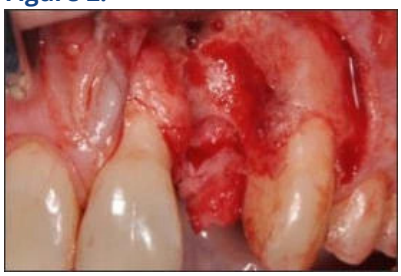
Autogenous Block Bone Grafts are surgically harvested from another site within the same patient. Autogenous block bone grafts are indicated when a staged approach for implant placement is being used in Class 4 defects (Table 1). Autogenous grafts have remained the gold standard for several years and have proven to increase bone volume and quality prior to implant placement.[34] However, disadvantages include higher morbidity, inadequate bone volume

Table 3.

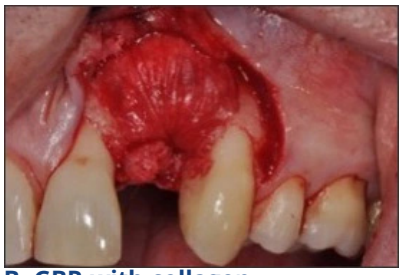
Type of Graft	Origin	Example	Properties
Autograft	Patient's own tissue	Intra-orally harvested from jaw, or extra-orally from iliac crest, tibia, calvaria, fibula	Osteogenic Osteoinductive Osteoconductive
Allograft	Tissues from individuals of same species	Fresh-frozen bone, freeze-dried bone, demineralized freeze-dried bone from cadaver	May have osteoinductive potential Osteoconductive
Xenograft	Tissue from another species	Bovine, porcine, equine bone mineral	Osteoconductive
Alloplast	Synthetically produced	Tricalcium phosphate, hydroxyapatite, calcium phosphate cement, calcium bioactive glass, polymers	Osteoconductive

Adapted from Benic et al, Periodontology; 2000.[26]

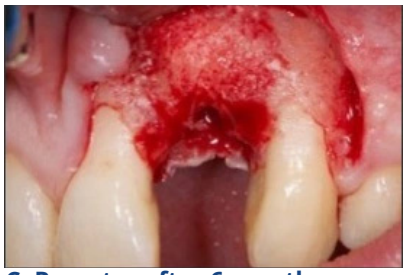
Figure 2.



A. Defect after debridement of edentulous #10.



B. GBR with collagen membrane and xenograft.



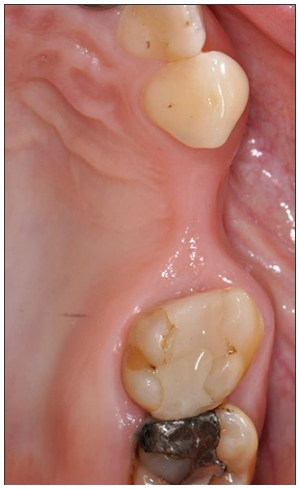
C. Re-entry after 6 months for staged implant surgery.

attainable depending on the defect size and the donor site anatomy. Extra oral donor sites for block bone grafts include iliac crest, tibia or calvaria. More commonly the blocks are harvested intra-orally from the mandibular ramus or the symphysis (the chin).[34]

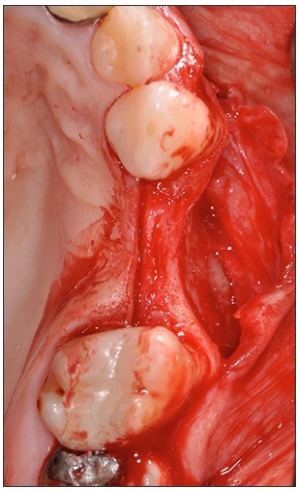
When harvesting, it is important to be wary of the nerves and vessels that span this area to avoid alteration of neural sensation and life-threatening hemorrhagic complications.[34]

Once harvested, the blocks are fixated to the underlying native bone, in the edentulous recipient site, using screws ensuring intimate contact.[32,34] A healing period of 4-6 months is necessary for the graft to integrate before one proceeds with implant placement. Though average bone gain with the autogenous graft is dictated by the anatomy of the donor site, a weighted mean gain of 4.25 mm was shown in a meta-analysis by Sanz et al.[33]

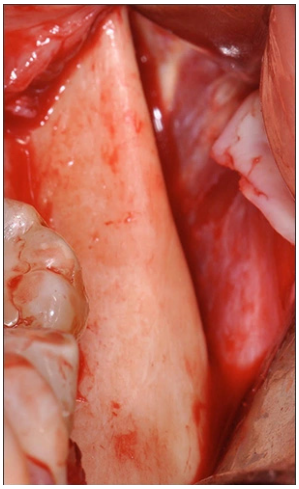
Figure 3.



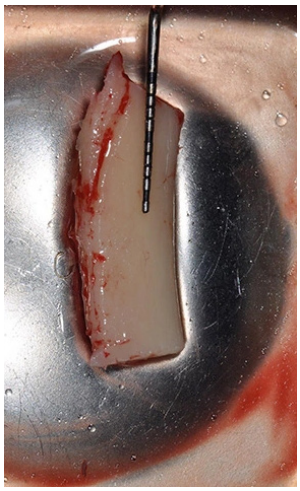
A. Class 4 defect in #12, 13 site.



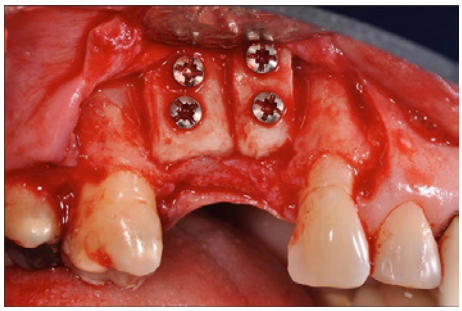
B. Recipient site - after flap elevation.



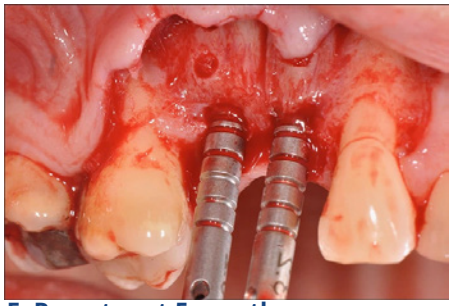
C. Donor site - mandibular ramus.



D. Ramus block graft harvested.



E. Autogenous block graft fixated to the recipient bed with screws



F. Re-entry at 5 months, screws removed, implant osteotomy done.

Allogenic and xenogenic block grafts have been proposed as an alternative to autogenous block grafts to reduce patient morbidity. Compared to autogenous block grafts, allogenic block grafts result in less vital bone, more graft resorption, and greater peri-implant marginal bone loss following 1-2 years of loading.[35] Although allogenic block grafts have demonstrated a horizontal gain ranging from 3-6mm, longer-term studies and studies that are more robust are necessary to determine if it is a comparable or superior option.[36] Scientific evidence for block xenografts is limited and caution should be used when considering this as a treatment option.[36]

Modifying Existing Bone Volume

These involve manipulation of the existing native bone to facilitate expansion of the volume. Expansion can be achieved by any one of the following methods:

