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Onlay grafting with bovine bone mineral block for horizontal reconstruction of severely atrophic alveolar ridges in anterior maxillae: A 6-year prospective study

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ABSTRACT

Purpose: The aim of this prospective study was to evaluate the efficacy and long-term outcomes of onlay grafting with bovine bone mineral block for reconstruction of horizontal alveolar ridge defects in anterior maxillae.

Materials and methods: Fourteen patients requiring rehabilitation of edentulous anterior maxillae were enrolled to receive onlay grafting in two layers. A cortical block harvested from the lateral aspect of the mandibular ramus was split to acquire approximately 1-mm-thick bone laminae. The cortical bone plate and block graft were compressed and fixed to the recipient sites. After 6 months, the width of the augmentation was recorded, and implants were inserted. Provisional and definitive prostheses were delivered 3 and a further 6 months later. Implant success and associated complications were assessed.

Results: The horizontal bone gain was 8.73 ± 0.82, with a resorption rate of 7.03%. Severe bone resorption was noticed 6 months and 2 years after loading. Fistula occurred with the nonintegrated bovine block on the labial sides of the augmented sites 6 years after loading.

Conclusion: Onlay grafting with bovine bone mineral block in the anterior maxilla may yield optimal horizontal gain with low resorption rates, under the condition of at least 6 months' healing time, mixation with autogenous particulate bone, and application of a membrane to cover the graft site.

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1. Introduction

In the anterior maxillae, adequate bone volume at the implant site is a prerequisite for desirable esthetic outcomes and sound biomechanical support with implant placement. Severe bone deficiencies continue to be a considerable surgical challenge (Fretwurst et al., 2015; Sakkas et al., 2016). Although various techniques have been described to enhance the bone volume, autogenous bone block grafting is still considered the most reliable method for treatment of large and non–space-providing defects (Dasmah et al., 2013; Herford et al., 2013).

On the other hand, disadvantages of autologous bone block must be considered as well. Considerable graft resorption calls its reliability into question in terms of long-term stability (Schlegel et al., 2006). A retrospective study evaluated volume alterations of onlay autogenous grafts after implant placement. The mean volume resorption ranged from 35% to 51% (Sbordone et al., 2009). Moreover, limited graft availability should also be considered. Several clinical studies have demonstrated that the mean graft volume that could be obtained ranged from 0.9 to 2.4 cm^3, with a thickness of up to 6.5 mm (Misch, 1997; Nkenke and Neukam, 2014). Bilamina cortical tenting grafting could be used to compensate for the limited graft volume. However, a large amount of autogeneous bone chips were still required to fill in the space between the bilaminar cortical bone (Yu et al., 2016). Moreover, autogeneous particulate bone lacks the mechanical strength required for large-scale reconstructions.

In recent experimental and clinical studies, a bovine-bone mineral (BBM) block has been successfully used for alveolar sever ridge augmentation (Hammerle et al., 2008; Simion et al., 2006). Most studies used block grafts for vertical ridge augmentation of the posterior mandible, presented as case reports (Cardaropoli, 2009; Simion et al., 2007). On the other hand, few studies have addressed the use of BBM blocks in anterior maxillae. The present

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6-year prospective study assessed the technique of onlay grafting with bone block for horizontal reconstruction of severely atrophic alveolar ridges in the anterior maxillae, evaluating the stability of bone grafting and its long-term clinical outcomes.

2. Materials and materials

2.1. Patient selection

This study was designed as a prospective clinical trial. Between July 2009 and July 2010, a total of 14 patients (mean age: 29.3 years) were consecutively recruited from among patients who required rehabilitation of edentulous anterior maxillae at Peking University School and Hospital of Stomatology.

Adult individuals clinically indicated for lateral bone augmentation of severely atrophic ridge with an insufficient dimension to accommodate implant placement (Cawood-Howell Class IV resorbed ridges) were eligible for study enrollment, whereas bone height in the edentulous area did not preclude implant placement. All patients were in good systemic health and had no contraindications associated with oral surgical interventions. The exclusion criteria were as follows: general contraindications to implant surgery, severe hemophilia, history of irradiation in the head and neck regions <1 year before the study, poor oral hygiene, uncontrolled diabetes, pregnancy or current lactation, psychiatric issues or unrealistic expectations, human immunodeficiency virus infection, smoking >10 cigarettes or cigar equivalents per day, acute infection in the area intended for implant placement, or local inflammation, including untreated periodontitis.

