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Bilamina cortical tenting grafting technique for three-dimensional reconstruction of severely atrophic alveolar ridges in anterior maxillae: A 6-year prospective study

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ABSTRACT

Objective: To evaluate the efficacy and long-term outcome of the bilaminar cortical tenting grafting technique for reconstruction of vertical and horizontal alveolar ridge defects.
Material and methods: A bone block harvested from the lateral aspect of the mandibular ramus was bisected into two cortical laminae, which were then used to reconstruct the buccal and palatal walls of an alveolar ridge defect. The inter-laminar space was filled with particulate autogenous bone and the whole graft was covered with anorganic bone graft and collagen membrane. After 4–6 months, the width and height of the augmentation were recorded. The study sample consisted of 21 patients who were followed up for 6.09 ± 1.18-years.
Results: Vertical and horizontal bone gain was 5.70 ± 1.09 and 8.45 ± 0.87 mm, respectively, and respective resorption rates were 10.20% and 6.15%. One patient showed soft-tissue dehiscence, while all others healed without complication. After an average follow-up of 6-years, the block grafts were well integrated into the recipient sites and there was only a small reduction in the peri-implant bone level (0.77 ± 0.50 mm).
Conclusion: This technique was effective and reliable for three-dimensional reconstruction of severely atrophic alveolar ridges in anterior maxillae.

1. Introduction

In the anterior maxillary region, adequate bone volume at the future implant site is a prerequisite for ideal implant placement and a good esthetic outcome (Rieder et al., 2014). Following trauma to a tooth or its long-term absence, the alveolar bone becomes markedly reduced with respect to both height and width. Reconstruction of localized ridge deficiencies in the esthetic zone is a very challenging surgical procedure, especially in cases of extensive vertical and horizontal bone atrophy (Vierra et al., 2014). A variety of surgical techniques have been described to enhance the bone volume of deficient implant-recipient sites, such as distraction osteogenesis (Yamauchi et al., 2013), guided bone regeneration (GBR) (Dahlin et al., 2015) and onlay grafting (Fretwurst et al., 2015).

Distraction osteogenesis is technically demanding and often unacceptable for patients who cannot tolerate intraoral distraction devices (Kumar et al., 2014). Space is too limited for a single implant site. When the distracted bone block is small, it is easily absorbed causing exposure of the roots of adjacent teeth (Verlinden et al., 2015). In addition, distraction osteogenesis is generally limited to vertical bone augmentation, a problem when horizontal augmentation is also required (Verlinden et al., 2015). It has been reported that 25%–35% cases need an additional local bone graft after the bone distraction (Kontogiorgos et al., 2013). GBR is an alternative technique that can be used with a barrier membrane alone or in combination with bone grafts or bone substitutes (Dimitriou et al., 2012). In cases of a three-dimensional ridge defect, a nonabsorbable membrane with a supporting titanium frame is required (Funato et al., 2013). The possibility of grafting-material collapse or premature membrane exposure is greatly increased (Misch et al., 2015).

Autogenous bone, with its capacity to regenerate and form new bone through its osteoinductive, osteogenic and osteoconductive

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properties, is still the gold standard for treatment of large lateral and vertical bone defects (Khoury and Hanser, 2015). Onlay bone block grafting was introduced as the most reliable method for treating narrow ridges (Misch, 1997). However, considerable graft resorption following vertical augmentation via this method calls its reliability into question. For example, Cordaro et al. recorded a 42% reduction in the vertical augmentation after a 6 month healing period (Cordaro et al., 2002). As an alternative to the single block onlay graft, a method using two thinner cortical blocks (laminae) was introduced. These can be fixed into the defect area to create the occlusal bone plate and the vestibular plate or the buccal and lingual walls (Khojasteh et al., 2012). However, few reports in the literature address use of this technique in the anterior maxillae.

In the esthetic zone, implants should be placed slightly palatally to achieve a satisfactory outcome, but this may be unachievable in cases of palatal bone defects. At present, there are no reliable surgical techniques to reconstruct palatal bone defects. In our study, GBR and a buccal periosteal flap were applied to prevent bone resorption after implementing the bilaminar cortical bone block method.

This 6-year prospective clinical study assessed bilaminar cortical tenting grafting technique (BCT) for three-dimensional reconstruction of severely atrophic alveolar ridges in the esthetic zone; evaluating the stability of the bone grafting and the long-term clinical outcome.