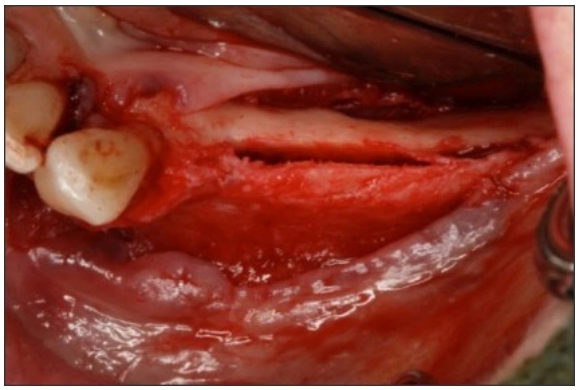
1. Ridge Expansion Osteotomy
2. Alveolar Ridge Split Technique
3. Distraction Osteogenesis
4. Alveolar Ridge Expansion by Osseodensification

These techniques eliminate the need for a second surgical site and facilitate implant placement simultaneously. If the bucco-lingual dimension of the edentulous ridge planned for implant is ≥3 mm but <6 mm, horizontal augmentation of the existing ridge can be performed using these approaches.[37] Having ≥3 mm of bone at the site ensures presence of a cancellous core of bone which lends itself to expansion and distraction without fracture.[37]

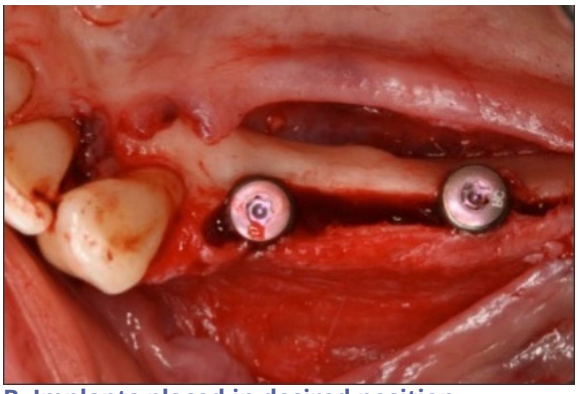
Ridge Expansion Osteotomy techniques focus on slowly expanding the bone during implant osteotomy, thus increasing the horizontal dimension simultaneous with implant placement. This technique was first introduced by Summers et al in 1994 and the expansion was achieved by the use of special instruments called osteotomes.[38] Expansion osteotomes are used with progressive increase in diameter until desired expansion is achieved and implants are inserted simultaneously. This approach not only helps create required bone volume to anchor the implant but also condenses bone laterally, thus improving bone quality surrounding the implants.[39] Studies have shown bone width gain between 3.5 and 3.9 mm using this method.[33]

Alveolar Ridge Split (ARS) Technique, introduced by Nentwig et al. in 1986, involves splitting the ridge using chisels and mallets with / without inter-positional bone graft. Advantages such as possibility of simultaneous implant placement, avoiding donor site, reducing morbidity and shortening treatment time have all been associated with this approach.[40,41] Modifications to this procedure have been made with the use of rotary and oscillatory instruments and surgical ultrasonics.[41] Studies have shown that the overall implant survival rate was 97%, and the average gain in alveolar bone thickness was 3.8 mm, regardless of the type of surgical instruments used.[41]

Figure 4.



A. Alveolar ridge split osteotomy at edentualous site using piezo inserts.



B. Implants placed in desired position simultaneously.

Distraction Osteogenesis can be used to reconstruct larger bone defects. It is a technique that involves repositioning a bony block segment to improve vertical dimension in select cases but may also be used to augment horizontally. To mobilize the bone block segment, two vertical and one horizontal cut is made into the bone.[42] The segment is then moved to the desired position gradually and the bone is given time to heal, filling in the gaps.[42,43] There is a latent period of 7 days to allow for initial soft tissue healing.[43] Following this is the distraction phase in which the two pieces of bone undergo incremental separation at a rate of 0.5 to 1 mm per day and a consolidation phase of 6 to 12 weeks which allows the bone to regenerate.[43] Distracting devices can be either intraosseous, within the bone, or extraosseous, attached outside the cortical bone.[43] There are certain factors which limit the success of this procedure, such as a minimum of 6 to 7 mm of bone height must be present above vital structures such as nerves or sinuses.[44] In addition, the defect size should be 3 to 4mm and should span at least 3 teeth.[44] The adjacent teeth should not have large vertical defects, as these are used as reference points and may limit the amount of vertical gain achievable.[43,44] A systematic review and meta-analysis by Zhao et al. showed that a vertical gain ranging from 4-20 mm and on average 7.92 mm could be achieved.[45]

Alveolar Ridge Expansion by Osseodensification is a more recent expansion technique developed by Huwais et al.[46] in 2015 in which special drills, called Densah burs, were designed to cut in reverse. This method allows for bone preservation through slow plastic deformation of the native bone.[46] Through reverse drilling of the special burs, autograft particles are formed and present along the inner surface of the osteotomy. This condensed autograft around the implant increases the bone density and the primary stability of the implant.[46,47] Using the osseodensification technique, patients with an alveolar ridge width of 3-4 mm, 5-6 mm, and 7-8 mm, showed 75%, 27%, and 17% increase in bone width, respectively.[47] Overall, the procedure has been shown to increase the bone width by 2- to 3-fold, and provides stability for implants, resulting in double the insertion torque.[47]

Surgical Considerations

Technique Selection

With this huge array of techniques to select from, one may wonder if there are specific indications for the different alveolar bone augmentation procedures. Systematic review by Milinkovic et al,[48] aimed to answer this question based on available evidence. They concluded that there is evidence to support use of:

1. GBR at the time of implant placement when dehiscence or fenestration defects are present.
2. Staged GBR for horizontal augmentation in preparation for implant placement when residual crest is 2.9 mm or wider.
3. Block bone grafts as a two-stage approach when the initial width of the ridge is at least 3.2 mm.
4. Ridge splitting and expansion techniques when horizontal deficiency when mean ridge width is at least 3.37 mm with presence of cancellous bone between the cortical plates.
5. Staged approach using either GBR or block grafts or distraction osteogenesis techniques for vertical height gain when 4-7 mm of vertical bone gain is needed.

The authors did note that there was significant heterogeneity and lack of precise description of the edentulous ridge defect in papers selected in this systematic review and hence one cannot extract clear indications for each augmentation technique still leaving the clinician the ultimate responsibility for the final choice. As a general rule, a surgical technique should be chosen in relation to the anatomy at presentation and the expected outcome.[48] One should be mindful that these procedures are technique – operator – experience sensitive and hence the clinicians expertise plays a significant role in assuring long-term success as much as patient selection and their post-implant therapy maintenance.

Anatomical Overview

When performing any surgical procedure, it is important to be aware of the anatomy to guide one's incisions and avoid damage to or impingement on nerves, vessels, or other vital structures. Often, a cone beam computed tomography (CBCT) image becomes necessary

to determine the location of the anatomical features to reduce the risk of surgical complications as there is variability amongst patients.[49] Important landmarks in maxillary and mandibular arches are described in brief below.

Maxilla
The nasopalatine foramen contains the nasopalatine nerve and descending palatine vessels. It is located anteriorly along the midline of the palate.[49] Larger canal dimensions may affect the amount of available bone to place implants in these sites. To circumvent this issue, the canal contents may be removed and grafted to enable implant placement.[49,50] The greater palatine artery is located opposite the 2nd and 3rd molar area on the palate and has the potential of causing intra operative hemorrhage if damaged intra-surgically.[49] It is important to take note of these features especially in edentulous sites, as their locations will appear closer to the crest.