The study protocol was evaluated and approved by the institutional ethics committee (PKUSSIRB-2016113115). All patients provided written informed consent regarding the grafting procedure and implant placement.

2.2. Clinical procedures

2.2.1. Preoperative procedure

Following selection, cone-beam computed tomography (CT) was performed to quantify the amount of available bone of the alveolar process in order to determine whether or not patients could be included in the study.

2.2.2. Surgical procedures

All patients received prophylactic antibiotic therapy in the form of 2 g of amoxicillin (500 mg of clarithromycin in the case of penicillin allergy) 1 h before treatment. All surgeries were performed under local anesthesia with articaine plus 1:100,000 epinephrine.

Cortical bone block grafts were harvested from the lateral aspect of the mandibular ramus. The harvesting osteotomy was performed according to a standard protocol (Khoury and Hanser, 2015). Blood was collected at the same time.

Midcrestal incisions were made in the regions of the edentulous sites, followed by two buccal vertical releasing incisions. Full-thickness mucoperiosteal flaps were elevated to expose the alveolar ridge. The width of the residual ridge was measured. The harvested cortical bone block was split with a diamond disk saw to acquire approximately 1-mm-thick bone laminae. A large contouring bur was used to trim the laminae for accurate adaptation to the defect site and to round off sharp edges. BBM blocks (Geistlich Pharma AG, Wolhusen, Switzerland) were dipped in the blood obtained from the surgical site and then trimmed for appropriate adaptation into recipient sites. By using the lag screw technique, the laminar bone plate and BBM graft were evenly compressed and fixed to the recipient sites by means of 2 miniscrews (KLS Martin: 1.5 mm in diameter and 12 mm in length), while ensuring that the miniscrew engaged the inner side wall and did not extend beyond the palatal side of the recipient site. A particulate anorganic BBM graft (Bio-Oss, Geistlich AG, Wolhusen, Switzerland) was used to cover the graft and the spaces around it. Subsequently, the recipient site was covered using double layers of Bio-Gide membranes Fig. 1. The periosteum of the buccal flap was dissected to allow tension-free adaptation of wound margins and to obtain double layers of connective tissue covering the crest. The recipient site was closed using 4-0 absorbable sutures.

2.2.3. Postoperative management

For the initial 3 days after surgery, patients were instructed to use a 0.2% chlorhexidine rinse for 20 s and were prescribed 500 mg of amoxicillin (both 3 times per day). Patients were advised to consume a soft diet during the first postoperative week, and their healing outcomes were evaluated after 14 days.

2.2.4. Re-entry and implantation surgery

Six months after the augmentation surgery, re-entry and implantation surgery were performed. Following elevation of a partial-thickness flap, the fixing screws were removed, and implants (NobelSpeedy™ Replace, NobelReplace® Tapered Groovy, Nobel Biocare) were placed based on standard protocols in a prosthetically ideal position. Healing abutment connection and soft tissue adjustments were performed at the same time.

After another 2–3 months of the healing period, implant-supported temporary crown was completed to shape the gingival contour. The final restoration was finished 3–6 months later.

2.3. Follow-up protocol

The follow-up protocol included patient assessments every 3 months during the first year and annually thereafter.

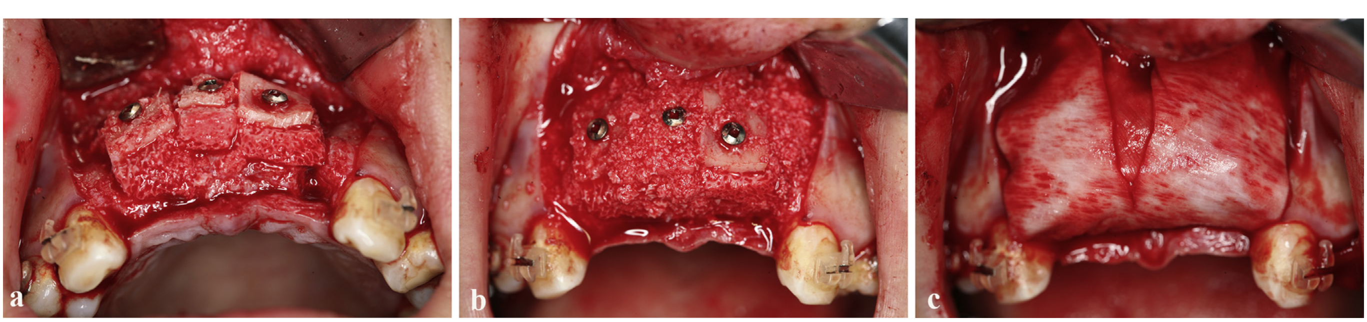

Fig. 1. (a) The laminar bone plate and BBM graft were compressed and fixed rigidly to the recipient sites by means of 2 miniscrews. (b) Bio-Oss was utilized to cover the graft and spaces around it. (c) The augmented site was further protected using 2 layers of collagen membrane.

