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**Concepts and challenges of alveolar ridge preservation and augmentation**

Munhoz EA *et al.* Concepts and challenges of alveolar ridge preservation

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**Abstract**

The loss of the post-extraction alveolar ridge vertical and horizontal volume constitutes an irreversible process and presents a considerable impact on the prosthetic rehabilitation, particularly when implant-supported. Therefore, alveolar ridge resorption has become a challenge on contemporary clinical dentistry and alveolar ridge preservation and augmentation is an interesting therapeutic approach. The employment of biomaterials, as a therapeutic alternative to preserve bone in height and volume, has been frequently studied over the years, due to its conceptual attractiveness and its simple technique. The purpose of this study was to review and discuss current methods to optimize the alveolar bone repair while maintaining its horizontal and vertical dimensions. The research was based on scientific researches published in English including systematic reviews and also animal and human studies using the keywords “alveolar ridge preservation,” “bone substitute”, biomaterials”, “bone graft” and “grafting”. Either autogenous bone as xenogenic and alloplastic materials, platelet rich plasma and use of membrane as alternatives. It becomes fundamental to understand that alveolar bone loss is still a clinical challenge and alveolar ridge preservation techniques can minimize, but not completely eliminate the resorption process. The goal of alveolar ridge preservation and augmentation is to use a combination of bone or biomaterials to create bone which is sufficient for dental implant placement. Freeze-dried bone is generally recognized as giving more predictable treatment outcomes than synthetic materials or platelet rich plasma, membranes must always be used to separate hard and soft tissues to promote optimal tissue healing.

**Key words:** Alveolar ridge preservation; Tooth extraction; Bone substitute; Bone regeneration

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**Core tip:** The placement of dental implants generally requires the preservation and augmentation of theAlveolar ridge with freeze-dried bone or bone substitutes. Our analysis of animal studies, clinical trials, reviews and meta-analyses has revealed that freeze dried bone, despite its limitations, is still among the most predictable of all the available biomaterials for creating high quality bone that can support dental implants.

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**INTRODUCTION**

The alveolar healing process can be conceptualized as a combination of biological events which occur from the extraction, aiming the total filling of the dental socket with bone tissue. Immediately after extraction, the alveolus is filled with blood clot mainly composed of erythrocytes and platelets attached to a fibrin system, which will be replaced by a highly vascularized granulation tissue, starting the bone formation process inside the alveolus[1,2]. Preclinical and clinical studies in the absence of bone augmentation have shown that post-extraction alveolar ridge volume loss constitutes an irreversible process which involves both horizontal and vertical reduction, thus, the buccal wall becomes more affected than the lingual wall[3-5]. Alveolar ridge atrophy can cause a considerable impact on the prosthetic rehabilitation, particularly when implant-supported[5,6]. Therefore, the alveolar ridge preservation has become a key component of contemporary clinical dentistry[5,6].

The use of freeze-dried bone and synthetic bone arose in the 80s, as a therapeutic alternative for the maintenance of tooth root, in order to preserve bone density. This approach has gained popularity over the years, due to its conceptual attractiveness and simple technique[5,7]. However, there are several discussions about the employment of materials for graft procedures, either for autogenous bone as allogenic, xenogenic materials or alloplastic constitute alternatives to be employed.

In previous studies, grafting are reported in reference to autogenous bone, for its osteogenic capacity, considering that it does not trigger a specific immune response[8]. Frequently, the disadvantages associated with this approach are related to the necessity of a second surgical site, risks of vascular and neurological injuries and postoperative morbidity[9].

Due to these factors, improvements on the technological development of biomaterials have been made, in an attempt to influence selectively the tissue response of the receptor site[10]. This study aimed to review and discuss current methods to optimize the alveolar bone repair while maintaining its horizontal and vertical dimensions.

**LITERATURE REVIEW**

The research was based on scientific researches published in English including systematic reviews, including animal and human studies. The exclusion criteria constituted case reports and discussion articles. The inclusion criteria comprised studies published in English from 1960 to 2015 searched at MEDLINE (PubMed) and Bireme databases. The keywords “alveolar ridge preservation,” “bone substitute”, biomaterials”, “bone graft” and “grafting” were employed for searching.