The maxillary sinus is a prominent feature in the posterior maxilla. When posterior teeth are extracted pneumatization ensues, limiting the vertical dimension of the bone available for implant placement.[51] In such cases, sinus membrane elevation and augmentation procedures may become necessary. The amount of native alveolar bone available below the sinus floor, will determine staging of implant and approach to sinus augmentation. Shorter implants (implant length 6 mm) have also been proven to be successful in sites with decreased height of bone and have comparable survival rates when compared to longer implants.[52] This may be a feasible alternative, eliminating the need for additional surgical procedures.

Mandible
In the mandible, the inferior alveolar canal, which houses the inferior alveolar nerve as well as an artery, vein and lymphatic vessels, is located in the posterior regions.[49] The canal is located about 3.5-5.4 mm from the apices of the mandibular molars.[49] As the inferior alveolar nerve approaches the premolar region, it divides into the mental nerve, which emerges from the mental foramen usually between the first and second premolar region, and the incisive nerves more anteriorly. A branch of the inferior alveolar nerve may form an intraosseous loop, which extends beyond the mental foramen.[53] This anatomical variation, called the anterior loop of the mandibular canal has a prevalence ranging from 27-100% in the literature.[54,55] Cone Beam CT studies have shown that the anterior loop is located at a mean of 3.1mm anterior to the mental foramen and the majority are less than 4mm in length.[54,56] A 2 mm zone of safety between the implant and these structures can avoid nerve damage.[22]

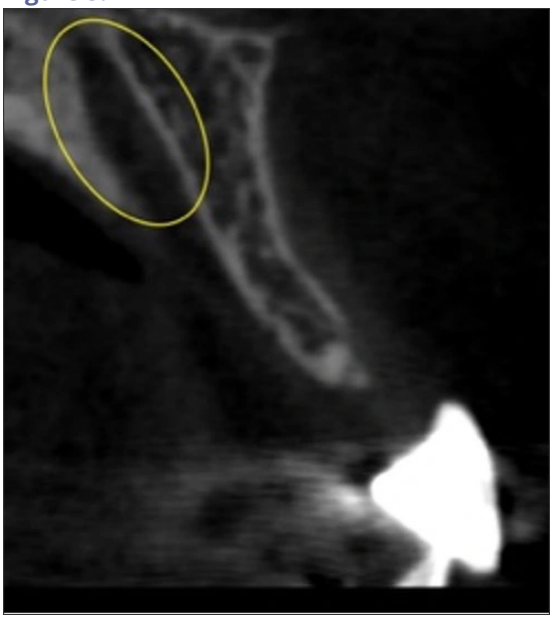
The lingual nerve is a branch of the mandibular nerve and is located, on average, at a vertical distance of 9.6, 13, 14.8 mm from the second molar, first molar, and second premolar, respectively.[57] Vertical incisions should be avoided in this area and care should be taken when elevating a flap to avoid injury to the nerve.

Another important anatomical feature of the mandible to note is the lingual concavity. The depth of this undercut is on average 2.4 mm and located about 11.7 mm from the CEJ of the second premolar.[58] Perforation is likely to occur during osteotomy preparation if not identified and may result in damage to surrounding vital structures. Hemorrhage resulting from lingual cortex perforation and injury to sublingual vessels can cause life threatening sublingual hematomas and airway obstruction. 3D imaging to visualize the individual shape of the mandible can help reduce these complications.[59]

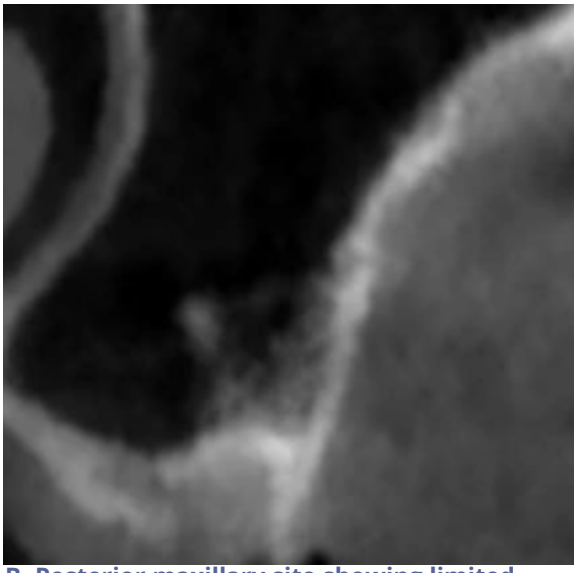
Surgical Technique
Irrespective of the technique chosen by the clinician, there are some key elements such as flap design, recipient site preparation and flap closure that will define the outcome of the surgery.

The flap design should include vertical, crestal and sulcular incisions such that it has a wide base. This design will maximize blood supply and allow for adequate access and visibility of the defect. In addition, the periosteum may be scored using a blade or scissors in order to

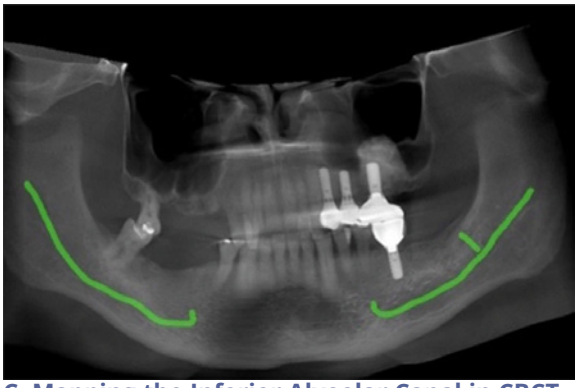
Figure 5.



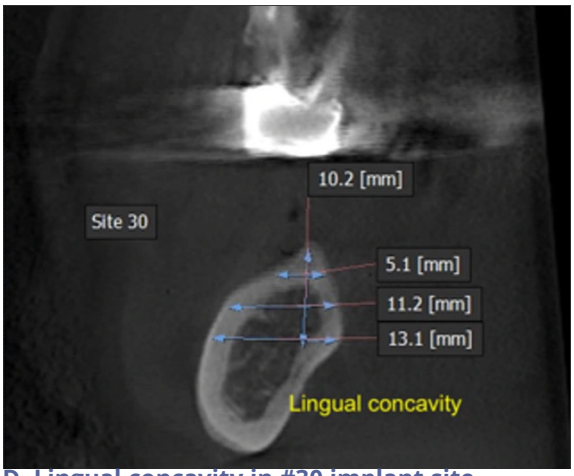
A. Nasoplalatine foramen in #9 edentulous site.



B. Posterior maxillary site showing limited bone due to sinus pneumatization.



C. Mapping the Inferior Alveolar Canal in CBCT Scan.



D. Lingual concavity in #30 implant site.

further release tension and advance the flap coronally.[60] The aforementioned techniques will allow for tension free closure over the surgical site.

Recipient Site Preparation and Decortication is done after the flap is elevated in the edentulous site. This involves thorough debridement of all granulation tissue and creating perforations or intra-marrow penetration in the cortical bone using a round bur. There is weak evidence to support the benefit of decortications as most studies are animal studies and there are no randomized controlled trials available; however, it is thought that this will enhance the development of blood clot and trigger the process of angiogenesis and cell migration justified by the regional acceleratory phenomena (RAP).[62] The concept of RAP suggests that the tissue response to a noxious stimulus will result in acceleration of normal cellular activity, in this case, increased bone turnover. In addition, decortication allows for mechanical interlocking of bone grafting material and the recipient site.