2.3.1. Clinical assessment

Healing of the surgical site was clinically assessed and defined as primary healing without any tissue necrosis, suppuration, or infection.

Successful integration of the graft was determined according to the following criteria: absence of pain or subjective discomfort, graft stability at the time of implant placement, absence of infection, and absence of radiographic signs of bone graft resorption Fig. 2.

Implant survival was assessed on the basis of the following criteria: absence of clinically detectable implant mobility, absence of pain or any subjective sensation, absence of recurrent peri-implant infection, and absence of continuous radiolucency around the implant.

2.3.2. Bone gain measurements

At the time of surgery, oro-facial bone width was measured using a calibrated caliper at 1 mm below the highest point of the remaining crest. During the re-entry surgery for implant placement, these measurements of ridge width and height were repeated Fig. 3.

2.4. Statistical analysis

All data were analyzed using Statistical Package for Social Sciences (SPSS) software, version 14.0 (SPSS Inc., Chicago, IL, USA). Continuous and discrete variables were described using mean (±standard deviation [SD]) and frequency, respectively.

The contents were in accordance with the STROBE checklist.

3. Results

Of the 14 sites, the average follow-up time was 6.1 years. Details regarding patient distribution are presented in Table 1.

3.1. Bone augmentation data

Table 2 provides detailed information regarding the original ridge defect and ridge width after augmentation. After 6–7 months of healing period, the mean crestal bone width had increased from 3.36 mm to 9.39 mm; this difference was statistically significant ($P < 0.005$).

During the second surgery, all BBM blocks were stable and completely integrated with residual bone, with a resorption rate of 7.03%. The regenerated tissue appeared as normal bone tissue during preparation of the implant socket, although deproteinized bovine bone particles could be observed. All implants could be placed with good primary stability (>35 Ncm).

3.2. Postoperative complications

All sites healed uneventfully. No flap dehiscence or infection was observed. After the bone augmentation procedure, all patients experienced edema and pain at varying levels of severity. However, these complications did not result in graft mobility or failure.

However, certain severe complications occurred after loading Table 3. In one case, an isolated bovine block was noticed on the buccal side of the augmented sites 6 months after provisional restoration. After flap elevation, obvious bone resorption and exposed implant threads were observed Fig. 4.

Gingival recession occurred in 2 cases in 1–3 years after loading, with obvious bone graft resorption and thread exposure Fig. 5.

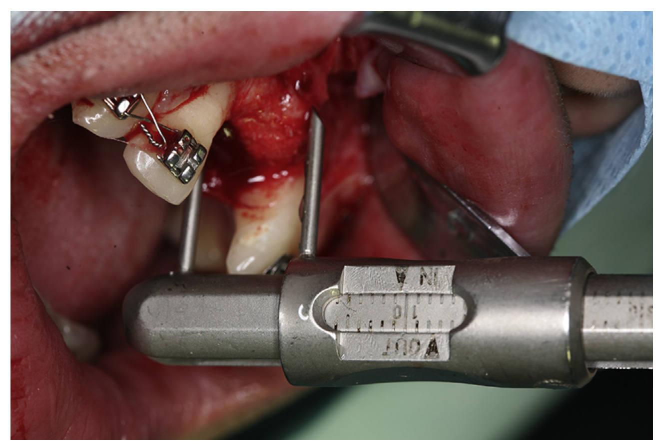

Fig. 3. Measurement of recipient site's horizontal dimension.

