Surgical Techniques to Increase Bone Augmentation Success

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In implant dentistry today, bone grafting has become a common treatment modality. It is imperative to have adequate hard- and soft-tissue volume to allow for ideal implant placement, decreased morbidity, and increased success rates for both the surgical and prosthetic phases of treatment. The bone grafting options of materials and techniques are very numerous in implant dentistry. Consistent bone grafting success has been difficult to achieve on a continuous basis because practitioners often use similar techniques, regardless of the existing conditions, bone volume, and graft location. Thus, this article will discuss techniques and principles that will increase bone grafting success rates with decreased complications.

**REMOVE ALL SIGNS OF INFECTION/SURGICAL ASEPSIS**

It is imperative that bone grafting is completed free of any existing pathology, and that bacterial contamination is minimized via surgical asepsis and antimicrobial prophylaxis.

**Removal of pathology**—Prior to bone grafting, all signs of pathology and infection need to be removed. Bone grafting in the presence of pathology will most likely lead to increased morbidity of the graft and recipient site bone loss. Prior to grafting, whether in a fresh extraction socket, residual ridge, or maxillary sinus, all evidence of active infection needs to be eradicated. When bone becomes infected, a low pH results in rapid solution-mediated resorption, which decreases bone formation and increases the morbidity of the graft. Therefore, prior to bone grafting, it is vital that all signs of infections are eliminated.

**Surgical asepsis**—By definition, bone grafting in dental implantology has been classified as a clean-contaminated surgical procedure with an associated 15% infection rate. However, if proper asepsis and prophylactic antimicrobial treatment is utilized, the infection rate may decrease to less than 1.0%. To minimize postoperative infection, a controlled, well-monitored aseptic surgical setting is beneficial. The aseptic component should include proper disinfection and draping procedures for patients, sterile gloves, and gowns worn by surgical members, and strict sterility of instrumentation and grafting materials.

**Use of prophylactic antimicrobials**—Postoperative infections may lead to a multitude of complications including pain, swelling, bone graft loss, and recipient site bone loss. Antibiotic prophylaxis has been shown to be effective in reducing postoperative infections after bone grafting procedures. The use of a beta-lactam antibiotic (amoxicillin) pre- and postoperatively will provide adequate systemic coverage. Another modality for antimicrobial prophylaxis is the use of 0.12% chlorhexidine digluconate (Peridex [3M ESPE]). Chlorhexidine gluconate is a potent antibacterial, which causes lysis by binding to bacterial cell membranes. It has high substantivity, which at high concentrations exhibits bactericidal qualities, thereby causing bacterial cytoplasm precipitation and cell death.

Unfortunately for allograft bone grafts, there exists minimal immediate blood supply with an absence of the host's cellular defense mechanisms. This results in the graft site being prone to infection.
to infections, and the osteogenic induction may be greatly reduced by the infectious bacteria. To minimize the possibility of infection, local administration of antibiotics should be used within the graft material. The parenteral use of the pure form of antibiotics (eg, Ansef, Cleocin) is recommended to be added to the graft to decrease the possibility of infection from early contamination. Numerous studies have shown no deleterious effects on bone growth from locally delivered antibiotics. Because the incidence of allergy is high with penicillin containing antibiotic drugs, the parenteral form of cefazolin (Ancef) or clindamycin (Cleocin) is selected. Orally administered capsules and tablets should not be used within the graft, because they contain fillers that are not favorable for osteogenesis (Figure 1).

**FLAP DESIGN**

The flap design is extremely important to the success of the bone graft. If basic principles are not adhered to in the design of the flap, the bone graft may be placed at risk.

- **Maintain blood supply to reflected flap**—a broad-based incision should be completed to maintain blood supply and to allow for elevation, retraction, repositioning, and suturing without tension.
- The facial flap, which is the most common flap reflected for a bone graft, contains mostly unkeratinized mobile mucosa. The vertical release incisions should be made to the height of the mucogingival junction, with the facial flap only reflected approximately 5 mm above the height of the mucogingival junction. The larger the bone graft site, the larger and more distal the vertical incisions. This will decrease the possibility of tearing the tissue, allows for increased blood supply to the graft area (broad-based), and allows for the margins of the flap to be over host bone, instead of the graft. The soft-tissue reflection distal to the graft site should be ideally split thickness as this maintains the periosteum on the bone. This will improve early vascularization to the incision line.
- **Adequate attached tissue**—Graft sites should have an adequate zone of attached keratinized tissue. If adequate attached tissue is not present, soft-tissue grafting should be completed. Another option would be the placement of an acellular dermal matrix (eg, allograft). Additionally, when inadequate keratinized tissue is present, the incision should be made more toward the lingual as to preserve as much attached tissue on the facial as possible. This allows for greater resistance to muscle pull and will decrease incision line opening.
- **Margins over host bone**—The margins of the wound should always be over host bone, as this allows for better healing, prevents loss of graft material, and allows the periosteum to regenerate faster. The incision margins should be lateral to the membrane position, as this will decrease the possibility of membrane exposure or incision line opening (Figure 2).