Primary Closure or re-approximating the wound edges to their original position to allow healing by primary intention, is a fundamental requirement for optimal healing without

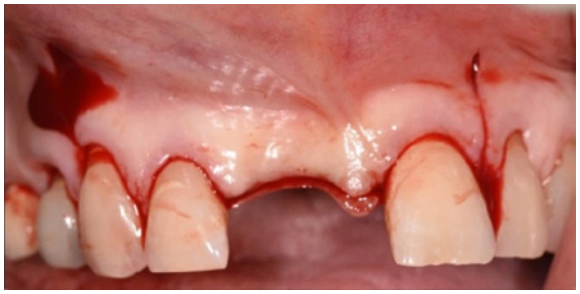
complications.[60,62] This creates an environment that is undisturbed and unexposed to bacterial or mechanical insults from the surrounding environment.[60] Passive, tension-free closure of the wound edges allows for better soft tissue healing, less remodeling of the bone, and less post-operative discomfort. This is achieved by use of vertical and periosteal releasing incisions. Non resorbable mono-filamentous sutures are preferred to hold the flap in place during the early healing phase for predictability of primary closure with minimal bacterial wicking.[60]

Complications

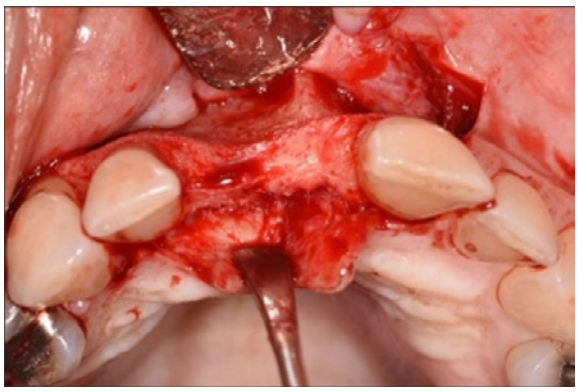
Augmentation procedures are technique sensitive and require a high level of expertise in order to avoid intra and post-operative complications.

General intra-operative complications that pertain to all grafting procedures such as hemorrhage, nerve damage, inability to obtain adequate graft or place implant with good stability can be avoided by thorough understanding of anatomy and use of advanced diagnostic procedures for treatment planning.

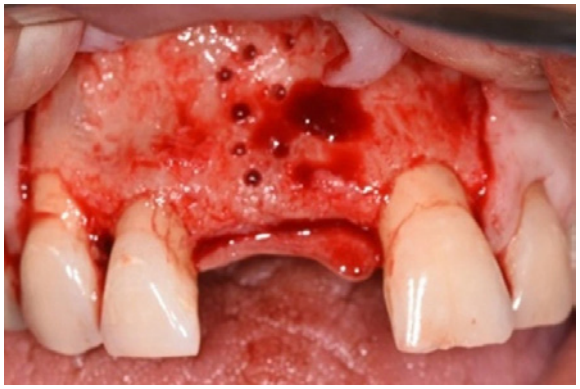
Figure 6.



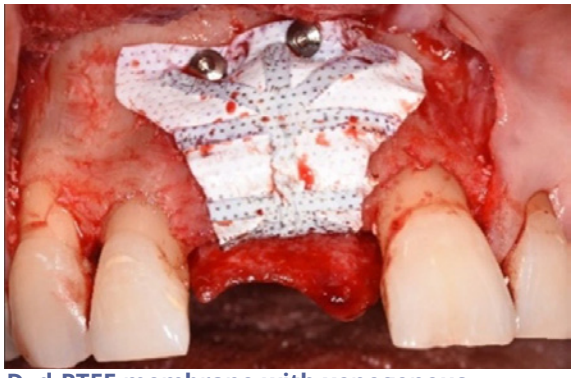
A. Vertical, crestal and sulcular incisions.



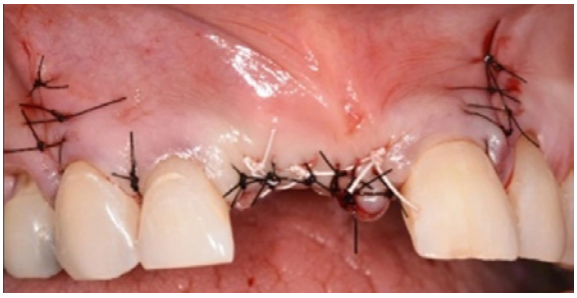
B. Full thickness flap elevation and adequate access for debridement of the defect.



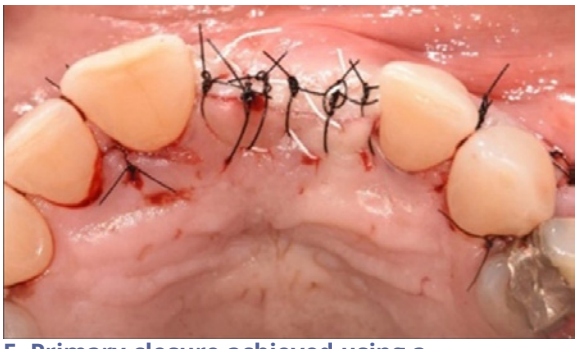
C. Decortication/intra marrow penetration.



D. d-PTFE membrane with xenogenous particulate graft.



E. Primary closure achieved using a combination of nylon and PTFE sutures.



F. Primary closure achieved using a combination of nylon and PTFE sutures.

The paragraphs below will highlight specific complications related to above mentioned techniques.

Common complications resulting from additive bone augmentation procedures are lesser than expected bone gain, soft tissue complications, and implant loss. [63-65]

Autogenous block grafts, in particular, have been known to have a high resorption rate, at times resulting in inadequate bone volume. Corticocancellous blocks, such as those harvested from the hip or symphysis may demonstrate resorption of up to 60% of the initial volume within the first 6 months.[66] However, studies have shown with the use of a membrane, these resorptive changes may be minimized.[66] In addition, if the block graft is not adequately fixated, it will lead to fibrous tissue formation between the graft and the recipient bed, ultimately resulting in loss of the graft.[67] Allogenic block grafts, when compared with autogenous block grafts, have a higher rate of complications including soft tissue dehiscence, incision line opening, exposure of graft, partial or total loss of graft, and infection.[35,36] With advancing three dimensional computer assisted surgical planning and matching of the graft to defect morphology, surgical time and post-operative complications may be reduced.[36]

When performing guided bone regenerative procedures, soft tissue complications which include dehiscence, membrane exposure, and infections/abscess may result, occurring at a rate of about 16.8%.[63] Membrane exposure can occur as early as 1 week or as late as 6 months.[63] There appears to be no difference between resorbable and non-resorbable membrane exposures.[63] However, if membranes are exposed, there is a 3 times less likely gain in bone than in non-exposed sites.[64] When an exposure occurs, the presentation is usually in the form of swelling, pain, inflammation, suppuration, or it could even be asymptomatic.[63] The membrane is usually removed, especially if it is non resorbable; in this case the entire site will be cleaned, and the procedure may be re-attempted.[65] Exposed resorbable membranes may remain; frequent follow ups may be necessary to ensure proper healing. In addition, antibiotics or Peridex rinses may be prescribed post operatively to minimize the risk of infection.[65]

When performing procedures that modify the existing bone volume different complications may arise. For example, crestal bone resorption surrounding implants may occur following ridge expansion/splitting techniques if the blood supply is diminished to the surrounding area.[40,67] This is more likely to occur if the ridge is less than 3 mm in thickness.[40,67]Other common complications include lack of implant primary stability, and partial or complete fracture of the bone segment.[36] With reduced ridge thickness, Ella et al,[68] found that 3 mm fractures in the crests of the buccal wall occurred in 43% of cases.

