

Review Article

Novel Approaches for Alveolar Ridge Preservation

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Abstract: It is proven that after every extraction of one or more teeth the alveolar bone of the respective region undergoes resorption and atrophy. Alveolar ridge preservation procedures have been introduced to maintain an acceptable ridge contour in areas of aesthetic concern, as well as to prevent alveolar ridge atrophy and maintain adequate dimensions of bone in order to facilitate implant placement in prosthetically driven positions. There are numerous techniques available for ridge preservation. Recent advancements in barrier membranes, bone grafting substitutes, and surgical techniques have led to predictable treatment methods for ridge preservation procedures. This article will focus on some of the novel approaches for alveolar ridge preservation procedures.

Keywords: Tissue Engineering, Bio-Col, Open barrier Technique, Cytoplast ridge preservation, Hyaluronic acid, Open healing approach.

Introduction

The alveolar ridge is a tooth-dependent structure that develops in conjunction with tooth eruption and undergoes volume and morphologic alteration subsequent to tooth loss. It has important implication on retention, resistance, stability and esthetics of the prosthesis and also has a significant role in assessing prognosis of mucogingival surgeries. The successful esthetic and functional restoration of an implant depends on its optimal placement, which is influenced by its height and buccolingual position as well as by the alveolar ridge dimensions. Loss of alveolar ridge significantly affects the esthetics and functional qualities of the prosthesis.

The loss of alveolar bone volume can occur before dental extraction due to periodontal disease, periapical pathology and trauma to the teeth and bone [1]. The traumatic removal of teeth can cause bone loss and in most of the cases alveolar bone suffers atrophy after tooth extraction. Volume and morphologic alteration of alveolar ridge occur rapidly within the first 3 months to 6 months of tooth extraction and continue gradually at a slower rate thereafter. At 6 months, the ridge may lose up to 63% of its width and up to 22% of its original height. An estimated mean bone loss of 3.87 mm horizontally and 1.25 mm to 1.67 mm vertically can be expected [2, 3]. Alveolar bone resorption usually is more pronounced on the facial side, which leads to relocation of the ridge to an unfavorable position chronic and the alveolar bone continuous to resorb even after 25 years of extraction [1].

To meet the contemporary requirements of three dimensional prosthetically-guided implant placements, for better prosthetic support, esthetic & function, the remaining alveolar ridge must be restored. Preservation of the ridge volume and contour facilitates de novo bone formation within the socket. Alveolar ridge preservation techniques have been widely used in the past and are

continuously evaluated. These techniques are performed to counteract changes in soft tissue and hard tissue that follow tooth extraction. More recent research has focused on a variety of materials and techniques and has different aims depending on the need for preservation of soft tissue and/or hard tissue, as well as on the optimization of the ridge profile.

Novel Tissue Engineering Approaches

In order to overcome the limitations of routinely adopted biomaterials as allografts, xenografts and alloplasts in terms of predictability and quality of bone formation and ability to sustain alveolar ridge morphology over long periods of time, novel tissue engineering therapies have been developed including the delivery of growth factors incorporated in carriers, the stimulation of the selective production of growth factors using gene therapy, and the delivery of expanded cellular constructs [4]. Bone morphogenetic proteins (BMPs) are an example of growth factors; they have the ability of inducing the differentiation of the host stem cells into bone forming cells in a process known as osteoinduction [5].

A feasibility study introducing the use of rhBMP-2 absorbed in a collagen sponge for alveolar ridge preservation after tooth extraction was published in 1997 [6]. Howell et al. demonstrated the safety of this grafting material. Patients receiving socket grafting demonstrated increase in bone height while patients receiving a ridge augmentation procedure showed no evidence of augmented ridge width or height. Implants placed in the regenerated bone were stable and presented healthy peri-implant tissues. After this pilot study, Fiorelini and coworkers [7] performed a randomized clinical trial testing the regenerative potential of the recombinant BMP-2 in the collagen sponge compared to the use of the collagen sponge alone.

Anterior maxillary postextraction alveolar defects in which more than 50% of the alveolar buccal bone had been lost prior to extraction were treated with either of the two grafting material [8]. Two different rhBMP-2 concentrations were used (0.75mg/mL and 1.50mg/mL). Significantly greater augmentation was noted in the 1.50mg/mL group and both rhBMP-2 groups outperformed the control groups. Histological findings showed generation of bone no different from native bone.

