Shell Technique with a Xenogeneic Cortical Bone Lamina and Particulated Bone Graft for Horizontal Ridge Augmentation: A Case Series

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The aim of this prospective case series was to evaluate the efficacy and safety of a xenogeneic cortical bone lamina utilized as a “shell” on the buccal aspect of narrow alveolar ridges for horizontal bone augmentation. A total of 15 patients requiring multiple implant restorations at sites with moderate to severe horizontal bone deficiency were consecutively enrolled. Horizontal bone augmentation was performed using a xenogeneic cortical bone lamina (XCBL) that was fixed on the buccal aspect of the
ridge using titanium screws and a mixture of particulate autogenous bone graft and porcine hydroxyapatite. CBCT scans were taken at baseline and 6 months after bone augmentation. The healing was uneventful, with no intra- or postoperative complications. A total of 27 dental implants were placed in the augmented sites. The calculated average horizontal bone gains from CBCT scans were $4.79 \pm 1.64$ mm, $5.59 \pm 1.51$ mm, and $5.79 \pm 2.53$ mm at the 1-, 3-, and 5-mm reference points apical to the buccal bone crest, respectively. The present case series demonstrated that the shell technique with the XCBL and particulate bone graft can be an effective approach for horizontal bone augmentation prior to implant placement. *Int J Periodontics Restorative Dent* 2022. doi: 10.11607/prd.5671

**INTRODUCTION**

Tooth loss is followed by a physiologic resorption of the alveolar ridge that often complicates implant-supported rehabilitations (1, 2). Severely resorbed alveolar ridges can pose challenges to proper positioning and primary stability of implants (3-5). Hence, performing bone augmentation has been advocated either prior to or at the same time of implant placement (3, 4, 6).

A large variety of techniques have been described for increasing horizontal bone width (HBW) prior to implant placement, including guided bone regeneration (GBR), with different combinations of graft materials and membranes, transplantation of autogenous bone grafts, ridge splitting and utilization of bone substitutes alone (3, 4, 7-11). According to a recent systematic review and meta-analysis, the HBW gain after 6 months for block grafts and GBR was $4.03 \pm 0.49$ mm, and $2.59 \pm 0.23$ mm, respectively (12). One of the main advantages of block graft procedures is the rigidity of the material that can serve as a scaffold for bone regeneration in case of missing buccal bone (13, 14). Khoury et al. described a technique involving the harvesting of autogenous bone blocks from the
external oblique ridge of the mandible and the splitting of the graft in two thin blocks that were stabilized at the recipient site (13, 15). The authors claimed that this approach can improve revascularization as well as bone regeneration (e.g., HBW gain) (13). The “shell” technique with autogenous split bone graft has also been utilized for bone augmentation at the same time of implant placement (16).

Nevertheless, high bone resorption and patient morbidity have been associated with the use of autogenous bone grafts, regardless of the location of the donor site (4, 17). It is, therefore, reasonable to assume that a xenogeneic cortical bone lamina plate can be combined with a particulate bone graft to serve as a scaffold/“shell” that prevents flap collapse and maintains the biologic space necessary for bone regeneration, while substantially reducing patient morbidity.

The aim of this manuscript was therefore to describe the use of a xenogeneic cortical bone lamina in combination with a particulate bone graft for horizontal bone augmentation prior to implant placement.

Materials and Methods

Study Population

Fifteen patients in need of multiple implant restorations at sites with a moderate horizontal bone deficiency (≥3mm) were consecutively enrolled in three private practices between October 2018 and February 2019. Cone-beam computed tomography (CBCT) scans (KaVo, Biberach an der Riss, Germany) were obtained at baseline and at 6 months after the treatments to evaluate ridge dimensions. The inclusion criteria were as follows: i) age of at least 18 years, ii) good general health with no systemic/periodontal disease, iii) good oral hygiene with full-mouth plaque scores ≤ 15%, iv) moderate/severe horizontal bone deficiency (≥ 3mm), v) presence of bone height of at least 10 mm, and vi) tooth extraction at the edentulous site at least 3 months ago. Smoking, pregnancy (or planning to become pregnant), or medications that could compromise bone augmentation/implant surgery (e.g.,
IV bisphosphonate, uncontrolled diabetes) were considered among the exclusion criteria. The protocol of the study was in full accordance with the Helsinki Declaration of 1975, as revised in 2000. Written informed consents were obtained from all individuals who participated in the study prior to the surgical procedures.