2. Material and methods

2.1. Patient selection

Over a 2-year period from 2007 to 2009, 21 patients (10 women and 11 men) ranging from 19 to 46-years old were consecutively recruited from those requiring rehabilitation of edentulous anterior maxillae in our school.

To be eligible for the present study, adult individuals had to have a completely healed edentulous site and clinical indication for horizontal and vertical bone augmentation as a result of the bone being too thin to host dental implants (Fig. 1).

The exclusion criteria were as follows: general contraindications for implant surgery; severe hemophilia; history of irradiation in the head and neck regions less than 1 year before the study; poor oral hygiene; uncontrolled diabetes; pregnancy or lactating status; psychiatric problems or unrealistic expectations; human immunodeficiency virus infection; smoking >10 cigarettes or cigar equivalents per day; chewing tobacco corresponding to >10 cigarette equivalents per day; acute infection in the area intended for implant placement; local inflammation, including untreated periodontitis; severe bruxism or clenching habits.

The study protocol was evaluated and approved by the institutional ethics committee prior to patient selection.

2.2. Clinical procedures

2.2.1. Preoperative procedure

Following selection, all patients were evaluated and treated for periodontal and dental health and received oral hygiene instructions until a clinically acceptable oral environment was achieved. Radiographic evaluations were performed to assess the dimensions of the alveolar process and the requirements for three-dimensional prosthodontically driven implant placement were identified.

2.2.2. Surgical procedure

All surgical procedures were performed by one experienced surgeon. 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.

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). The volume of bone to be obtained depended on the size and extent of the bone needed for grafting (Fig. 2). Bone chips were collected at the same time.

At the recipient site, a midcrestal incision was made, followed by intrasulcular buccal and palatal incisions at the adjacent teeth, including two buccal vertical releasing incisions. Full mucoperiosteal flaps were raised on the facial and palatal aspects to expose the alveolar ridge (Fig. 11a). The harvested cortical bone block was split along its long axis into two thin laminae with a diamond disk saw, and were then thinned to a thickness of 1 mm using a bone scraper (Fig. 3). A large contouring bur was used to trim the laminae

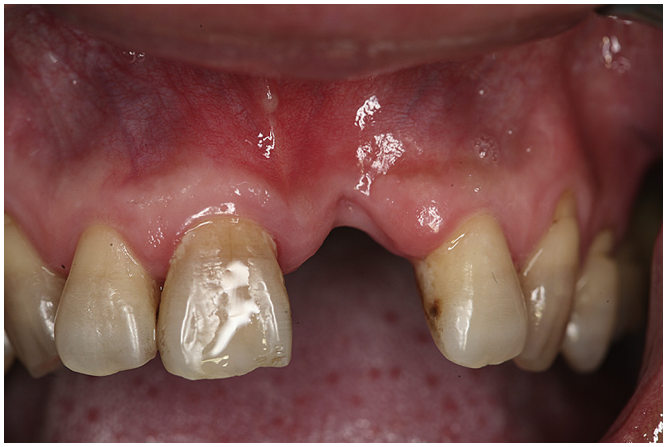

Fig. 1. Severe periodontitis case with horizontal and vertical bone defects in the esthetic zone (left central maxillary incisor).

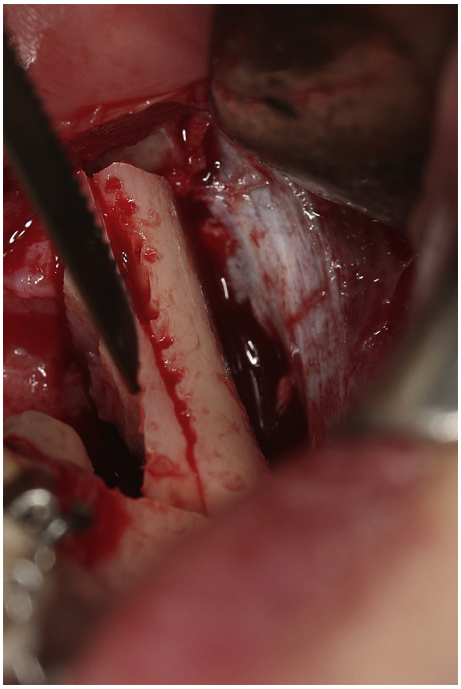

Fig. 2. A cortical bone block graft was harvested from the lateral aspect of the mandibular ramus.