PDGF-BB in a β -TCP carrier is a material accepted from the FDA for regeneration of bone and PDL elements in guided tissue regeneration procedures. Nevins et al. [9] evaluated the use of the recombinant protein in socket grafting. In this case series, 8 extraction sockets received Bio-Oss Collagen hydrated with 0.3mg/mL PDGF-BB, and flaps were released for closure by primary intention. Then 4 or 6 months after grafting bone core, biopsies revealed robust bone formation. Also $23.2 \pm 3.2\%$ new bone and 9.5 ± 9.1 residual grafting material were noted at 4 months. However, $18.2 \pm 2.1\%$ new bone and $17.1 \pm 7.0\%$ residual grafting material were noted at 6 months in the histomorphometrical evaluation.

More recently, tissue repair cells (TRC), a cell construct derived from each patient's bone marrow and cultivated using automated bioreactors to concentrations not achievable through a simple bone marrow aspiration, were evaluated in socket healing [10, 11]. This study showed that this cell construct is able to produce significant concentrations of cytokines and maintains the cells' ability to differentiate toward both the mesenchymal and endothelial pathway and produce angiogenic factors. TRC therapy enhanced formation of highly vascular mature bone as early as 6 weeks after implantation when compared to guided bone regeneration with no serious study-related adverse event reported and lower degrees of alveolar ridge resorption were noted.

Bio-Col or Resorbable Hemostatic Plug Technique

Bio-Col alveolar ridge preservation technique [12], is one option for patients undergoing tooth removal to preserve hard and soft tissue alveolar ridge anatomy in preparation for immediate or delayed implant placement. This ridge preservation technique takes advantage of the synergistic effect of combining surgical and prosthetic site preservation protocols. The surgical protocol ensures

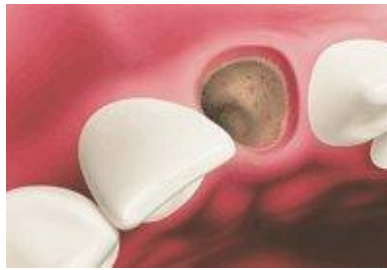
the preservation of both hard and soft tissues at the time of tooth extraction, and it diminishes or eliminates bone resorption that would normally follow tooth removal [13]. The prosthetic protocol uses interim provisional restorations to support the soft tissues surrounding the extraction site, thereby preventing their collapse during maturation. This result in the preservation of the natural soft tissue anatomy, which when lost is extremely difficult to recreate.

This technique can be used to reduce or avoid osseous ridge resorption by minimizing trauma during tooth removal. The prepared extraction sockets or the voids surrounding the immediately placed implant are then grafted with Bio-Oss (Osteohealth, Shirley, NY), a natural, porous bone-grafting material [13]. Subsequently, the grafted socket is isolated with an absorbable collagen material (Collaplug; Zimmer Dental, Carlsbad, CA) that has been coated with impervious tissue cement (Isodent; Ellmann International, Hewlett, NY); this allows for guided bone regeneration without the need for flap elevation and primary closure, thus preserving the surrounding soft tissue volume.

Finally, the scalloped soft tissue architecture is preserved with the use of interim provisional restorations, anatomic healing abutments, or custom tooth form healing abutments designed to support the marginal tissues and interdental papillae. This is of critical aesthetic importance for implant patients who present with thin scalloped periodontal biotypes who are predisposed to loss of alveolar ridge volume secondary to remodeling, resorption of bone following tooth removal, and soft tissue recession following subsequent surgical or restorative interventions.



**Figure 1. Bleeding
Extraction socket with no
defect**



**Figure 2. Graft placed up
to alveolar crest**



**Figure 3. Immediate
implant placement**

The “Modified” Bio-Col Technique for Ridge Preservation

The Bio-Col technique is a minimally invasive approach for socket preservation [14]. Its advantage lies in a flapless approach, thus preserving periosteum and blood supply to thin residual crestal lamellar bone and soft tissue. Following tooth removal using a minimally traumatic protocol, evaluation of the extraction socket will determine if the Bio-Col technique is indicated. Appropriate sites are those with optimal healing potential; that is, minimal soft tissue disturbance and minimal to no damage to the buccal and lingual/palatal cortical plates. Larger defects or vertical defects extending into the interproximal region(s) are better managed with an open or closed barrier technique.