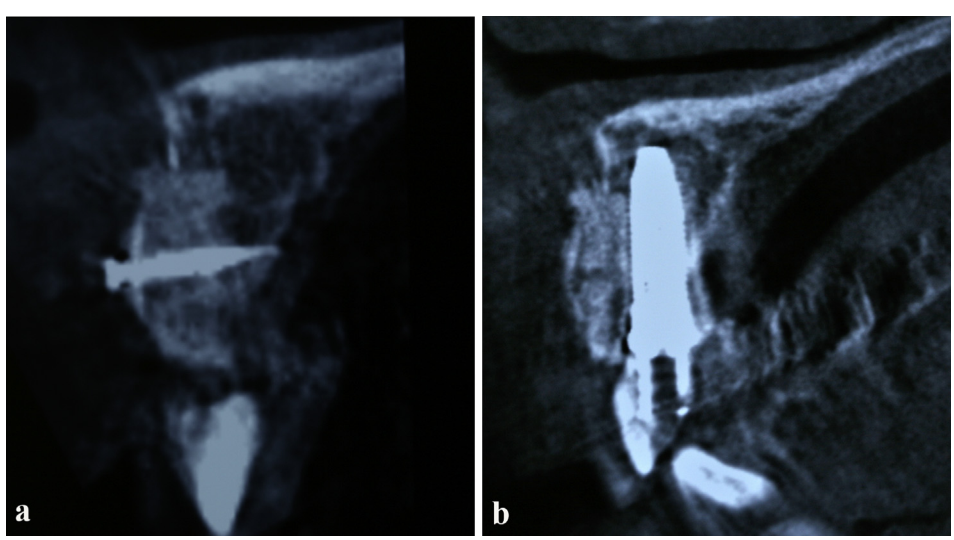

Fig. 2. (a) Cone-beam CT immediately after bone augmentation surgery. Note the lamina on the outer bone graft site and BBM bone applied to fill the space between the cortical bone and the recipient bone. (b) Cone-beam CT after implant placement. BBM graft appeared stable and completely integrated with the residual bone and implant.

Table 1
Patient distribution and intervention characteristics.

Gender	Male	10
	Female	4
Age (yr) at implant insertion		29.3
Smoking status	Smoker	6
	Nonsmoker	15
Periodontal status	Treated periodontitis	7
	Nonperiodontitis	7
Total number of inserted implants		21
Healing time of bone grafting (mo)		6.4
Follow-up (yr)		6.1

Table 2
Horizontal bone augmentation and remodeling.

	iBW	post-BW	Re-entry BW	BR	RR
Mean ± SD	3.36 ± 0.69	9.39 ± 0.71	8.73 ± 0.82	0.66 ± 0.29	7.03%
Minimum	2.0	8.5	7.8	0.39	
Maximum	4.0	10.5	10.0	0.59	

iBW: initial bone width; post-BW: postaugmentation bone width at the time of surgery; Re-entry BW: bone width at re-entry; BR: bone resorption; RR: resorption rate; SD: standard deviation.

Table 3
Incidence of surgical complications.

	Patients (n)	%	Occurrence time after loading (yr)
Early bone resorption	1	7.1	0.5
Gingival recession (bone resorption)	2	14.3	2.2
Fistula with isolated graft	1	7.1	1

At one site, a fistula was observed with a nonintegrated BBM block on the labial side of the augmented site 6 years after loading Fig. 6.

4. Discussion

The present study evaluated the application of onlay grafting in two layers with BBM blocks under laminar cortical bone for severe alveolar ridge reconstruction in the anterior maxillae. Results suggest that onlay grafting with BBM blocks can be an alternative technique for reconstruction of extensive horizontal deficiencies.

In the present study, the amount of horizontal bone gain was 8.73 mm, with a resorption rate of 7.03%, compared with a rate of 10%–15% noted with conventional onlay grafting (Khoury and Hanser, 2015). During implant placement, although grafting particles could be observed, BBM blocks completely integrated with the residual bone, in which all implants were placed with good primary stability. The minimal bone remodeling seen in this study could be justified by the fact that the laminar cortical bone was rigidly fixed to the recipient site by using titanium miniscrews, which has been proved to be essential for prevention of fibrous ingrowth between the allograft and the host (Peleg et al., 2010). Although a single block is large enough to rehabilitate a deficient alveolar ridge, its potential resistance to blood vessel ingrowth is detrimental to bone regeneration (von Arx and Buser, 2006). The thin laminar block used in the present study allowed for relatively easy vessel penetration (Peleg et al., 2010). BBM blocks were used to fill gaps between cortical and residual alveolar bone. This bone substitute material consists of a wide interconnecting pore system that serves as a physical scaffold for the immigration of osteogenic cells (Tapety et al., 2004). Unlike particulate materials that lack volume stability, BBM blocks can be fixed rigidly to diminish macro-movement and have also been shown to be resistant to resorption as an onlay graft (Schmitt et al., 2013). However, certain authors have pointed out that the fragility of BBM blocks resulted is some easy fractures (Simion et al., 2006, 2007). Therefore, it seems appropriate to combine the strength of the cortical bone and osteoconduction of BBM blocks for reconstruction of severely atrophic alveolar ridges in the anterior maxillae.