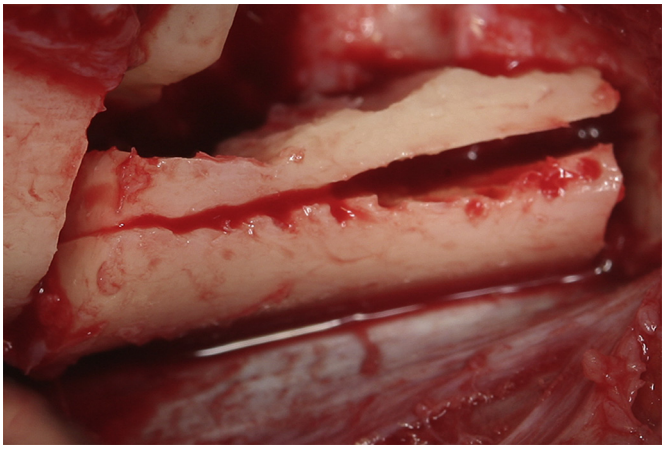

Fig. 3. The bone block was split longitudinally into two thinner blocks (laminae).

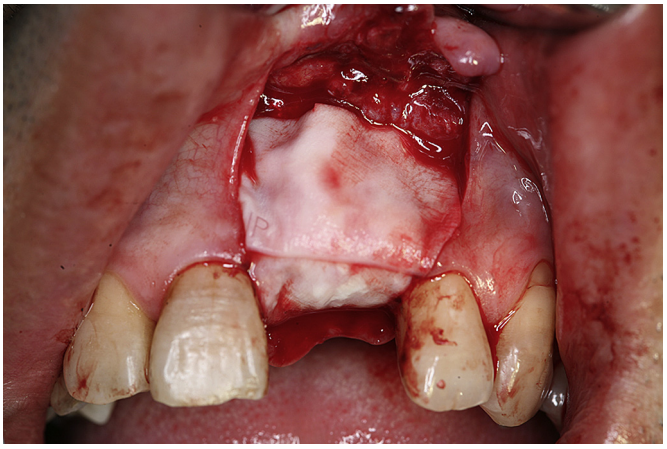

Fig. 6. Bio-Oss was applied to mesially and distally cover the laminae and inter-laminar space. The augmented site was further protected with a two layers of collagen membrane.

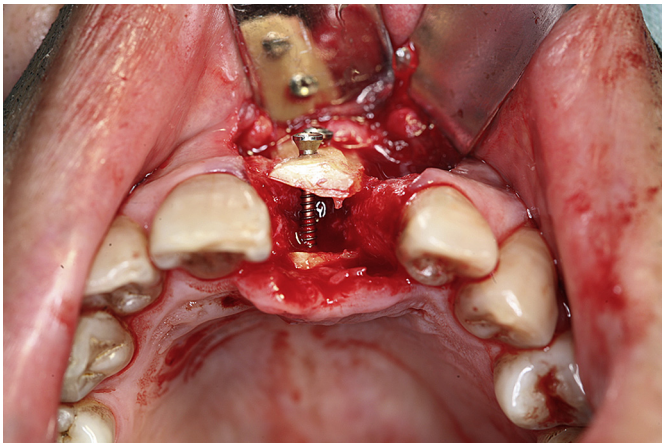

Fig. 4. Two cortical bone laminae were fixed rigidly with miniscrews to reconstruct the buccal and palatal walls of vertical defects and maintain the desired horizontal distance.

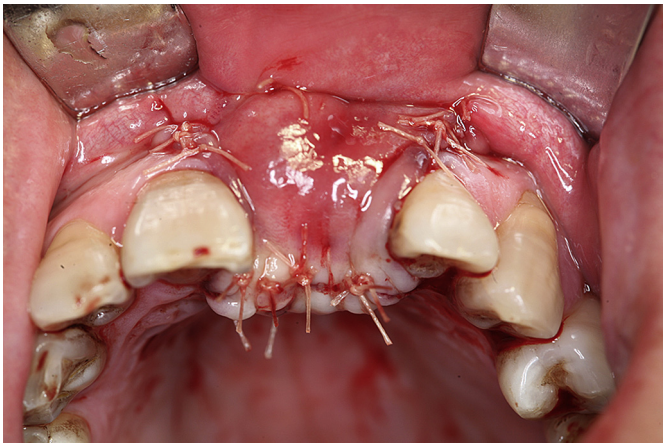

Fig. 7. The soft-tissues were closed up using horizontal mattress sutures.

for best adaptation to the defect site morphology and to round their sharp edges. The two laminae were then adapted into the defect site to reconstruct the buccal and palatal walls of vertical defects and to maintain the desired horizontal dimension of the reconstruction. Using the lag screw technique, the laminae were fixed rigidly to the original alveolar bone with 1–2 miniscrews (10–12 mm in length; Figs. 4 and 11b).