If the Bio-Col technique is selected, the debrided extraction socket is gently packed with a mineralized, particulate graft material such as bovine xenograft (e.g. Bio-Oss, Geistlich, Princeton, NJ) which acts as an osteo-conductive scaffold that will support new bone formation and minimize loss in bucco-lingual/palatal alveolar ridge dimension. The graft particles are then covered with a layer of an absorbable collagen sponge (e.g. Ora-Plug, Salvin Dental, Charlotte, NC) secured with a figure of eight fixation suture. Cyanoacrylate (e.g. PeriAcryl, GluStitch Inc., Delta, BC, Canada) is then flowed over the exposed surface to protect the collagen from salivary enzyme degradation, mechanical trauma, and/or micromotion during initial healing. This technique is particularly applicable for extraction sites with single-rooted teeth where the progression of secondary intention

wound healing from the periphery can quickly coalesce for wound closure. Because of the greater dimensions of molars, fibrin deposition and granulation from the wound periphery will take longer; and for larger defects, consideration of the hd-PTFE open-barrier technique can be helpful.

Modifications of the Bio-Col technique include using other graft materials (e.g. mineralized allograft or alloplastic material) in order to achieve different wound healing kinetics, or using autologous venous blood to saturate graft particles and the collagen plug prior to their placement. These steps have been suggested to improve healing by incorporating native growth factors from platelet degranulation. Alternatively, commercially available growth factor such as recombinant human platelet-derived growth factor (rhPDGF–GEM 21S, Osteohealth Inc., Shirley, NY) can be used in an “off-label” application.

Additionally, protection of the collagen from any contact with saliva or mechanical trauma during surgery or the early healing period is important. The salivary enzymes quickly begin degradation of the collagen and can result in early exposure of the graft material. A light-cured periodontal dressing (Barricaid, Dentsply-Caulk, Milford, DE) can be placed over the wound to protect the collagen layer, and this is especially helpful at larger multirooted tooth defects.



Figure 4. Atraumatic tooth removal



Figure 5. Grafting with mineralised allograft

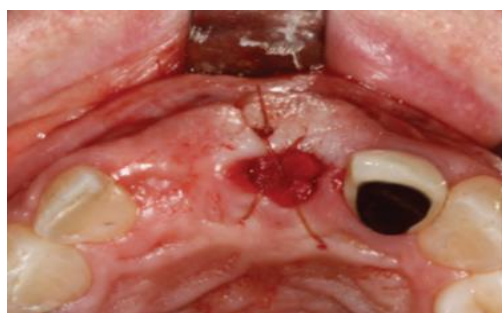


Figure 6. Sectioned collagen plug saturated in rh-PDGF



Figure 7. After 10 days of healing

Open-Barrier Techniques

Larger extraction defects, such as those of a single molar tooth, multiple tooth defects, or defects that include substantial loss of buccal or lingual/palatal cortical plate, may not be appropriate for the Bio-Col technique. While the original porous PTFE membranes can work well with these types of defects, primary soft tissue closure is a major technical challenge, and bacterial cell penetration with resulting infection can occur with exposure to the oral environment. This limitation led to the development of a second-generation PTFE barrier membrane [15, 16] formed from hd-PTFE. Hd-PTFE is impervious to bacteria, and if properly adapted over the grafted socket has a very low incidence of infection. Animal studies confirmed the efficacy of hd-PTFE as a guided tissue regeneration material, and US Food and Drug Administration clearance was granted in 1994. Techniques for use of these hd-PTFE barriers can be very effective and relatively inexpensive for a variety of clinical applications [17].

The Cytoplast® (hd-PTFE) Ridge Preservation Technique

In sockets grafted with mineralized bone allograft and covered with hd-PTFE, vertical bone loss at 4 months post-extraction was 0.25 mm while horizontal loss was 0.30 mm. This compared favourably with sockets grafted with mineralized bone allograft and covered with acellular human dermis (1.10 mm vertical and 0.44 mm horizontal loss). Histomorphometric analysis [18] revealed a vital bone percentage of 47.4% for hd-PTFE and 41.8% for the human dermis membrane group. In a retrospective, non-randomized human study reporting on 276 treated sockets, predictable bone regeneration was found with no reported cases of infection associated with the exposed hd-PTFE membranes. Dental implant success rates in bone regenerated with the hd-PTFE technique for a case series with 5-year results showed 98% survival of 99 implants placed into the regenerated bone [19].

Results of another published series of 420 treated cases using hd-PTFE with and without lyophilized mineralized bone allograft indicated preservation of bone, preservation of the position of the mucogingival junction, and formation of adequate keratinized tissue, as was earlier reported by Barber et al [20]. The technique is indicated for any extraction site where ridge preservation is desired, and can also be employed in conjunction with immediate implant placement. Normally, a particulate graft material is used under the membrane, although Barboza et al [21] have shown that the graft may in fact not be needed, at least if sufficient buccal cortical bone remains to support the membrane. If additional soft tissue augmentation is desired in thin gingival biotype cases, the technique may be modified by adding a layer of collagen membrane or autogenous connective tissue under the hd-PTFE layer.