**THE ATROPHY OF THE ALVEOLAR RIDGE AFTER TOOTH EXTRACTION**

After tooth extraction, the alveolar bone undergoes an additional atrophy as result from natural remodeling process[11,12]. This process begins immediately after extraction and may result up to 50% of ridge width reabsorption, within 3 mo[4]. Studies show higher oral absorption as compared to the lingual wall, and the influence of some factors, such as age, in the amount of horizontal and vertical ridge reabsorption[12,13]. A recently published systematic review[14] reported higher horizontal reduction of the alveolar ridge (29%-63%, 3.79 mm) than vertical bone loss (11%-22%, 1.24 mm in vestibular, 0.84 mm mesial and 0.80 mm distal) in 6 mo. In a long term study, Ashman, 2000[15], reported reduction of 40%-60% alveolar bone height and width, within the first 2-3 years[2,15,16].

For oral rehabilitation after tooth loss, the preservation of the alveolar ridge is extremely important. These vertical as well as horizontal dimensional changes of the alveolar ridge may complicate the rehabilitation procedures when dental implants are used[17]. Over the recent years, the theme alveolar ridge preservation has been studied, which was defined as “any procedure undertaken at the time, or following an extraction, designed to minimize external reabsorption of the ridge and maximize bone formation within the socket”[18]. Many studies using different techniques have been performed.

**ALVEOLAR RIDGE PRESERVATION**

The autogenous graft and the employment of various synthetic materials are often contraindicated[19,20] and xenogenous graft[21,22] are being widely employed, but some properties of these materials for bone neoformation are being studied; as for instance, the employment of different preparation of mineral bovine bone and the period of bone tissue formation[20]. However, some studies demonstrated histological findings which present partial reabsorption of the material, questioning their potential for absorption[23,24].

Therefore, when the objective consists on the preservation of the alveolar ridge, certain factors are critical for the selection and indication of the material, such as: the type of mucosal closure required; gain of horizontal and vertical bone tissue; time required for installing implants; success rate of implants in the grafted area and the remaining material.

As for bone tissue gain, systematic review has demonstrated that to preserve the alveolar ridge with bone graft, by employing techniques, is effective, both horizontally and vertically, but loss of bone volume should always be expected[5,25-32].

In a review study comparing the blood clot with the employment of materials and barrier to preserve the alveolar ridge, it was clinically observed mean variation of width from the ridge preservation group between -1.0 and -3.5 ± 2.7 mm[12]. In the control group, the variation of width was between -2.5 and -4.6 ± 0.3 mm. These outcomes revealed lower statistically significant decrease in the preservation groups (in five out of seven studies). Regarding the ridge height, the average clinical change in the preservation groups was +1.3 ± 2.0 to 0.7 ± 1.4 mm and in the control groups: -0.8 and -3.6 ± 1.6 ± 1 5 mm[12]. These results showed that the height reduction of the conservation groups was significantly lower in six out of eight trials[12]. This study concluded that reabsorption in alveolar ridge may be limited, but can not be totally eliminated by the employment of grafts or membranes[12].

In a systematic review and meta-analysis, Avila-Ortiz *et al*[5] (2014) observed that alveolar ridge preservation is effective in limiting physiologic ridge reduction, when compared with tooth extraction only. The clinical magnitude of the effect was 1.89 mm in the buccolingual width, 2.07 mm in the midbuccal height, 1.18 mm in the midlingual height, 0.48 mm in the mesial height and 0.24 mm in the distal height. The flap elevation, membrane utilization, and the application of a xenograft or an allograft are associated with superior outcomes, particularly on midbuccal and midlingual height preservation[5].

Recently, Jambhekar *et al*[33] (2015) showed in a systematic review that randomized controlled clinical trials observed lowest loss of buccolingual width for xenografts (1.3 mm). The allografts showed 1.63 mm, followed the alloplasts with 2.13 mm, and sockets without any bone substitute: 2.79 mm[33]. Regarding the loss of buccal wall height, the lowest results were represented by xenografts (0.57 mm) and allografts (0.58 mm). The alloplast and sockets without any grafting demonstrated respectively (0.77 mm) and (1.74 mm)[33]. Microscopic evaluation revealed the highest vital bone content for sockets grafted with alloplasts 45.53%. The sockets with no graft material demonstrated 41.07% of vital bone content followed by xenografts and allografts showing 35.72%, 29.93% respectively[33]. Regarding the amount of remnant graft material, sockets grafted with allografts demonstrated the highest value (21.75%), followed by xenografts (19.3%) and alloplasts (13.67%)[33]. Also, the sockets with no grafting (52.53%) revealed the highest connective tissue content at reentry time, followed by allografts (51.03%), xenografts (44.42%), and alloplast (38.39%), respectively[33].