Finally, minor adjustments to the graft were made after screw fixation using a large round diamond bur. The created space between the two cortical laminae was filled with chips of autogenous

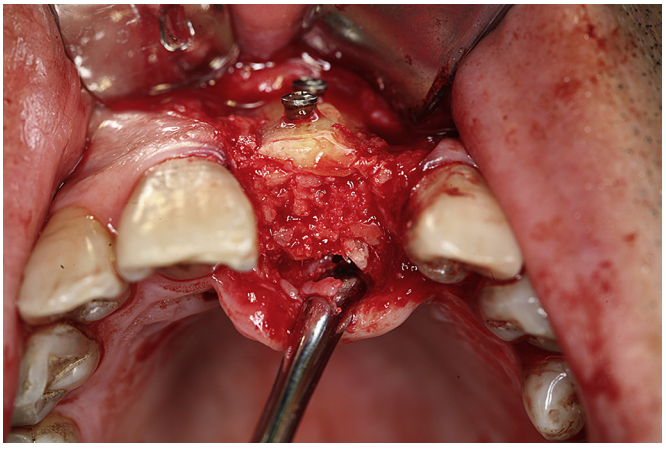

Fig. 5. The inter-laminar space was filled with particulate autogenous bone.

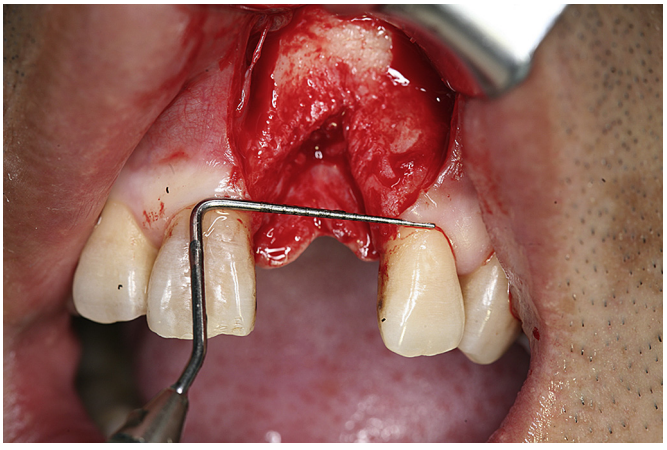

Fig. 8. Measurement of recipient site's horizontal dimension.

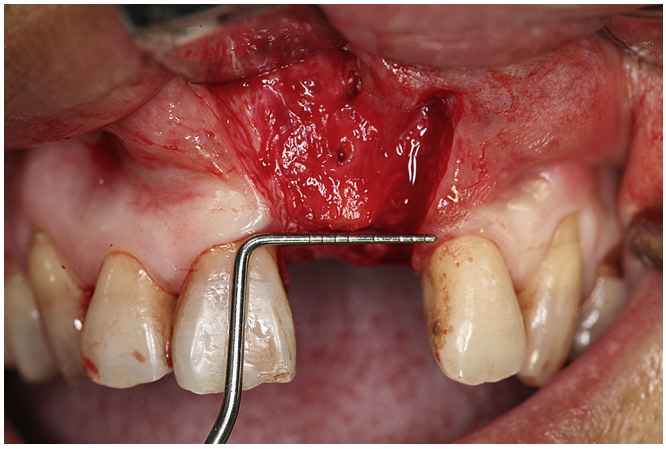

Fig. 9. Upon reentry, the fixing screws were removed and a second measurement of the ridge height was taken.

bone (Figs. 5 and 11c). A particulate anorganic bovine bone mineral (ABBM) graft (Bio-Oss, Geistlich AG, Wolhusen, Switzerland) was applied to cover the graft and spaces around it. The augmented site was further covered by two layers of collagen membrane (Bio-Gide, Geistlich AG; Figs. 6 and 11d). Then the buccal periosteal flap was prepared down to the level of the attached gingiva. The periosteal flap was reflected over the alveolar crest and sutured to the palatal flap (Fig. 11e). To end the procedure, the soft-tissues were closed by means of horizontal mattress sutures (Figs. 7 and 11f).