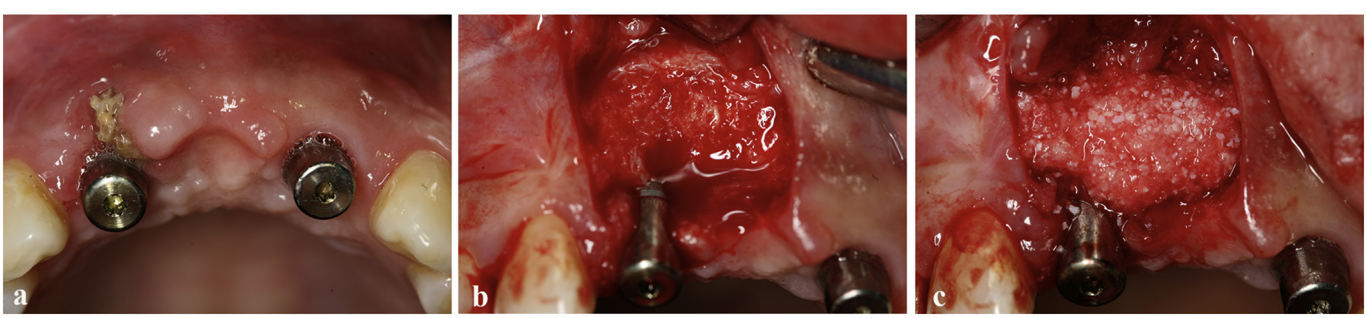

Fig. 4. (a) Note BBM graft detachment was noticed at the cervical portion on the buccal side of the augmented site 6 months after loading. (b) Obvious bone resorption and exposed implant threads were observed. (c) Coverage of particulate graft to the exposed threads for bone re-augmentation.

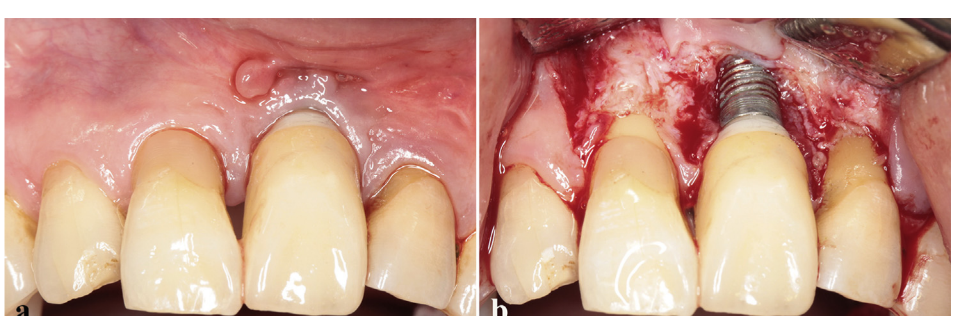

Fig. 5. (a) Gingival recession occurred 2 years after loading. (b) After flap elevation, bone resorption and implant thread exposure were noticed.

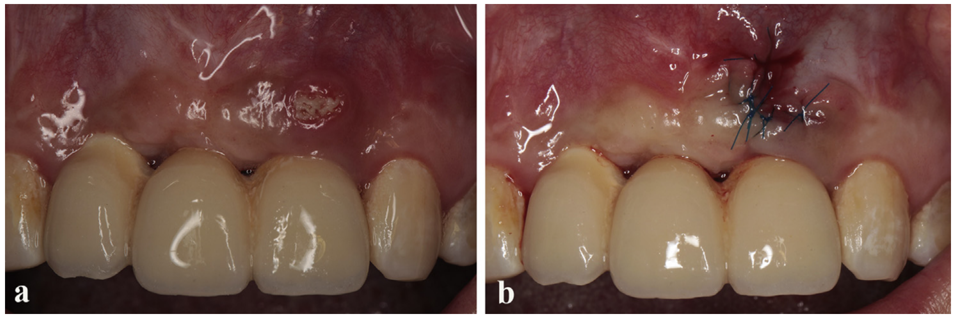

Fig. 6. (a) Fistula occurred on the buccal side of the augmented site. Note the nonintegrated BBM block. (b) The soft tissue was sutured after cleaning up the nonintegrated BBM block.