**INORGANIC BOVINE BONE GRAFT**

Kotsakis *et al*[34] (2014) compared the blood clot with inorganic bovine bone and bioactive glass ceramics in human alveolar sockets and analyzed the preservation of the alveolar ridge width, considering that higher alveolar preservation was observed in the group with inorganic bovine bone (1.39 ± 0.57 mm) followed by the group with ceramic bioactive glass (1.26 ± 0.41 mm) and lower preservation in the control group, filled only by blood clot[34]. Although, this difference did not seem to be clinically significant.

Another randomized study of inorganic bovine bone was suggested in order to compare to a control group[27]. Histological and histomorphometric analyses were performed from biopsies of 40 sites, 7 mo after the surgery[27]. As a result, it was observed higher horizontal reabsorption in the control group (4.3 ± 0.8 mm) when compared to the bovine graft group (2.5 ± 1.2 mm). The reduction in the ridge height of the vestibular side was 3.6 ± 1.5 mm for the group without graft, whereas it was observed 0.7 ± 1.4 mm for the graft group. Moreover, the vertical change in the lingual was 0.4 mm in the graft group, and 3 mm in the group without graft[27]. Histologically, it was observed the presence of structured trabecular bone mineralization, as well as particles of grafted material, in all samples. The bone formed in the control sites was well structured, with a lower percentage of mineralized bone. The amount of connective tissue was significantly greater in the group without graft, than in the graft group[27]. The approach for ridge preservation, employing bovine bone in combination with collagen membrane has limited significantly the hard tissue reabsorption, after tooth extraction[27]. In addition, 7 mo after tooth removal, the histological analysis showed a significantly higher percentage of total trabecular bone mineralized tissue at preservation sites, referring only to the extraction sites[27].

Munhoz *et al*[35,36] (2011 and 2012) evaluated the biomechanical response of previously grafted bone with inorganic bovine bone graft, to titanium implants in rabbits mandible. After periods of 2 and 6 mo, the force necessary to retrieve implants was quantified and no significant differences in removal torque was observed[35]. Also titanium implants were inserted in the studied areas and after 0, 30, 60, and 180 the sides were analyzed radiographycally and histomorphometrically[36]. No significant differences were detected in radiographic vertical bone height and bone area. Histologically, bone to implant contact was statistically lower in the control group on day 0 (same day of implantation); however, a significant increase was observed after 60 and 180 d[36]. The use of an inorganic xenograft prior to insertion of a titanium implant did not interfere on the course of osseointegration[36].

Artzi, Tal and Dayan, in 2000[23] and 2001[37], assessed clinically and pathologically, during 9 mo, the behavior of the porous inorganic bovine bone (PBBM) in human alveoli, after extraction. The results of this study clearly show that 9 mo after material insertion into the alveolus, the particles were still in place, even in the apical portion[23,37]. The studies concluded that the spongy PBBM is a biocompatible filling agent in extraction sites and an acceptable graft to preserve the toothless ridge in sites prepared to receive osseointegrated implants. Besides that, additional studies are necessary to determine the reabsorption capacity, as well as the nature and the importance of the PBBM amorphous organic substance, observed in the grafted particles[37].

**ALLOPLASTIC MATERIALS**

The use of bioactive glass was evaluated for alveolar ridge preservation in humans by Clozza *et al*[38], 2012. Subjects who needed titanium implant therapy after tooth extract were grafted and assessed after 1 wk and 3 mo. Alveolar sites treated, demonstrated preservation of about 77% of the original width dimensions, with 1.8 ± 1.1 mm width mean loss. Moreover, it was observed that vertical loss of the buccal bone was 2.7 ± 1.1 mm, while loss of the lingual bone was 1.9 ± 1.2 mm[38].