**PREPARATION OF THE RECIPIENT SITE**

The recipient site should always be prepared with the regional acceleratory phenomenon (RAP) technique to improve and accelerate healing processes. RAP is a local response to a noxious stimulus (decortication), which may result in healing 2 to 10 times faster than normal. The recipient site should be decorticated by placing pilot holes in the cortical bone, which allows for trabecular bone blood vessels to increase revascularization and integrate bone growth factors to the graft site. This will include platelets, which release growth factors such as platelet-derived growth factor and transforming growth factor along with increasing osteogenic cells to the graft site. The decortication will also allow for better

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**Figure 2.** (a) A large, broad-based flap design to minimize tension on graft site, and (b) post-op Bio-Oss (Geistlich) xenograft. (c) When lack of attached tissue exists, an incision should be made toward the lingual to maximize attached tissue on facial, and (d) vertical releases should be made over bone and lateral to the margins of the membrane (CopiOs Pericardium Membrane [Zimmer Dental]).

**Figure 3.** Regional acceleratory phenomenon: (a) decortication with fissure bur (702 L [Salvin Dental Specialties]) and (b) completed decortication showing bleeding holes.
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**Integration of the Graft to the Host Bone**
The technique includes the use of a small fissure bur drill (eg, 702 L [Salvin Dental Specialties]) with copious amounts of irrigation to prevent thermal trauma (Figure 3).

**Graft Containment and Maintaining Space**
For the graft to heal and form new bone, it must be contained at the site of the defect. The concept of bone growth is based on space (anatomic size and contour of the desired augmentation) and maintenance (space must exist long enough for bone to fill in the desired area). A barrier membrane is used to prevent soft-tissue growth into the graft. There exist many options available today in implant dentistry to contain the graft. The ideal particulate containment system would maintain the graft, assist with maintaining space, prevent exposure to the oral environment and soft-tissue ingrowth, and also possess the ability to slowly resorb or easily be removed. Many resorbable membranes are available which are derived from xenogenic collagen sources or cadaver dermis. These membranes are popular because they are slowly resorbed; however, they are not ideal for space maintenance. Non-resorbable membranes include various forms of polytetrafluoroethylene (PTFE) and titanium mesh. They are excellent for graft containment as well as space maintenance. However, they do have the disadvantage of needing to be removed via a second surgical procedure (Figure 4).

**Use of Bone Growth Factors**
The use of bone growth factors in implant dentistry has been shown to be advantageous, as they enhance bone healing and improve success rates. The types and various techniques for implementing these factors into grafting procedures—eg, platelet-rich fibrin (PRF), recombinant human bone morphogenetic proteins (rhBMP-2)—have increased substantially.

**Platelet-Rich Fibrin**
PRF is an autologous fibrin matrix that is used as a healing biomaterial in implant dentistry. This fibrin matrix incorporates platelets, leucocytes, cytokines, and circulating stem cells that are gradually released to accelerate physiologic healing. It is easily obtained and does not require any biochemical blood handling. After drawing blood and placing in a centrifuge for 12 minutes, the coagulation cascade will be triggered. The end result is a fibrin clot in the middle layer, situated between the acellular platelet-poor plasma and the red blood cells. Thus, when the fibrin clot (PRF) is used as a membrane, it will protect the wound and serves as a matrix to accelerate healing. When the PRF is mixed with the graft material (allograft), the fibrin clot will act as a biological connector between all the elements of the graft, while also acting as a matrix that initiates angiogenesis, stem cell accumulation, and migration of osteoprogenitor cells to the graft. Thus, the synergistic effects of the fibrin matrix and growth factors allow for the enhanced healing of the hard and soft tissues. Studies have shown PRF with freeze-dried bone allograft (FDBA) heal faster than FDBA alone.

**Recombinant Human Bone Morphogenetic Proteins**
The rhBMP-2 are a group of sequentially arranged amino acids and polypeptides that are osteoinductive proteins, acting to initiate, stimulate, and amplify bone morphogenesis. BMPs stimulate mesenchymal stem cells to induce bone formation via differentiation to osteoblasts, which form and mineralize new bone. BMP-2 has been purified, sequenced, and cloned, and is marketed as rhBMP-2 (Infuse Bone Graft [Medtronic]). Infuse Bone Graft consists of 2 components: a 1.5 mg/mL concentration of rhBMP-2 and an absorbable collagen sponge. Studies have shown rhBMP-2 with titanium mesh to be an effective treatment for augmentation of the posterior mandible prior to implant placement. The new bone formed by rhBMP-2 has been shown to be similar to native bone and can withstand the stresses of implant placement and prosthetic function (Figure 5).