2.2.3. Postoperative management

For the first three days postop, patients were instructed to use a 0.2% chlorhexidine rinse for 20 s and to take 500 mg of amoxicillin, both at a frequency of three 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. Reentry

4–6 months after the bone graft surgery, a second-stage surgery was performed. Following mucoperiosteal flap elevation and debridement, the fixing screws were removed and the implant (Thommen Medical AG, Grenchen, Switzerland) was placed according to standard surgical protocols. If necessary, additional Bio-Oss was applied to cover the bone defect around the implant. Healing abutment connection and soft-tissue adjustments were carried out at the same time. After another 2–3 months of healing, an implant-supported temporary crown was completed to shape the gingival contour. The final restoration was finished 3–6 months later.

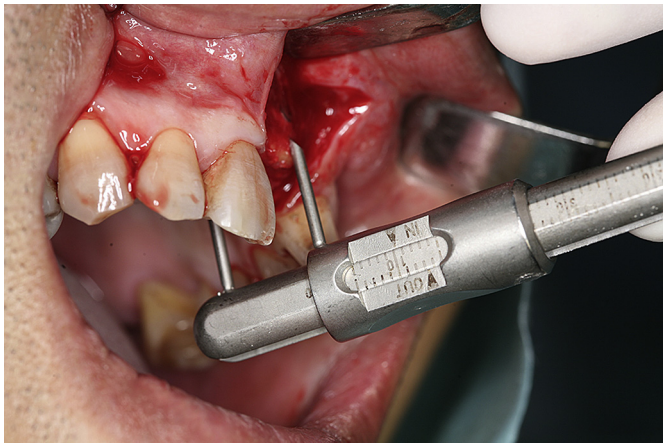

Fig. 10. Upon reentry, the horizontal dimension (width) of the bone graft was measured.

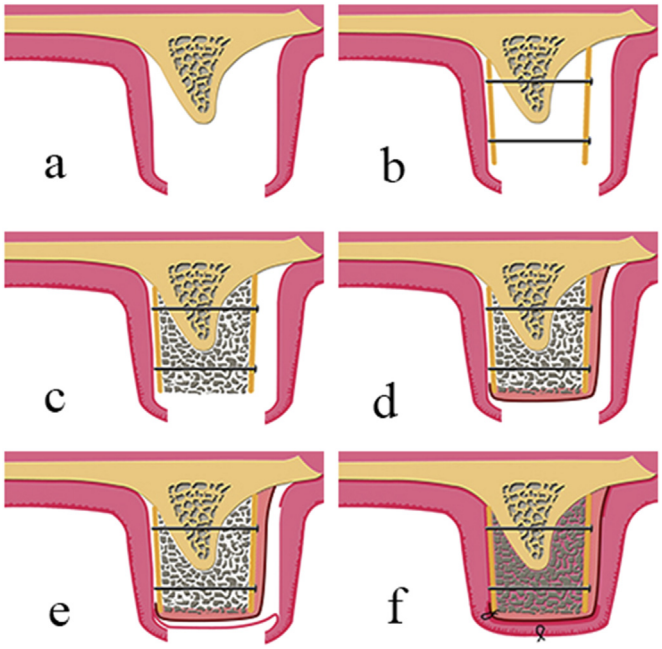

Fig. 11. Schematic illustration of the bilaminar cortical tenting grafting technique (a) A midcrestal incision was made and a full mucoperiosteal flap was raised. (b) Two thin bone blocks (laminae) were fixed to the original alveolar ridge to reconstruct the buccal and palatal plates. (c–d) The inter-laminar space was filled with autogenous bone and the augmented site was covered with Bio-Oss and then further covered by a two-layer collagen membrane. (e) The buccal periosteal flap was reflected over the grafting site and sutured to the palatal flap. (f) The soft-tissue was closed by means of horizontal mattress sutures.

2.3. Follow-up protocol

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.

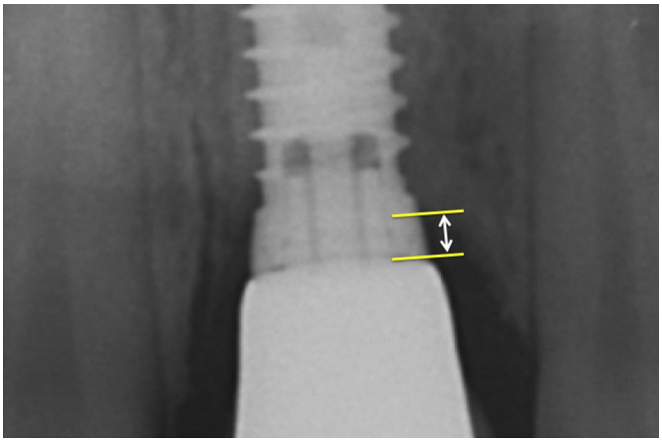

Fig. 12. The panoramic radiograph depicted bone levels measured as the average of the mesial and distal distance between the top level of the implant shoulder and the most coronal visible point of bone-implant contact Distance between the yellow lines: bone levels measured as the average of the mesial and distal distance between the top level of the implant shoulder and the most coronal visible point of bone-implant contact.