Adverse outcomes related to alveolar distraction osteogenesis include incomplete distraction, fracture of the device, relapse of the bone gained, or early resorption of the bony segment, infection, wound dehiscence, or nerve injury.[67,69] These complications arise in as many as 75% of cases.[67] Moreover, severe vertical deficiency of the mandible is a risk factor for neural damage or mandibular fracture; therefore, at least a height of 3 mm is necessary for the segment to be distracted.[69] Specific to this technique, the distracted segment of bone may be displaced lingually/palatally due to improper trajectory and/or pull of attached mucosa/periosteum.[67] A secondary grafting procedure may be necessary in order to attain adequate dimensions of bone for successful implant placement.[67]

Understanding the factors that may lead to post-operative complications are imperative for prevention of complications and their effective management if they occur.

Prognosis

The ultimate goal of all of these preservation and augmentation procedures is the stability of the grafted site and long-term survival of implants placed in augmented sites.

Implants placed in sites grafted with additive techniques have shown high survival rates over several years. In fact, the cumulative

implant survival rates in sites of autogenous block grafts harvested from chin, ramus, or iliac crest are as high as 98.1% at 3 years and 93.9% at 5 years.[70] Although limited reports and short term follow ups, implants placed in sites with block allografts have a 99-100% survival rate at 3 years.[71] In regard to guided bone regeneration with or without bone substitutes, a systematic review by Donos et al,[72] showed comparable survival of implants placed in augmented sites versus pristine sites (91.7-100% in augmented and 93.2%-100% in pristine sites) for a period of 12-59 months. This was further supported by a 5-10 year follow up retrospective analysis of dental implants placed in grafted versus non grafted site by Tran et al.[74]

Procedures involving modification of existing bone may have high implant survival rates as well. The implant survival rates for split crest techniques and distraction osteogenesis are 97% and 96%, respectively.[41,74] Implants placed with osseodensification have a survival rate of 98.1%.[75] It is important to note that many of the studies are short-term or retrospective studies, and higher quality human studies with extended follow-up periods are needed for more conclusive findings of long-term implant survival in the aforementioned procedures.[41,47,74]

Though these procedures yield successful results in long- and short-term studies, multiple factors such as patient selection, compliance and operator expertise play a critical role in defining the outcomes of therapy rendered.

Course Test Preview

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1. Following extraction, the average vertical and horizontal reduction in bone dimensions is about how many mm?

A. 1, 1
B. 2.5, 3
C. 1.7, 3.9
D. 3.9, 1.7

2. What is the correct order of socket healing?

A. Provisional matrix, blood clot, woven bone lamellar bone
B. Blood clot, provisional matrix, lamellar bone, woven bone
C. Blood clot, provisional matrix, woven bone, lamellar bone
D. Provisional matrix, blood clot, lamellar bone, woven bone

3. Which of the following is true regarding the benefits of alveolar ridge preservation?

A. Favorable outcomes in terms of horizontal but not vertical ridge preservation
B. Facilitates implants in a prosthetically acceptable position
C. Results in a higher survival rate of implants when compared to unassisted socket healing

4. A safe distance of ____ is recommended between implant and adjacent teeth.

A. 1.5 mm
B. 1 mm
C. 2 mm
D. 2.5 mm

5. The inter-implant distance of ____ is critical to maintain crestal bone levels.

A. 1 mm
B. 2 mm
C. 2.5 mm
D. 3 mm

6. According to the classification by Benic et al, which of the following bone defects can be grafted along with simultaneous implant placement?

A. Class 0, and 1 only
B. Class 0, 1, 2, 3
C. Class 0, 1, 2, 3, 4
D. Class 1, 2, 3, 4, 5

7. According to the classification by Benic et al, what is the definition of a Class 3 bone defect?

A. Peri-implant dehiscence, in which the volume stability of the area to be augmented is provided by the adjacent bone walls
B. Peri-implant dehiscence, in which the volume stability of the area to be augmented is not provided by the adjacent bone walls
C. Horizontal ridge defect requiring bone augmentation before implant placement
D. Vertical ridge defect requiring bone augmentation before implant placement

8. According to the classification by Benic et al, for a Class 5 defect, which of the following is the best type of membrane to use?

A. Non-resorbable
B. Resorbable
C. Both perform the same in this type of defect

9. Which of the following are considered additive bone augmentation procedures?

A. Distraction Osteogenesis
B. Autogenous block grafts
C. GBR with particulate graft
D. A, B and C
E. B and C

10. Which of the following particulate graft materials are osteogenic, osteoinductive, and osteoconductive?

A. Autograft
B. Allograft
C. Xenograft
D. Alloplast

11. According to the systematic review by Sanz et al, approximately how much horizontal augmentation can be achieved using the combination of xenograft, autograft, and bio-resorbable membrane?

A. 3 mm
B. 4 mm
C. 6 mm
D. 8 mm

12. Autogenous grafts, although considered the gold standard, have which of the following disadvantages:

A. Higher morbidity
B. Inadequate bone volume attainable depending on defect size and donor site anatomy
C. High rate of infection
D. A, B and C
E. A and B

13. When performing ridge expansion/split procedures, how much native bone is necessary in order to successfully perform and prevent fracture?

A. >2 mm
B. >3 mm
C. >4 mm
D. >5 mm

14. Which method allows for bone preservation through slow plastic deformation and condensation of the native bone, resulting in increased density and primary stability of the implant?

A. Ridge expansion osteotomy
B. Alveolar ridge split
C. Distraction Osteogenesis
D. Osseodensification

15. Lingual vertical incisions should be avoided in the mandible to avoid injury to which of the following nerves?

A. Mental nerve
B. Inferior alveolar nerve
C. Lingual nerve

16. What is the recommended safety distance from vital structures when placing implants?

A. 1 mm
B. 2 mm
C. 2.5 mm
D. 3 mm

17. The mental foramen is generally located between _____.

A. the canine and first premolar
B. the first and second molar
C. the first and second premolar
D. the second and third molar

18. In cases where the maxillary sinus has pneumatized slightly, limiting the vertical dimension, shorter implants may be placed and have been proven to be just as successful as longer implants.

A. True
B. False

19. Decortication are believed to enhance blood clot formation, angiogenesis and cell migration. This is justified by the Regional Acceleratory Phenomena.

A. Both statements are true.
B. The first statement is true, the second statement is false.
C. The first statement is false, the second statement is true.
D. Both statements are false.

20. Primary closure is imperative in GBR procedures because it allows for an environment unexposed to bacterial or mechanical insults. It also allows for more bone remodeling.

A. Both statements are true.
B. The first statement is true, the second statement is false.
C. The first statement is false, the second statement is true.
D. Both statements are false.

21. Membrane exposures can occur as late as 6 months.

A. True
B. False

22. Soft tissue complications which include dehiscence, membrane exposure, and infections/abscess occur at a rate of about ____.