Another study, which demonstrated successful implantation in areas with inorganic bovine bone graft and also with bioactive glass, was carried out by Kotsakis *et al*[34] (2014), which showed 94.1% of overall success rate (16 out of 17 implants were successful) considering that no implant was lost in the bioactive glass group, and one implant failed in the inorganic bovine bone group. Additionally, the study analyzed the torque and primary stability of the implant for each group and concluded that the bioactive glass may be more appropriate to achieve primary stability of implants placed 5-6 mo after extraction[34]. Conversely, Avila-Ortiz *et al*[5] (2014), in a meta-analysis study observed that the use of a xenograft or an allograft presented a beneficial effect in midbuccal alveolar bone height preservation when compared to alloplastic materials[5] and authors[33],in 2015, demonstrated that xenografts and allografts revealed lower loss values than any bone substitutes or sockets without grafting[5,33].

Brkovic *et al*[39] studied the preservation of the alveolar bone ridge with β-tricalcium phosphate, with and without the employment of type I collagen membranes, and observed after 9 mo that the horizontal dimension of the alveolar bone ridge had decreased significantly in the group without membrane; it was observed bone formation without significant differences between the two groups; presence of bone marrow and presence of beta-tricalcium phosphate[39]. Both groups demonstrated significant amounts of bone and morphology for implant placement, after a healing period of 9 mo[39].

Another study evaluated bone regeneration after teeth extraction[40], comparing histologically bioactive glass ceramic with inorganic bovine graft. Nineteen patients underwent 20 tooth extractions. Ten sites were grafted with bioactive glass and the other 10 with inorganic bovine bone[40]. The evaluation of bone regeneration and the installation of implants were performed after 4-6 mo of surgery. During the installation procedure of the implants, bone biopsies were taken[40]. The histomorphometric evaluation revealed that graft residual values were significantly higher in the inorganic bovine graft group (25.60 ± 5.89) in comparison with the bioactive glass group (17.40 ± 9.39)[40]. The amount of new bone regenerated also was statistically higher in the bioactive glass group (47.15 ± 8.5) in comparison with the inorganic bovine graft group (22.2 ± 3.5) [40]. The study suggests that bioactive glass seems to be a desirable graft, in addition to increasing bone regeneration, when compared to a xenotransplantation of inorganic bovine bone[40].

**PLATELET-RICH PLASMA**

The employment of platelet-rich plasma (PRP) constitutes an innovative technique to improve bone healing. Some studies have been conducted in order to verify the effectiveness of PRP with different bone substitutes. These studies have found that PRP when combined with autogenous bone, provide considerably faster bone regeneration results, radiographic and histomorphometrically, besides indicating denser bone[41]. Variable successful results have been demonstrated when the PRP is added to an allograft[42].

A study of Kaur[43] in 2013, evaluated by radiographs the employment of PRP with a hydroxyapatite compound with beta tricalcium phosphate, and compared to a control group. The results suggest radiographic evidence of early bone formation and maturation[43].

Another study, presently in animal model, performed inferior premolars extraction, of 12 beagle dogs and the alveoli were filled with Cerasorb, on the control side, and a Cerasorb mixture of PRP on the test side[44]. Samples from bilateral biopsies were removed from graft insertion sites, 6, 12, and 24 wk after surgery. Six weeks after grafting, proliferation of osteogenic cell mesenchyme was more abundant in the test group[44]. Histomorphometric data revealed a significantly higher percentage of bone area in the test group (45.9%) than in the control group (30.8%) (*P* < 0.05)[44]. Twelve weeks after grafting, the test group still presented some advantage over the control group, in terms of bone regeneration (52.5% of bone in the test group, versus 49.4% in the control group, *P* < 0.05)[44]. Twenty-four weeks after grafting, bone forming activity was almost identical in both groups, and the bone area in the two groups did not differ significantly (62.9% and 61.9%, respectively) (*P* < 0.05)[44]. The results, histomorphometrically suggested stronger bone regeneration in the early healing phase, after PRP topical application use[44].

**MUCOSAL CLOSURE**

Regarding the mucosal closure in the surgery, healing is ideally recommended. However, Meloni *et al*[45] (2015) showed in their study that inorganic bovine bone graft can be maintained either with epithelial conjunctive tissue flap, as with collagen matrix, showing no difference in the results. Although there were no statistically significant differences between the groups, after 5 mo of tooth extraction, it is noteworthy emphasize that the collagen matrix is more appropriate, because a second surgical site is not required in this case[45]. The same study reports a 100% implant success rate, considering that the 30 patients showed no failure or complication after one year of the installation procedure[45]. Furthermore, there were no statistically significant differences between the two groups, for peri-implant marginal alterations, at bone level (difference: 0.07 ± 0.11 mm; 95%CI: -0.02 to 0.16, *P* = 0.41) after one year of implant placement[45].