Contraindications include existing cigarette smoking, uncontrolled chronic periodontal disease, or acute infection with swelling and drainage. Chronic periodontal and/or periapical infections are relative contraindications, but may not present increased risk provided that preoperative antibiotics are prescribed along with aggressive site debridement.

Double-membrane technique was employed by first using a resorbable collagen membrane to cover the graft materials (Cytoplast® RTM Type I collagen, Osteogenics Biomedical Inc.). This membrane was trimmed to rest on 3–4 mm of buccal and palatal bone and on the interdental bone crests as well. An hd-PTFE membrane (Cytoplast TXT-200®, Osteogenics Biomedical Inc.) was trimmed with scissors to fit the site and placed over the collagen membrane and into the prepared buccal and palatal subperiosteal pouches. This membrane was carefully trimmed so as to fit precisely over the socket and associated bone defect, extending 3.0–4.0 mm onto bone beyond the socket margins for support. The corners of the membrane should be gently rounded and smooth. Sutures were used to stabilize the membrane and eliminate dead space under the barrier [22].

Monofilament PTFE suture is recommended for wound closure. Good, tension-free adaptation of the flap to the membrane and elimination of dead space are required. A “figure of-eight” suture technique may be used in single sockets or, alternatively, two interdental interrupted sutures can be placed across the interdental papillae combined with a horizontal mattress suture placed across the mid portion of the socket. Covering the wound site with light-cured periodontal dressing can aid in wound protection.

A temporary prosthesis, if present, should be carefully trimmed to avoid placing pressure from the pontic onto the surgical site. Even soft liners or tissue conditioners should not be in direct contact with the grafted site during the first 3 weeks, and the occlusion should be carefully adjusted to prevent micromotion of the temporary prosthesis during function. Complications, such as soft tissue dehiscence seen as flap retraction, are rare but can occur [22].



Figure 8 & 9. hd-PTFE barrier adapted and sutured



Figure 10. Provisional restoration given

Hyaluronic Acid in Alveolar Ridge Preservation

The use of Hyaluronic Acid that can promote wound healing may be beneficial and indicated when treating infected sockets. Hyaluronate, also known as hyaluronic acid (HA) or hyaluronan, is a high molecular weight non-sulfated glycosaminoglycan present within the extracellular matrix. Hyaluronic acid can promote cell migration and differentiation during tissue formation and plays an important role in wound healing [24]. Because Hyaluronic acid has been shown to promote bone formation and wound healing in extraction sockets, clinical application may be considered to counteract the delayed healing that results from grafting the socket, eventually reducing the time until implant surgery. HA also has bacteriostatic and anti-inflammatory properties [23] that can be applied to the infected sockets after tooth extraction as a result of periodontal or endodontic infection.

To improve bone formation in infected sockets and avoid erratic healing as three factors are required for tissue engineering:

1. Cells with an osteogenic capacity;
2. A scaffold for maintaining the entire structure; and
3. Signals for inducing osteogenesis [24].

Grafts used in ridge preservation can provide a scaffold for maintaining volume, whereas osteoconductivity is also needed to induce the migration of osteogenic cells. However, deficiency in signaling molecules and reduced healing potential in infected sockets may retard the healing process. Therefore, the osteoinductive effect of HA combined with an adequate graft material for structural integrity may enhance the clinical results as anticipated [25].

Alveolar Ridge Preservation with an Open-Healing Approach

Alveolar ridge preservation with an open-healing approach using singlelayer or double-layer coverage with collagen membranes was originally proposed by Buser et al [26, 27], and Kim et al. [28]. They reported that the double-layer technique significantly reduced the resorption rate of overlay block-bone graft. After tooth extraction, each extraction site was filled with 250 mg of deproteinized bovine bone matrix mixed with 10% collagen (DBBM-C, Bio-Oss® Collagen, Geistlich Pharma, Wolhusen, Switzerland) up to the highest bone level. After filling the sockets, the sites were randomly assigned to the SL group or the DL group.

In the SL group, a single-layer of resorbable collagen membrane (13×25 mm, Bio-Gide®, Geistlich Pharma) was used to cover the operated sites at the level of the adjacent soft tissue. In the DL group, resorbable collagen membrane was trimmed into two pieces and double-layers of resorbable collagen membrane covered the sites. The upper sides of all the membranes were laid facing the occlusal plane. The membrane was held in place by suture thread (Ethilon 4-0, Ethicon, Cincinnati, OH, USA), using hidden X sutures or X sutures, and secondary healing was obtained. No efforts were made to obtain primary closure. Four months after surgery, the flaps were elevated and non-

submerged dental implants (Luna®, Shinhung, Seoul, Korea) were inserted immediately after cone-beam computed tomography (CBCT) re-scanning.