Although onlay bone graft completely integrated with residual bone in the present study, the number of postloading complications was still relatively high; BBM block detachment, followed by bone grafting infection and resorption was noticed 6 months after loading. Furthermore, BBM blocks are relatively brittle and can easily fracture. If graft detachment occurs during or after surgery, the loading exacerbates its separation, which, in turn, may result in failure of augmentation (Fontana et al., 2008). Hence, maintenance of block integrity could be crucial to ensuring a stable platform for bone augmentation. Gingival recession occurred in 2 cases in 2–3 years after loading, with obvious bone graft resorption and thread exposure. Moreover, fistulas were noticed with nonintegrated BBM blocks on the labial sides of the augmented sites 6 years after loading. These may be attributed to incomplete maturation of the grafted site and less vital bone formation, particularly when large-scale augmentation is needed. The more solid the bone graft, the more able it is to withstand mechanical stress (Simion et al., 2007). The bending stresses generated by masticatory forces negatively influence bone formation and integration (Steigmann, 2008). Given the crucial effect of penetration of blood vessels into the grafted bone, use of BBM blocks for extreme deficiencies might prolong neovascularization, since the increased distance between the cortical bone and the recipient bone will probably weaken the vascularization, thereby jeopardizing the graft. Thus, it is necessary to allow prolonged healing time (>6 months) for bone grafts to incorporate into the native bone. Moreover, with osteoconductive properties, this artificial grafting material lacks osteoinductive properties, including local stimulating factors that cause mesenchymal cells to disaggregate, migrate, re-aggregate, proliferate, and differentiate into chondroblasts or osteoblasts (Jensen et al., 1996). As demonstrated by Blokhuis and Arts (Blokhuis and Arts, 2011), mesenchymal stem cells, vital osteoblasts, and their precursors contribute to graft consolidation. In such cases, autogenous bone, with its capacity to regenerate and to form new bone through osteoinductive, osteogenic, and osteoconductive properties, is still the gold standard for the treatment of large bone defects (Nkenke and Neukam, 2014). In a previous study, two laminar cortical bone sections were used to reconstruct the buccal and palatal walls of a vertical defect, which was filled with chips of autogenous bone in the created space (Yu et al., 2016). After a 6-year follow-up, all implants were stable, and no postoperative complications such as graft separation or fracture had occurred. Thus, the technique of using laminar cortical bone and filling the residual space with BBM blocks mixed with autogenous particulate bone seems an effective and safe approach for reconstructing severely atrophic anterior maxillary alveolar bone.

Vascularization is an important component of bone formation and maintenance, and platelet-derived growth factor (PDGF) is a signaling molecule of blood platelets and bone matrix (Schmitt et al., 2013; Simion et al., 2007). It was hypothesized that a combined delivery with PDGF may have the potential to induce bone formation and maturation, particularly in large alveolar defects. Utilization of a membrane to cover the graft has been shown to significantly diminish the postsurgical resorption associated with onlay grafting (Khojasteh et al., 2012).

To minimize complications and morbidity of bone augmentation, it is necessary to avoid infection of the surgical site and to achieve tension-free wound closure. The split-thickness labial flap technique used in the present study facilitated greater flap advancement, thereby leading to fewer complications and less morbidity.

The present investigation was limited by a small sample size and the fact that the patients were not randomized to different treatment arms. Additional studies on the application of PDGF with onlay grafting are warranted to evaluate graft integration and clinical outcomes.

5. Conclusion

Based on our findings, we conclude the following: (1) Onlay grafting with BBM blocks in the anterior maxilla yields horizontal gain with a low resorption rate and provides an adequate amount of bone for implant placement. (2) The following steps should be undertaken in order to maintain long-term bone graft maturation and incorporation into the native bone: increasing the healing time to >6 months before loading; mixing BBM blocks with autogenous particulate bone; and using a bioresorbable membrane to cover the graft site. (3) Combining the delivery with PDGF may have the potential to induce bone formation and maturation, particularly for large alveolar defects.

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