A. 5%
B. 12%
C. 17%
D. 25%

23. The survival of implants placed in augmented sites is usually less than 90%.

A. True
B. False

References

1. Avila-Ortiz G, Chambrone L, Vignoletti F. Effect of alveolar ridge preservation interventions following tooth extraction: A systematic review and meta-analysis. J Clin Periodontol. 2019 Jun;46 Suppl 21:195-223. doi: 10.1111/jcpe.13057.
2. Scheyer ET, Sanz M, Dibart S, Greenwell H, John V, Kim DM, Langer L, Neiva R, Rasperini G. Periodontal soft tissue non-root coverage procedures: a consensus report from the AAP Regeneration Workshop. J Periodontol. 2015 Feb;86(2 Suppl):S73-6. doi: 10.1902/jop.2015.140377.
3. Diz P, Scully C, Sanz M. Dental implants in the medically compromised patient. J Dent. 2013 Mar;41(3):195-206. doi: 10.1016/j.jdent.2012.12.008. Epub 2013 Jan 11.
4. Heitz-Mayfield LJ. Peri-implant diseases: diagnosis and risk indicators. J Clin Periodontol. 2008 Sep;35(8 Suppl):292-304. doi: 10.1111/j.1600-051X.2008.01275.x.
5. Vissink A, Spijkervet F, Raghoebar GM. The medically compromised patient: Are dental implants a feasible option? Oral Dis. 2018 Mar;24(1-2):253-260. doi: 10.1111/odi.12762.
6. Ferreira SD, Martins CC, Amaral SA, Vieira TR, Albuquerque BN, Cota LOM, Esteves Lima RP, Costa FO. Periodontitis as a risk factor for peri-implantitis: Systematic review and meta-analysis of observational studies. J Dent. 2018 Dec;79:1-10. doi: 10.1016/j.jdent.2018.09.010. Epub 2018 Nov 2.
7. Schwarz F, Derks J, Monje A, Wang HL. Peri-implantitis. J Periodontol. 2018 Jun;89 Suppl 1:S267-S290. doi: 10.1002/JPER.16-0350. PMID: 29926957.
8. Cardaropoli G, Araújo M, Lindhe J. Dynamics of bone tissue formation in tooth extraction sites. An experimental study in dogs. J Clin Periodontol. 2003 Sep;30(9):809-18. doi: 10.1034/j.1600-051x.2003.00366.x.
9. Nevins M, Camelo M, De Paoli S, Friedland B, Schenk RK, Parma-Benfenati S, Simion M, Tinti C, Wagenberg B. A study of the fate of the buccal wall of extraction sockets of teeth with prominent roots. Int J Periodontics Restorative Dent. 2006 Feb;26(1):19-29.
10. Schropp L, Kostopoulos L, Wenzel A. Bone healing following immediate versus delayed placement of titanium implants into extraction sockets: a prospective clinical study. Int J Oral Maxillofac Implants. 2003 Mar-Apr;18(2):189-99.
11. Trombelli L, Farina R, Marzola A, Bozzi L, Liljenberg B, Lindhe J. Modeling and remodeling of human extraction sockets. J Clin Periodontol. 2008 Jul;35(7):630-9. doi: 10.1111/j.1600-051X.2008.01246.x. Epub 2008 May 21.
12. Tomasi C, Donati M, Cecchinato D, Szathvary I, Corrà E, Lindhe J. Effect of socket grafting with deproteinized bone mineral: An RCT on dimensional alterations after 6 months. Clin Oral Implants Res. 2018 May;29(5):435-442. doi: 10.1111/clr.13141. Epub 2018 Mar 13.
13. Van der Weijden F, Dell'Acqua F, Slot DE. Alveolar bone dimensional changes of post-extraction sockets in humans: a systematic review. J Clin Periodontol. 2009 Dec;36(12):1048-58. doi: 10.1111/j.1600-051X.2009.01482.x.
14. Tomasi C, Sanz M, Cecchinato D, Pjetursson B, Ferrus J, Lang NP, Lindhe J. Bone dimensional variations at implants placed in fresh extraction sockets: a multilevel multivariate analysis. Clin Oral Implants Res. 2010 Jan;21(1):30-6. doi: 10.1111/j.1600-0501.2009.01848.x.
15. Chappuis V, Engel O, Reyes M, Shahim K, Nolte LP, Buser D. Ridge alterations post-extraction in the esthetic zone: a 3D analysis with CBCT. J Dent Res. 2013 Dec;92(12 Suppl):195S-201S. doi: 10.1177/0022034513506713. Epub 2013 Oct 24.
16. Whetman J, Mealey BL. Effect of Healing Time on New Bone Formation After Tooth Extraction and Ridge Preservation With Demineralized Freeze-Dried Bone Allograft: A Randomized Controlled Clinical Trial. J Periodontol. 2016 Sep;87(9):1022-9. doi: 10.1902/jop.2016.160139. Epub 2016 Apr 30.
17. Avila-Ortiz G, Gubler M, Romero-Bustillos M, Nicholas CL, Zimmerman MB, Barwacz CA. Efficacy of Alveolar Ridge Preservation: A Randomized Controlled Trial. J Dent Res. 2020 Apr;99(4):402-409. doi: 10.1177/0022034520905660. Epub 2020 Feb 12.