Alveolar ridge preservation with membrane utilization resulted in statistically significantly less reabsorption in ridge width and height, compared to socket for natural healing[12,32,46]. The association of bone graft and membrane resulted in statistically significantly less reabsorption, horizontally[26,27] and vertically[26] in comparison to naturally socket healing. The histological evaluation demonstrated new bone formation with presence of graft particles[26,27].

Avila-Ortiz[5] (2014), in a meta-analysis study, also observed that membrane use, had a strong beneficial effect on the preservation of midbuccal and midlingual alveolar bone height.

In another systematic review study[12], comparing sockets left healing naturally and the use of membranes, it was observed, clinically, alveolar bone width variation between -1.0 and -3.5 ± 2.7 mm for experimental group and -2.5 and -4.6 ± 0.3 mm for control group, leading in an important preservation of the experimental groups (five of seven studies)[12]. The experimental groups demonstrated a change in alveolar bone height from 1.3 ± -0.7 ± 1.4 and 2.0 mm and between -0.8 and -3.6 ± 1.6 ± 1.5 mm, in the control groups[12]. Regarding the preservation of height, the experimental groups were significantly higher when evaluated six of eight studies[12]. The conclusion of this review was that the resorption of the alveolar edge may be reduced, however cannot be completely eliminated by the employment of membranes or grafts[12].

Hoffman *et al*[47] investigated clinically alveolar sockets regeneration using polytetrafluoroethylene (PTFE) membranes of high density (dPTFE) without the use of graft materials. A total of 276 alveolar sockets were obtained, which were flaps and a dPTFE membrane was placed on the site. Primary closure was not obtained along the use of these membranes[47]. Cemento-enamel junctions of adjacent teeth were used as reference points. The measurements have been taken immediately post extraction and 12 mo after surgery in the same areas. Hard tissue biopsies were taken from 10 representative cases after 12 mo, during implant placement[47]. A strict oral biofilm control scheme was applied in all individuals during the observation period. The study showed that there was a significant preservation of the volume, indicating that the newly formed tissue in the extraction sites was essentially bone[47]. In addition, the study pointed out that there was no influence of gender, smoking, age or clinical bone level before treatment on the results. The study concluded, then, that the use of membranes dPTFE was effective in preservation of soft and hard tissues in alveolar sockets after teeth extraction[47].

Still, regarding the use of membranes, a systematic review was conducted to evaluate the efficacy of barrier membranes in alveolar bone preservation[48,49]. A total of 3986 manuscripts were found in the initial search and 34 studies met the inclusion criteria[48]. Four animal studies concluded that the use of membrane increases the amount of bone (difference of 0.32mm mean). The qualitative results about horizontal bone augmentation were controversial[48]. The membranes have not increased the risk of inadequate healing, according to both human (odds ratio 5.67) and animal studies (odds ratio 3.35)[48]. This study concluded that there is limited evidence for the effectiveness of barrier membrance in the treatment of bone defects. Most of the results are based on animal studies[48].More randomized clinical trials are needed to measure objectively the effectiveness of membranes in alveolar ridge preservation[48].

**TIME OF IMPLANTATION AFTER ALVEOLAR RIDGE PRESERVATION**

The time of implantation after alveolar ridge preservation varies on the studies. Studies in rabbits using inorganic bovine bone graft showed a lower time of implantation, after 2[35,36] and 3 mo[24].

Human studies filled with the same graft showed time of implantation of 6[50,51] and 7 mo[52]. Alllograft showed the same period of 6 mo[53] and alloplastic materials varied from 3[54] to 6 mo[40,55]. The use of grafting materials for alveolar ridge preservation seems to delay the rehabilitation process in 6 moat most cases.

**CONCLUSION**

The goal of alveolar ridge preservation and augmentation is to use a combination of bone or biomaterials to create bone which is sufficient for dental implant placement. Freeze-dried bone is generally recognized as giving more predictable treatment outcomes than synthetic materials or platelet rich plasma, membranes must always be used to separate hard and soft tissues to promote optimal tissue healing.

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