**Tension-Free Soft Tissue**
Incision line opening is the most common postoperative complication to be reported during intraoral bone grafting. When the incision line breaks down, the graft often will become...
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contaminated or infected, leading to decreased vascularization and lack of bone growth. The most common reason for incision line opening is tension on the incision line. When tension-free soft-tissue closure is obtained, the graft area will heal by primary intention, which encourages osteo-competent cell proliferation. To obtain primary wound closure, the tissue must be manipulated to remove all tension.

*Stretching the tissue*—The submucosal space technique developed by Misch in 1980 is an effective method to expand the tissue over graft sites. An incision (one to 2 mm deep) is made through the periosteum parallel to the crestal incision, approximately 3 to 5 mm above the vestibular height of the mucoperiosteum. Tissue scissors (eg, Metzenbaum) are then used in a blunt dissection technique to create a tunnel apical to the vestibule and above the unreflected periosteum. The scissors are placed in a closed position and pushed through the initial scalpel incision approximately 5 to 10 mm deep, then opened. This submucosal space is parallel to the surface mucosa (not deep toward the overlying bone) and above the unreflected periosteum. Ideally, the facial flap should be able to advance over the lingual flap margin by 5 mm (Figure 6).

**IDEAL SUTURING**

To maintain closure of the graft site, the ideal suturing technique and material should be used. The suture material of choice should have high tensile strength so that muscle pull and tension are resisted with low probability of inflammation and wicking effect. Thus, plain gut, chromic gut, and silk should not be used. Polyglycolic acid (PGA, vicryl), because it maintains sufficient tension during the first 2 weeks and has been shown to have minimal tissue reaction, is an ideal suture material for bone grafts. Another alternative is the use of nonresorbable PTFE monofilament sutures (ie, Cytoplast PTFE suture). These sutures are biologically inert, high tensile strength, nonwicking, and have excellent knot security.

The sutures should be placed approximately 3 mm from the margin of the tissue. Sutures placed less than 3 mm away increase the possibility of tearing the flap. Also, care should be exercised to make sure that sutures are placed approximately 3 to 5 mm from each other and not too tight, as this may lead to tissue ischemia and a devitalized zone. No allograft material should be present within the incision line as this may delay healing. After the tissues are sutured, the incision line is inspected for any open areas or particles (Figure 7).

**PROVISIONAL RESTORATION**

Bone graft stabilization is paramount to predictable bone augmentation to ensure blood clot adhesion and the introduction of
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associated growth factors for predictable healing. As little as 20 μm of movement will result in a nonfixated graft and fibrous encapsulation as the graft cannot develop a blood supply for new bone formation. Graft immobility is vital to capillary ingrowth and graft revascularization. One of the most common and challenging roadblocks to implant treatment acceptance is the patient's perception of the temporization (provisionalization) of the edentulous areas after bone grafting. In most cases, pressure directly or indirectly on the surgical site can lead to bone loss and increased morbidity of the graft site. Ideally, no provisionalization after surgery is the best treatment. However, because of patient requests, many types of provisionalization techniques are being utilized. The 2 prosthesis types that minimize pressure on the graft site are the Essix Appliance (DENTSPLY Raintree Essix) and the Snap-On Smile (DenMat) concept. The thermoformed Essix Appliance is easily fabricated, inexpensive, and prevents pressure from being placed on the graft site. A Snap-On Smile is a noninvasive partial or full-arch removable prosthesis that is placed over the patient's dentition. This interim prosthesis is aesthetic, has excellent retention, no impingement on the soft tissues, and allows the adjacent teeth to absorb the occlusal force (Figure 8).

SUMMARY
Oral implantology has grown into a widely accepted and ever expanding discipline. Due to this phenomenon, more and more clinicians are offering dental implant surgery in their respective practices. As the discipline of implantology grows, the prevalence of bone grafting will become more significant. Restoring the lost hard tissue volume to allow ideal implant placement is crucial to decrease the morbidity of implants and the restorations they support. Bone augmentation comprises a wide range of materials, donor sites, and surgical approaches, with new advances arriving at a staggering rate. With all of the materials and varying techniques available today, the practitioner must have a solid understanding of adjunct techniques to increase the success of bone grafting.

References
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   a. True        b. False

2. If proper asepsis and prophylactic antimicrobial treatment is utilized, the infection rate may decrease to less than 1.0%.
   a. True        b. False

3. Numerous studies have shown many serious deleterious effects on bone growth from locally delivered antibiotics.
   a. True        b. False

4. The larger the bone graft site, the larger and more distal the vertical incisions.
   a. True        b. False

5. Regional acceleratory phenomenon (RAP) is a local response to a noxious stimulus (decortication), which may result in healing 2 to 10 times faster than normal.
   a. True        b. False

6. Incision line opening is the least common postoperative complication to be reported during intraoral bone grafting.
   a. True        b. False

7. Bone morphogenetic proteins (BMPs) stimulate mesenchymal stem cells to induce bone formation via differentiation to osteoblasts, which form and mineralize new bone.
   a. True        b. False

8. Graft immobility is not really vital to capillary ingrowth and graft revascularization.
   a. True        b. False
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