Surgical Procedure

The proposed “shell” horizontal bone augmentation was performed by the same clinician in each private center (G.V., A.R., L.B.). Systemic antibiotics (1 gram of Amoxicillin every 12 hours for 6 days) were prescribed to patients one day prior to the surgery. Local anesthesia with 2% mepivacaine was administered in the surgical area. A midcrestal incision was performed in the edentulous area, followed by intrasulcular incisions in the buccal and lingual aspects of the teeth adjacent to the surgical site. Two vertical releasing incisions were performed on the buccal aspect, while one vertical incision was performed on the lingual/palatal side on the mesial aspect of the tooth adjacent (mesial) to the defect. Periosteal elevators were used for full-thickness flap elevation in the buccal and lingual aspects. Decortication of the bone was performed using a small round bur (#2), aiming at exposing the medullary space. A xenogeneic (equine) cortical bone lamina (XCBL) graft (Tecnoss Medical Devices, Giaveno, Italy) with initial dimensions of 30x30x10 mm was obtained, trimmed, and adapted to the site and then stabilized on the buccal aspect of the ridge with titanium screws (Stoma, Emmingen-Liptingen, Germany). The bony defect was filled with a combination of approximately 50% of particulate autogenous bone graft – harvested from the adjacent sites using a bone scraper (Safescraper Twist, Meta, Reggio Emilia, Italy) – and 50% particulate porcine hydroxyapatite (Gen-Os, Osteobiol, Turin, Italy). No membranes were utilized, as previously described by Khoury and coworkers when utilizing the autogenous split bone block technique (13, 15). The buccal flap was then mobilized with a periosteal releasing incisions connecting the two vertical incisions to allow for a tension-free primary closure, while the lingual flap was released as previously described (18). The flaps were sutured only when they were able to be approximated without any tension. Horizontal mattress sutures (6/0
polypropylene) were first performed approximately 4-mm from the flap margin. Simple interrupted sutures (6/0 polypropylene) were then placed coronal to the line of the horizontal mattress suture for obtaining a closure by primary intention. Simple interrupted sutures were also placed on the vertical releasing incisions (Figures 1 and 2).

Oral and written post-operative instructions were provided to the patients, as well as prescriptions for analgesics (Ibuprofen 600 mg every 8 hours until needed), antibiotics (Amoxicillin), and a mouth rinse (chlorhexidine gluconate 0.12% for the first two weeks). The sutures were removed at the 2-week post-op recall. After 6 months of healing, the sites were reopened, the titanium screws were removed, and implants (Nobel Biocare, Zürich, Switzerland) were placed. The study protocol involved the removal of the XCBL in case it was not integrated into the regenerated bone at the time of surgical re-entry. After 3-4 months from implant placement, the implants were restored with provisional crowns and then finalized with zirconia screw-retained crowns.

CBCT Measurements

The CBCT DICOM files from baseline to 6 months were imported using a specific software (Blue Sky Plan, Blue Sky Bio, LCC, Libertyville, USA.) to analyze the changes in horizontal bone width. A calibrated examiner performed all the measurements as previously described by De Bruyckere and coworkers (17). The horizontal bone width (HBW) was calculated on axial slides (in the middle of the bony defect) at 1-, 3- and 5-mm reference points apical to the buccal bone crest (17).

Study Outcomes

The main outcome of the study was the assessment of HBW gain at the 6-month follow-up recall. Secondary outcomes included the incidence of post-operative complications, patient-reported outcomes, and the number of sites requiring additional bone grafting at the second surgical procedure.

Descriptive statistics were used to present the CBCT measurements as means ± standard deviations (SD). Adjusted paired t-tests were utilized to statistically compare the changes in ridge morphology (width, HBW) at the 1-, 3- and 5-mm stated reference points.
To obtain statistically meaningful comparisons of changes in terms of HBW at baseline compared to the evaluation at 6 months, linear mixed-model regression analyses was used which accounted for the repeated measures per subject and patient baseline characteristics that could potentially influence the outcomes (e.g., age, sex). A p value threshold of 0.05 was set for statistical significance. The analyses were performed in Rstudio (Rstudio Version 1.1.383, Rstudio, Inc., Boston, USA).

Results
Fifteen systemically healthy patients (4 males and 11 females, with a mean age of 59.9 ± 14.9 years) were included in the study. In seven patients, the surgical site was located in the maxilla, while in eight patients, it was located in the mandible. No intraoperative complications had occurred. The healing was uneventful at all sites with no post-operative complications at any sites during the healing period. At the 6-month re-entry appointment, implant placement was possible at all sites. Twenty-seven dental implants were successfully placed in the augmented sites. All the XCBLs were integrated and were not removed. Nonetheless, additional bone grafting was necessary in 5 cases, 4 of which had been in the maxilla. In three cases, the implants were completely surrounded by bone, however to maintain at least 1.5-2 mm of buccal bone thickness, additional bone grafting with a xenogeneic bone substitute and a collagen membrane were also performed as suggested in the literature (19-21). In two other scenarios, a shallow bone dehiscence was noted on the facial aspect of the implants, where a mixture of 50% autogenous bone collected from the adjacent area and 50% xenogeneic bone, together with a resorbable collagen membrane were applied. A submerged healing was performed in the cases that required additional grafting during the implant placement.