18. Tonetti MS, Jung RE, Avila-Ortiz G, Blanco J, Cosyn J, Fickl S, Figuero E, Goldstein M, Graziani F, Madianos P, Molina A, Nart J, Salvi GE, Sanz-Martin I, Thoma D, Van Assche N, Vignoletti F. Management of the extraction socket and timing of implant placement: Consensus report and clinical recommendations of group 3 of the XV European Workshop in Periodontology. J Clin Periodontol. 2019 Jun;46 Suppl 21:183-194. doi: 10.1111/jcpe.13131.
19. Barootchi S, Tavelli L, Majzoub J, Stefanini M, Wang HL, Avila-Ortiz G. Alveolar ridge preservation: Complications and cost-effectiveness. Periodontol 2000. 2023 Jun;92(1):235-262. doi: 10.1111/prd.12469. Epub 2022 Dec 29. PMID: 36580417.
20. Esposito M, Ekestubbe A, Gröndahl K. Radiological evaluation of marginal bone loss at tooth surfaces facing single Brånemark implants. Clin Oral Implants Res. 1993 Sep;4(3):151-7. doi: 10.1034/j.1600-0501.1993.040306.x.
21. Gastaldo JF, Cury PR, Sendyk WR. Effect of the vertical and horizontal distances between adjacent implants and between a tooth and an implant on the incidence of interproximal papilla. J Periodontol. 2004 Sep;75(9):1242-6. doi: 10.1902/jop.2004.75.9.1242.
22. Tarnow DP, Cho SC, Wallace SS. The effect of inter-implant distance on the height of inter-implant bone crest. J Periodontol. 2000 Apr;71(4):546-9. doi: 10.1902/jop.2000.71.4.546.
23. Merheb J, Quirynen M, Teughels W. Critical buccal bone dimensions along implants. Periodontol 2000. 2014 Oct;66(1):97-105. doi: 10.1111/prd.12042.
24. Spray JR, Black CG, Morris HF, Ochi S. The influence of bone thickness on facial marginal bone response: stage 1 placement through stage 2 uncovering. Ann Periodontol. 2000 Dec;5(1):119-28. doi: 10.1902/annals.2000.5.1.119. PMID: 11885170.
25. Greenstein G, Tarnow D. The mental foramen and nerve: clinical and anatomical factors related to dental implant placement: a literature review. J Periodontol. 2006 Dec;77(12):1933-43. doi: 10.1902/jop.2006.060197.
26. Benic GI, Hämmerle CH. Horizontal bone augmentation by means of guided bone regeneration. Periodontol 2000. 2014 Oct;66(1):13-40. doi: 10.1111/prd.12039.
27. Seibert JS. Reconstruction of deformed, partially edentulous ridges, using full thickness onlay grafts. Part I. Technique and wound healing. Compend Contin Educ Dent. 1983 Sep-Oct;4(5):437-53.
28. Soldatos NK, Stylianou P, Koidou VP, Angelov N, Yukna R, Romanos GE. Limitations and options using resorbable versus nonresorbable membranes for successful guided bone regeneration. Quintessence Int. 2017;48(2):131-147. doi: 10.3290/j.qi.a37133.
29. Jovanovic SA, Schenk RK, Orsini M, Kenney EB. Supracrestal bone formation around dental implants: an experimental dog study. Int J Oral Maxillofac Implants. 1995 Jan-Feb;10(1):23-31.
30. Simion M, Trisi P, Piattelli A. Vertical ridge augmentation using a membrane technique associated with osseointegrated implants. Int J Periodontics Restorative Dent. 1994 Dec;14(6):496-511.
31. Rocchietta I, Fontana F, Simion M. Clinical outcomes of vertical bone augmentation to enable dental implant placement: a systematic review. J Clin Periodontol. 2008 Sep;35(8 Suppl):203-15. doi: 10.1111/j.1600-051X.2008.01271.x.
32. Storgaard Jensen S, Bosshardt D, Buser D. Bone Grafts and Bone Substitute Materials. 20 Years of Guided Bone Regeneration, 2nd ed. Funk K, Ed. Hanover Park, IL. 2009:71-96.
33. Sanz-Sánchez I, Ortiz-Vigón A, Sanz-Martín I, Figuero E, Sanz M. Effectiveness of Lateral Bone Augmentation on the Alveolar Crest Dimension: A Systematic Review and Meta-analysis. J Dent Res. 2015 Sep;94(9 Suppl):128S-42S. doi: 10.1177/0022034515594780. Epub 2015 Jul 27.
34. Terheyden H, Cordaro L. Methods for Ridge Augmentation. ITI Treatment Guide: Ridge Augmentation Procedures in Implant Patients A Staged Approach, vol 7. Chen S, Buser D, Wismeijer D, Eds. Berlin, Germany. 2014:29-90.
35. Starch-Jensen T, Deluiz D, Tinoco EMB. Horizontal Alveolar Ridge Aumentation with Allogeneic Bone Block Graft Compared with Autogenous Bone Block Graft: a Systematic Review. J Oral Maxillofac Res. 2020; 11(1):e1. Published 2020 Mar 31. Doi:10.5037/jomr.2020.11101

36. Yu SH, Saleh MHA, Wang HL. Simultaneous or staged lateral ridge augementation: A clinical guideline on the decision-making process. Periodontol 2000. 2023;93(1):107-128. Doi:10.1111/prd.12512
37. Bassetti MA, Bassetti RG, Bosshardt DD. The alveolar ridge splitting/expansion technique: a systematic review. Clin Oral Implants Res. 2016 Mar;27(3):310-24. doi: 10.1111/clr.12537. Epub 2015 Jan 14.
38. Summers RB. A new concept in maxillary implant surgery: the osteotome technique. Compendium. 1994 Feb;15(2):152, 154-6, 158 passim; quiz 162.
39. Rambla-Ferrer J, Peñarrocha-Diago M, Guarinos-Carbó J. Analysis of the use of expansion osteotomes for the creation of implant beds. Technical contributions and review of the literature. Med Oral Patol Oral Cir Bucal. 2006 May 1;11(3):E267-71.
40. Elnayef B, Monje A, Lin GH, Gargallo-Albiol J, Chan HL, Wang HL, Hernández-Alfaro F. Alveolar ridge split on horizontal bone augmentation: a systematic review. Int J Oral Maxillofac Implants. 2015 May-Jun;30(3):596-606. doi: 10.11607/jomi.4051.
41. Waechter J, Leite FR, Nascimento GG, Carmo Filho LC, Faot F. The split crest technique and dental implants: a systematic review and meta-analysis. Int J Oral Maxillofac Surg. 2017 Jan;46(1):116-128. doi: 10.1016/j.ijom.2016.08.017. Epub 2016 Sep 14.
42. Nogueira RLM, Osterne RLV, Abreu RT, Araújo PM. Alternative Distraction Osteogenesis Technique After Implant Placement for Alveolar Ridge Augmentation of the Maxilla. J Oral Maxillofac Surg. 2017 Jul;75(7):1402.e1-1402.e8. doi: 10.1016/j.joms.2017.03.007. Epub 2017 Mar 18.
43. Sándor GK, Carmichael RP, Nish IA, Daskalogiannakis J. Distraction osteogenesis using dental implants. Atlas Oral Maxillofac Surg Clin North Am. 2008 Mar;16(1):137-46. doi: 10.1016/j.cxom.2007.10.008.
44. McAllister BS, Haghighat K. Bone augmentation techniques. J Periodontol. 2007 Mar;78(3):377-96. doi: 10.1902/jop.2007.060048.
45. Zhao K, Wang F, Huang W, Wu Y. Clinical Outcomes of Vertical Distraction Osteogenesis for Dental Implantation: A Systematic Review and Meta-Analysis. Int J Oral Maxillofac Implants. 2018 May/Jun;33(3):549-564. doi: 10.11607/jomi.6140.
46. Huwais S, Meyer EG. A Novel Osseous Densification Approach in Implant Osteotomy Preparation to Increase Biomechanical Primary Stability, Bone Mineral Density, and Bone-to-Implant Contact. Int J Oral Maxillofac Implants. 2017 Jan/Feb;32(1):27-36. doi: 10.11607/jomi.4817. Epub 2016 Oct 14.
47. Elsayyad AA, Osman RB. Osseodensification in Implant Dentistry: A Critical Review of the Literature. Implant Dent. 2019 Jun;28(3):306-312. doi: 10.1097/ID.0000000000000884.
48. Milinkovic I, Cordaro L. Are there specific indications for the different alveolar bone augmentation procedures for implant placement? A systematic review. Int J Oral Maxillofac Surg. 2014 May;43(5):606-25. doi: 10.1016/j.ijom.2013.12.004. Epub 2014 Jan 19.
49. Greenstein G, Cavallaro J, Tarnow D. Practical application of anatomy for the dental implant surgeon. J Periodontol. 2008 Oct;79(10):1833-46. doi: 10.1902/jop.2008.080086.
50. Artzi Z, Nemcovsky CE, Bitlitum I, Segal P. Displacement of the incisive foramen in conjunction with implant placement in the anterior maxilla without jeopardizing vitality of nasopalatine nerve and vessels: a novel surgical approach. Clin Oral Implants Res. 2000 Oct;11(5):505-10. doi: 10.1034/j.1600-0501.2000.011005505.x.
51. Chanavaz M. Maxillary sinus: anatomy, physiology, surgery, and bone grafting related to implantology--eleven years of surgical experience (1979-1990). J Oral Implantol. 1990;16(3):199-209.
52. Pohl V, Thoma DS, Sporniak-Tutak K, Garcia-Garcia A, Taylor TD, Haas R, Hämmerle CH. Short dental implants (6 mm) versus long dental implants (11-15 mm) in combination with sinus floor elevation procedures: 3-year results from a multicentre, randomized, controlled clinical trial. J Clin Periodontol. 2017 Apr;44(4):438-445. doi: 10.1111/jcpe.12694. Epub 2017 Mar 6.