Complications related to the augmentation procedure were recorded: sensory disturbances (paresthesia, hypesthesia) and wound dehiscence with bone graft exposure or exposure of the screw without graft exposure.

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 during the healing period and absence of radiographic signs of bone graft resorption.

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, bone width was measured using a calibrated caliper at 1 mm below the highest point of the remaining crest. For horizontal measurements, the point half-way between the adjacent teeth was used, while vertical measurements were taken from the highest point of the remaining crest to the line connecting the mesial and distal bone peaks; the distance from the highest point of the remaining crest to neighboring teeth's cementoenamel junction (CEJ) was used to standardize the vertical measurements (Fig. 8). During the reentry surgery for implant placement, these measurements of ridge width and height were repeated (Figs. 9–10).

2.3.3. Radiographic assessment of peri-implant marginal bone loss

Standardized panoramic radiographs were acquired at the end of the operation, 12 months after implant placement and then reevaluated every year. All images were separately scaled based on the distance between consecutive threads (1.00 mm). The mesial and distal bone levels were measured as the distance between the top level of the implant shoulder and the most coronal visible point of bone-implant contact (DIB). For each implant, this value was taken as the average of the mesial and distal measurements, and the DIB values calculated at each follow-up visit were compared with those calculated at baseline (Fig. 12).

2.4. Statistical analysis

All data were analyzed using the Statistical Package for Social Sciences (SPSS software, version 14.0, IBM, Armonk, NY, USA). Continuous and discrete variables, were respectively described using the mean (±standard deviation) and the frequency.

3. Results

Of the 21 sites that were grafted, prosthetically ideal positioning of the implant was achieved at 17 of them, while a small amount of additional grafting was required at 4 sites. The longest follow-up time was 8-years (average follow-up, 6.09 ± 1.18-years). Details of the patient distribution are shown in Tables 1 and 2.

All implants were inserted as planned, and no intraoperative complications such as graft separation or fracture occurred. During the follow-up, no patient reported adverse effects after dental implant placement and all the implants remained stable, with no complications reported. Accordingly, the implant survival rate was determined as 100%.

3.1. Bone augmentation data

Tables 3 and 4 provide detailed information regarding the original ridge defect and the ridge (bone) width and height after augmentation. The mean healing time was 5.14 ± 0.91 months. At reentry, mean bone width and height were found to be 7.93 ± 0.92 and 5.12 ± 1.05 mm, respectively; amounting to respective increases of 5.49 mm and 5.12 mm over the original defect values.

Periapical radiographs obtained at the end of operation and at the last follow-up revealed no signs of continuous peri-implant radiolucency for any of the implants. The mean resorption of peri-implant alveolar bone was 0.77 ± 0.50 mm (Table 2).

Table 1
Patient distribution and intervention characteristics.

Gender	Male	11
	Female	10
Age (years) at implant insertion		28.14
Etiology of ridge atrophy	Trauma	9
	Periodontitis	8
	Implant failure	4
Smoking status	Smokers	6
	Nonsmokers	15
Periodontal status	Treated periodontitis	7
	Nonperiodontitis	14
Total number of inserted implants		21
External oblique ridge (donor site)	Right	12
	Left	9
Length of placed implants	11 mm	14
	12.5 mm	7
Diameter	3.5 mm	5
	4.0 mm	14
	4.5 mm	2

Table 2
Augmentation parameter values.

	CBL	Healing time	Follow-up
Mean (standard deviation)	0.77 ± 0.50	5.14 ± 0.91	6.09 ± 1.18
Minimum	−0.2	4	4
Maximum	1.86	6	8

CBL: crestal bone loss.

3.2. Complications and corresponding management

Wound dehiscence occurred in one patient shortly after the bone augmentation; however, after irrigation with saline solution the grafting sites spontaneously re-epithelized with no need for resuturing and no further problems. All other sites showed normal healing.