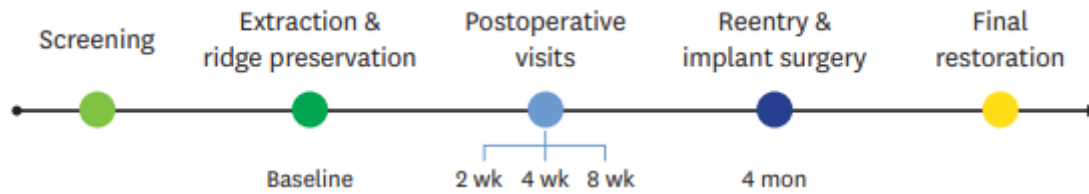


Figure 11. Schematic presentation of the procedure

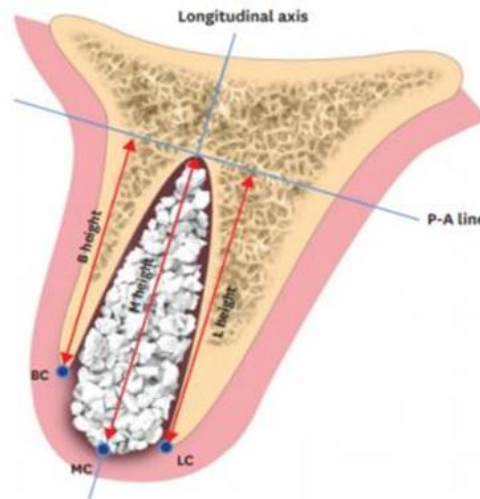


Figure 12. Schematic drawing in the radiographic analysis

Double-layer would preserve the alveolar ridge dimension better than the single-layer, because

1. Double-layers of collagen membrane take longer to be degraded than single-layer and can therefore provide better stabilization for bone graft materials, and
2. The inner layer of the double-layer would be rapidly incorporated into the host tissue and infiltrated by vascularization [29].
3. While the outer layer was expected to function as a dressing for the inner layer, enhancing its barrier function.

Nevertheless, the results did not show any substantial difference in the radiographic analysis or clinical analysis between the SL and DL groups in the quantitative evaluation, contrary to our hypothesis.

Advantages

It is well accepted that exposure of collagen membranes to the oral environment makes them degrade even faster. Therefore, the outer layer of collagen membranes applied in double-layer coverage still can function as an extra barrier membrane, helping ensure a stable healing process by protecting the underlying collagen membrane. Double-layer membrane coverage may prove useful for clinicians, especially when treating patients with a delayed healing potential or who cannot comply well with the oral hygiene requirements for soft tissue.

Conclusion

The alveolar ridge assisted healing concept was to minimize postextraction alveolar ridge alterations, preservation of the ridge volume and contour which facilitates bone formation within the socket. However, the indication of specific approaches to achieve a predictable and satisfactory outcome in a given scenario remains a significant challenge in clinical practice. Number of factors may influence ridge resorption patterns such as the number of extracted neighbouring teeth, morphology of socket

(i.e., single vs multirooted teeth and socket integrity), periodontal biotype (i.e., bony buccal plate and soft tissue thickness), grafting material, smoking status, systemic factors (e.g., uncontrolled diabetes, bone metabolic disorders), and patient compliance. Less invasive grafting techniques should be adopted when indicated especially when treating defects in the esthetic or molar areas. It should be understood that the use of osteoconductive mineralized grafts does not accelerate bone healing, but may allow for a better preservation of the ridge volume that is highly desirable for both esthetic and function of the future implant restoration.

As dentistry evolves into a modern era, research aimed at further understanding the biological processes underlying alveolar bone healing, osseointegration, and tissue augmentation procedures is critical to develop predictable and successful restorative therapy protocols with the ultimate goal of providing high-quality patient care. Over the past 2 decades, numerous hard and soft tissue augmentation techniques have been proposed to recreate missing structures that would facilitate implant placement, as well as ridge preservation approaches to minimize bone loss after tooth extraction. However, the indication of specific approaches to achieve a predictable and satisfactory outcome in a given scenario remains a significant challenge in clinical practice. The mechanical stability synthetic biomaterials also enable clinicians to utilize minimally invasive flapless procedures without primary wound closure for socket grafting that reduce the patient's morbidity, while preserving the attached keratinized gingiva and allowing for further production of newly formed keratinized soft tissue.

Conflict of Interest: The authors declare that they have no conflicts of interest.

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