53. Khetal NM, Ansari ST, Malik R, Lanjekar AB, Jirafe SJ, Gajghate AS. Assessment of anterior loop of mandibular canal and its implication in implant therapy. J Indian Soc Periodontol. 2022;26(4):342-347. doi:10.4103/jisp.jisp_642_20.
54. Gómez-Román G, Lautner NV, Goldammer C, McCoy M. Anterior Loop of the Mandibular Canal – A Source of Possible Complications. Implant Dent. 2015;24(5):578-585. doi:10.1097/ID.0000000000000312.
55. Kuzmanovic DV, Payne AG, Kieser JA, Dias GJ. Anterior loop of the mental nerve: a morphological and radiographic study. Clin Oral Implants Res. 2003;14(4):464-471. doi:10.1034/j.1600-0501.2003.00869.x
56. Yu SK, Kim S, Kang SG, et al. Morphological assessment of the anterior loop of the mandibular canal in Koreans. Anat Cell Biol. 2015;48(1):75-80. doi:10.5115/acb.2015.48.1.75.
57. Chan HL, Leong DJ, Fu JH, Yeh CY, Tatarakis N, Wang HL. The significance of the lingual nerve during periodontal/implant surgery. J Periodontol. 2010 Mar;81(3):372-7. doi: 10.1902/jop.2009.090506.
58. Chan HL, Brooks SL, Fu JH, Yeh CY, Rudek I, Wang HL. Cross-sectional analysis of the mandibular lingual concavity using cone beam computed tomography. Clin Oral Implants Res. 2011 Feb;22(2):201-6. doi: 10.1111/j.1600-0501.2010.02018.x. Epub 2010 Oct 6.
59. Law C, Alam P, Borumandi F. Floor-of-Mouth Hematoma Following Dental Implant Placement: Literature Review and Case Presentation. J Oral Maxillofac Surg. 2017 Nov;75(11):2340-2346. doi: 10.1016/j.joms.2017.07.152. Epub 2017 Jul 21.
60. Wang HL, Boyapati L. "PASS" principles for predictable bone regeneration. Implant Dent. 2006 Mar;15(1):8-17. doi: 10.1097/01.id.0000204762.39826.0f.
61. Alvira-González J, De Stavola L. The role of cortical perforations in bone regeneration: a systematic review. Int J Oral Maxillofac Surg. 2020 Jul;49(7):945-951. doi: 10.1016/j.ijom.2019.10.011. Epub 2019 Nov 9.
62. Terheyden H, Cordaro L. ITI Treatment Guide: Ridge Augmentation Procedures in Implant Patients A Staged Approach, vol 7. Chen S, Buser D, Wismeijer D, Eds. Berlin, Germany. 2014:29-81.
63. Lim G, Lin GH, Monje A, Chan HL, Wang HL. Wound Healing Complications Following Guided Bone Regeneration for Ridge Augmentation: A Systematic Review and Meta-Analysis. Int J Oral Maxillofac Implants. 2018 January/February;33(1):41–50. doi: 10.11607/jomi.5581. Epub 2017 Sep 22.
64. Machtei EE. The effect of membrane exposure on the outcome of regenerative procedures in humans: a meta-analysis. J Periodontol. 2001 Apr;72(4):512-6. doi: 10.1902/jop.2001.72.4.512.
65. Garcia J, Dodge A, Luepke P, Wang HL, Kapila Y, Lin GH. Effect of membrane exposure on guided bone regeneration: A systematic review and meta-analysis. Clin Oral Implants Res. 2018 Mar;29(3):328-338. doi: 10.1111/clr.13121. Epub 2018 Jan 24.
66. Storgaard Jensen S, Bosshardt D, Buser D. Bone Grafts and Bone Substitute Materials. 20 Years of Guided Bone Regeneration, 2nd ed. Funk K, Ed. Hanover Park, IL. 2009:71-96.
67. Garcia J, Dodge A, Luepke P, Wang HL, Kapila Y, Lin GH. Effect of membrane exposure on guided bone regeneration: A systematic review and meta-analysis. Clin Oral Implants Res. 2018 Mar;29(3):328-338. doi: 10.1111/clr.13121. Epub 2018 Jan 24.
68. Ella B, Laurentjoye M, Sedarat C, Coutant JC, Masson E, Rouas A. Mandibular ridge expansion using a horizontal bone-splitting technique and synthetic bone substitute: an alternative to bone block grafting? Int J Oral Maxillofac Implants. 2014 Jan-Feb;29(1):135-40. doi: 10.11607/jomi.2201.
69. Terheyden H, Cordaro L. Consensus Statemens and Treatment Guidelines Formulated at the 2008 ITI Consensus Conference. ITI Treatment Guide: Ridge Augmentation Procedures in Implant Patients A Staged Approach, vol 7. Chen S, Buser D, Wismeijer D, Eds. Berlin, Germany. 2014:3-12.

70. Nkenke E, Neukam FW. Autogenous bone harvesting and grafting in advanced jaw resorption: morbidity, resorption and implant survival. Eur J Oral Implantol. 2014 Summer;7 Suppl 2:S203-17.
71. Waasdorp J, Reynolds MA, Allogeneic bone onlay grafts for alveolar ridge augmentation: a systematic review. Int J Oral Maxillofac Imlants. 2010;25(3):525-531.
72. Donos N, Mardas N, Chadha V. Clinical outcomes of implants following lateral bone augmentation: systematic assessment of available options (barrier membranes, bone grafts, split osteotomy). J Clin Periodontol. 2008 Sep;35(8 Suppl):173-202. doi: 10.1111/j.1600-051X.2008.01269.x.
73. Tran DT, Gay IC, Diaz-Rodriguez J, Parthasarathy K, Weltman R, Friedman L. Survival of Dental Implants Placed in Grafted and Nongrafted Bone: A Retrospective Study in a University Setting. Int J Oral Maxillofac Implants. 2016 Mar-Apr;31(2):310-7. doi: 10.11607/jomi.4681.
74. Rachmiel A, Srouji S, Peled M. Alveolar ridge augmentation by distraction osteogenesis. Int J Oral Maxillofac Surg. 2001 Dec;30(6):510-7. doi: 10.1054/ijom.2001.0134.
75. de Carvalho Formiga M, Grzech-Leśniak K, Moraschini V, Shibli JA, Neiva R. Effects of Osseodensification on Immediate Implant Placement: Retrospective Analysis of 211 Implants. Materials (Basel). 2022;15(10):3539. Published 2022 May 15. doi:10.3390/ma15103539.

Additional Resources

- No Additional Resources Available.

About the Authors

Lavanya Rajendran, DMD, MDSc

Lavanya Rajendran is a board certified Periodontist and Master of Dental Science. She currently works full time in private practice at Shoreline Periodontics in New London, CT and Westerly, RI, and teaches at UConn Health as a volunteer clinical faculty in the Department of Periodontology.

Email: rajendran@uchc.edu

Sejal Thacker, DDS, MDSc

Sejal Thacker is a board certified Periodontist and a Master of Dental Science. She directs the post-graduate Periodontology program at UConn Health and maintains a private clinical practice in Shelton, Glastonbury and Manchester. She received an award for *Outstanding Teaching and Mentoring in Periodontics* by the American Academy of Periodontology in 2015 and 2019. She has participated in multiple clinical trials and was recently honored with the *Bud and Linda Tarrson Fellowship*.

Email: drsejalthacker@gmail.com