After the bone augmentation procedure, all patients showed edema and pain to varying degrees. However, these complications did not result in graft mobility and failure (Table 5).

4. Discussion

In our study, severe alveolar ridge loss occurred because of trauma (9 sites), periodontitis (8 sites) and implant failure (4 sites). In such cases, adequate grafting technique, rigid fixation, use of a barrier membrane and tension-free soft-tissue closure are critical for achieving positive outcomes. Many techniques have been presented to enhance bone augmentation (Funato et al., 2013; Kim et al., 2015; Rakhmatia et al., 2013); however, many systematic reviews have failed to identify one that is particularly effective and reliable for reconstruction of three-dimensional ridge defects, and there are no reliable surgical techniques for reconstruction of palatal bone defects (Jensen and Terheyden, 2009; Rocchietta et al., 2008) (Bidra, 2011). Aiming to benefit from the high density of cortical ramus bone, many studies have used autogenous bone block grafts from this region to reconstruct vertical and/or

Table 3
Horizontal bone augmentation and remodeling.

	iBW	Post-BW	Re-entry BW	BR	RR
Mean (standard deviation)	2.44 ± 0.98	8.45 ± 0.87	7.93 ± 0.92	0.52 ± 0.19	6.15%
Minimum	1	7.5	6.8	0.3	
Maximum	4.3	10.3	10	0.9	

iBW: initial bone width.
Post-BW: post augmentation bone width at the time of surgery.
Re-entry BW: bone width at re-entry.
BR: bone resorption.
RR: resorption rate.

Table 4
Vertical bone augmentation and remodeling.

	iVD	Post-VH	Re-entry VH	BR	RR
Mean (standard deviation)	4.94 ± 1.15	5.70 ± 1.09	5.12 ± 1.05	0.58 ± 0.24	10.20%
Minimum	3	4	3.6	0.2	
Maximum	7.1	7.8	7.4	1.1	

iVD: initial vertical defect.
Post-VH: post augmentation bone height at the time of surgery.
Re-entry VH: vertical height at re-entry.
BR: bone resorption.
RR: resorption rate.

horizontal defects before or concomitant with implant placement (Khoury and Hanser, 2015; Misch et al., 2015).

The mean volume of ramus graft obtained varies from 0.9 to 1.9 cm^3 due to differences in harvesting techniques and instrumentation (Khoury and Hanser, 2015; Misch, 1997). In cases of extensive vertical and horizontal bone atrophy, autogenous bone block grafts may only be able to provide a quantity of bone that is very small compared with that missing from the defect. Horizontal onlay grafts, buccal GBR and palatal implant placement will not solve this problem, but the BCT grafting technique used in this study has the advantage of reducing the correlation between the bone block volume and the volume of augmentation required, while producing an improved contour along the palatal alveolar ridge.

Khoury and Khoury first used thin mandibular cortical bone blocks (laminae) to reconstruct the buccal and palatal (lingual) walls or the occlusal wall of vertical defects, filling the intervening space with autogenous bone (Khojasteh et al., 2012). A mean vertical volume increase of 7.8 mm was obtained. The concept of 'tenting' by combining multiple bone blocks with particulate bone material was introduced by Le et al (Le et al., 2008). This technique, applied to restore horizontal or vertical deficiencies, allows dentists to perform long-span bone grafting with limited quantities of bone block (Simon et al., 2010). In the present study, cortical bone, split into two thin laminae, offered the possibility of fixation to the buccal and palatal surfaces of the alveolar ridges individually. The space between the two cortical laminae was filled with autogenous bone granules and then covered with a layer of Bio-Oss granules, followed by a two-layer collagen membrane (Bio-Gide). The height and width of the alveolar ridge were thereby reconstructed simultaneously. The height of the alveolar bone around the adjacent teeth increased at the same time. Our technique achieved a mean horizontal augmentation of 8.45 ± 0.87 mm and a mean vertical augmentation of 5.70 ± 1.09 mm; vertical augmentation was determined based on the vertical defect size. This amount of width enhancement should allow for prosthodontically driven implant placement. Palatal cortical bone allows implants to be placed in a slightly palatal position to achieve the contours desired for esthetic restoration (Bidra, 2011).

Table 5
Distribution of sites according to treatment and frequency of complications (n = 21).

		n sites
AG		6
IT	>35 cm	18
	<35 cm	3
ME		1

AG: additional grafting.
IT: insertion torque.
ME: membrane exposure.

