World Journal of Stomatology

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DOI: 10.5321/wjs.v5.i1.8

World J Stomatol 2016 February 20; 5(1): 8-14
ISSN 2218-6263 (online)

MINIREVIEWS

Concepts and challenges of alveolar ridge preservation and augmentation

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Author contributions: All authors equally contributed to this paper with conception and design of the study, literature review and analysis, drafting and critical revision and editing, and final approval of the final version.

Conflict-of-interest statement: No potential conflicts of interest.

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Received: August 22, 2015
Peer-review started: August 25, 2015
First decision: September 22, 2015
Revised: November 16, 2015
Accepted: December 17, 2015
Article in press: December 18, 2015
Published online: February 20, 2016

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 in contemporary clinical dentistry and alveolar ridge preservation and augmentation are 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 paper is to review and discuss current methods to optimize the alveolar bone repair while maintaining its horizontal and vertical dimensions. This paper is based on scientific studies published in English including systematic reviews and also animal and human studies that were searched 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 are 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, and 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

Core tip: The placement of dental implants generally requires the preservation and augmentation of the alveolar 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.

Munhoz EA, Cardoso CL, Bodanezi A, Mello MB, Yaedu RYF, Ferreira Junior O. Concepts and challenges of alveolar ridge preservation and augmentation. *World J Stomatol* 2016; 5(1): 8-14 Available from: URL: http://www.wjgnet.com/2218-6263/full/v5/i1/8.htm DOI: http://dx.doi.org/10.5321/wjs.v5.i1.8

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 to start 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 is 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 paper aims to review and discuss current methods to optimize the alveolar bone repair while maintaining its horizontal and vertical dimensions.

LITERATURE REVIEW

This paper is based on scientific researches published in English including systematic reviews, including animal and human studies. Case reports and discussion articles were excluded. Studies published in English from 1960 to 2015 were searched in 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 a result of the natural remodeling process[11,12]. This process begins immediately after extraction and may result in up to reabsorption of 50% of ridge width within 3 mo[4]. Studies show higher oral absorption as compared to the lingual wall, and the influence of some factors, such as age, on the amount of horizontal and vertical ridge reabsorption[12,13]. A recently published systematic review[14] reported a 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 in 2000, Ashman[15] reported a 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 procedure when dental implants are used[17]. Over recent years, the theme of 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 grafts[21,22] are being widely employed, but some properties of these materials for bone neoformation are being studied, for instance, the employment of different preparations 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; and success rate of implants in the grafted area and the remaining material.

As for bone tissue gain, a 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 that the mean variation of width in the ridge preservation group was 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 a statistically lower 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 cannot 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 the lowest loss of buccolingual width for xenografts (1.3 mm). The allografts showed 1.63 mm, followed by 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 did not demonstrate any grafting (0.77 mm and 1.74 mm, respectively)[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% and 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 alloplasts (38.39%)[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, higher horizontal reabsorption was observed 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 0.7 ± 1.4 mm for the graft group. Moreover, the vertical change in the lingual thickness was 0.4 mm in the graft group, and 3 mm in the group without graft[27]. Histologically, the presence of structured trabecular bone mineralization, as well as particles of grafted material was observed 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 difference in removal torque was observed[35]. Also titanium implants were inserted in the studied areas and after 0, 30, 60, and 180 d the sides were analyzed radiographycally and histomorphometrically[36]. No significant differences were detected in radiographic vertical bone height or 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 in the course of osseointegration[36].

In 2000 and 2001, Artzi *et al*[23,37] 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] in 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 a mean width loss of 1.8 ± 1.1 mm. 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 an overall success rate of 94.1% (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 another study[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; there was no significant difference in bone formation between the two groups, with the presence of bone marrow and 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 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, provides considerably faster bone regeneration results, radiographically 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 *et al*[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 animal study performed inferior premolars extraction in 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 advantages over the control group, in terms of bone regeneration (52.5% of bone in the test group *vs* 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 or with collagen matrix, which showed no difference in the results. Although there were no statistically significant differences between the groups, after 5 mo of tooth extraction, it is noteworthy to 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 complications after one year of the installation procedure[45]. Furthermore, there were no statistically significant differences between the two groups in peri-implant marginal alterations at bone level (difference: 0.07 ± 0.11 mm; 95%CI: -0.02-0.16, $P = 0.41$) 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 *et al*[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 that alveolar bone width variation was between -1.0 and -3.5 ± 2.7 mm for experimental groups and -2.5 and -4.6 ± 0.3 mm for control groups, leading 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 socket 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 with 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 dPTFE membranes 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 (mean difference of 0.32 mm). 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 membrane 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 across 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]. Allografts 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 mo at 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, and membranes must always be used to separate hard and soft tissues to promote optimal tissue healing.

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P- Reviewer: Jeng JH, Kotsakis GA, Liu L **S- Editor**: Ji FF
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