Vertical resorption and horizontal resorption were 0.58 ± 0.24 mm and 0.52 ± 0.19 mm respectively after a 5-month healing period. The amount of horizontal bone gain was 7.93 ± 0.92 mm, with a resorption rate of 6.15%. This is similar to the 7.2%–9.3% rate reported for horizontal (only) ridge augmentation via the onlay technique (single relatively large bone block) (Maiorana et al., 2005; von Arx and Buser, 2006). The reason for this similarity may be that the single block is large enough to act as a dense barrier, protecting the newly formed bone (Peleg et al., 2010). However, a major problem with the large-single block approach is resistance to blood-vessel ingrowth, which is detrimental for bone regeneration (Schmid et al., 1997). Splitting the block into two thin (1 mm) laminae effectively addresses this issue, allowing for relatively easy vessel penetration. Moreover, filling the gap between the laminae with particulate autogenous bone (high vascularization potential) most likely further improves vascularization of the reconstructed area (De Stavola and Tunkel, 2013), resulting in greater osteogenesis than the onlay technique. The ground autografts used in this study have been demonstrated to better maintain cell viability and to provide greater quantities of osteoblasts and bone morphogenetic proteins (BMPs), thereby improving bone regeneration (Miron et al., 2013).

Considerable graft resorption following vertical augmentation with the onlay method was reported in a Cochrane systematic review by Esposito et al. (2006) (Esposito et al., 2006), and a retrospective study by Sbordone et al. (2009) evaluated vertical volume alterations after onlay autogenous grafts, finding that the mean volume resorption rate was 35% (Sbordone et al., 2009). In the present study, the amount of vertical bone gain was 5.12 ± 1.05 mm,

with a resorption rate of 10.2%. This lower resorption rate might be explained by our use of Bio-Oss and collagen membranes to cover the reconstruction site. This would be consistent with the findings of Maiorana et al (Maiorana et al., 2005), who reported resorption rates of 9.3% and 18.3% for sites with and without ABBM-particle coverage, respectively (Maiorana et al., 2005). This protective effect may be attributed to the minimal resorption of this bone substitute (Jensen et al., 1996). Then, top of all this, two layers of collagen membrane were applied; these provide a scaffold that enhances bone growth (von Arx and Buser, 2006), potentially improving the augmentation outcome (Antoun et al., 2001). Antoun et al. (Antoun et al., 2001) found that membrane coverage significantly decreased the amount of resorption within a 6 month follow-up period (13.5% versus 34.5% for the membrane-free group). In our study, four of the implants required additional particulate bone grafts at the time of implant insertion to cover peri-implant defects, but the amount required was relatively small. After a follow-up period averaging 6-years, our study demonstrated favorable outcomes for the BCT grafting technique, with the mean peri-implant bone level decreasing by only 0.77 ± 0.50 mm over the 6-years.

Complications at the recipient site are often caused by soft-tissue problems such as wound dehiscence, flap necrosis and membrane exposure (Penarrocha-Diago et al., 2013). Soft-tissue closure and preservation of membranes by the gingival tissues may protect against the loss of growth factors and generally maintain the regenerative environment at the site (Triaca et al., 2001). To minimize the risk of dehiscence, it is necessary to achieve tension-free wound closure, especially in cases of severe ridge defects that are in need of large scale bone augmentation. Several surgical techniques have been developed to achieve primary closure of extraction sites, including coronally advanced buccal flaps (Rosenquist, 1997), connective tissue grafts and extension of palatal tissues (Khoury and Happe, 2000). The technique used in the present study was simpler than these and can augment the keratinized tissue. Only one patient exhibited dehiscence and after irrigation, the recipient sites re-epithelialized without further problems. No signs of erythema, suppuration or infection were observed.

The limitation of the present investigation was the small sample size. In addition, changes in bone height and width were not analyzed with three-dimensional projection, which is more accurate and reliable.

5. Conclusions

(1) The bilaminar cortical tenting grafting technique served as a highly effective and reliable augmentation method for treatment of horizontal and vertical ridge defects.
(2) Particulate autogenous graft combined with coverage by particulate ABBM and a two-layer collagen membrane supported successful augmentation with low bone resorption.
(3) The buccal periosteal flap was much simpler to perform than most other procedures for achieving tension-free primary closure, and it was characterized by low levels of soft-tissue complications.

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Competing interests

None declared.

Ethical approval

The institutional ethic committee approved the research protocol.

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