At baseline, the CBCT analysis showed an average HBW of 3.19 ± 0.99 mm, 3.81 ± 1.09 mm and 4.65 ± 2.02 mm, at the 1-, 3- and 5-mm reference points, respectively. The average HBW gain after bone augmentation with the xenogeneic cortical lamina and particulate bone graft was 4.79 ± 1.64 mm
at 1-mm, 5.59 ± 1.51 at 3-mm and 5.79 ± 2.53 at 5-mm reference points apical to the buccal crest. The differences in the amount of HBW gain when comparing the maxilla and mandible did not reach statistical significance (p>0.05). The HBW after bone augmentation with the described “shell” technique was significantly higher than HBW at baseline (p<0.01, in all the levels). Table 1 reports the average HBW at baseline and at the 6-month follow-up visit. Subjects were followed, up to 6 months after the final loading of implants. All implants were osseointegrated and healthy, with no signs of peri-implant disease or complications. All subjects expressed satisfaction about the overall treatment and the outcomes. Figure 3 shows a histological section of an implant site 6 months after staged horizontal bone augmentation with the shell technique.

Discussion

The present case series demonstrated the use of a xenogeneic cortical bone lamina (XCBL) in combination with particulate bone graft (estimate 1:1 ratio of autogenous bone and porcine hydroxyapatite) for predictable horizontal bone augmentation prior to implant placement. No associated complications were noted after performing this procedure, and it was possible to place implants in all the augmented sites at the re-entry appointment. The average HBW gain after 6 months ranged between 4.79 and 5.79 mm, which agrees with the regenerative outcomes reported in the literature (3, 4, 12, 22).

Thoma and coworkers observed a median HBW increase from 2 mm to 7 mm and from 4 mm to 7 mm for horizontal ridge augmentation with autogenous bone block and xenogeneic bone block loaded with recombinant human bone morphogenetic protein-2 (9). While the difference in HBW between the two groups was not statistically significant, patients allocated in the group with the xenogeneic bone block reported significantly less morbidity compared to the subject that underwent augmentation with autogenous block graft (9). Similarly, a recent systematic review and meta-analysis concluded that no...
differences should be expected between autogenous and allogeneic bone block in terms of horizontal ridge augmentation (22).

The XCBL utilized in the present case series has been previously documented in other clinical scenarios, such as in the reconstruction of orbital floor defects (23) and temporomandibular joints (24). The XCBL undergoes a process of superficial decalcification that results in an elastic consistency of the material (23). In addition, it is relatively easy for surgical site adaptation and stabilization.

Basically, the advantages of xenogeneic block grafts compared to autogenous blocks include reduced patient morbidity, surgical time and less time needed for recovery after the surgical procedure, aside from not being limited in quantity for augmentation. In addition, a xenogeneic block graft (either equine or porcine) can be used in countries which do not allow the utilization of human allograft materials due to legal reasons (23). Among our patients, we observed no complications or adverse reactions with the XCBL, which seemed integrated at all sites at the 6-month re-entry procedure.

The choice of utilizing a mixture of particular autogenous and xenogeneic bone graft between the alveolar ridge and the XCBL has also likely contributed to the HBW observed in this study, with the osteogenic properties of the autogenous bone graft harvested with a scraper (25) combined with the osteoconductivity and slower resorption rate of the xenograft. Indeed, a potential drawback of utilizing xenogeneic block grafts only for horizontal bone regeneration may be the “bone quality”, as a recent randomized clinical trial demonstrated that xenogeneic blocks were associated with a similar horizontal volume gain but with a lower implant insertion torque than autogenous blocks (26). The present shell technique with the XCBL and a mixture of particulate autogenous and xenogeneic bone graft may overcome this shortcoming by promoting vascularization and new bone formation from the autogenous bone chips.

Within the limitations of the present study, the nature of the study design should be mentioned which lacked a control group, as well as the lack of an objective method assessing implant stability and the short-term observation period. In addition, the long-term assessment of implant survival rate and
histomorphometric analyses would have been beneficial and should be explored in future studies. Nevertheless, the aim of this study was to present the surgical technique as well as the preliminary data of the XCBL “shell” approach for horizontal bone regeneration. Future comparative studies with longer follow-up time points are underway to further evaluate the efficacy of this approach and to compare its outcomes with other techniques.

Conclusions

The present case series described the use of a xenogeneic cortical bone lamina in combination with a particulate bone graft for horizontal ridge augmentation prior to implant placement. The clinical-, radiographic- and patient-centered outcomes suggest that this approach can be efficiently employed for horizontal bone augmentation. Nonetheless, future studies with longer follow-up periods are required to validate this approach.

Acknowledgments

The authors declare no conflicts of interest.

References


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Figures Legends

Figure 1. Staged horizontal bone augmentation with the described shell technique in the posterior mandible. A) Preoperative cone-beam computed tomography of the left mandibular area. B) Xenogeneic (equine) cortical bone lamina (XCBL) graft (Tecnoss Medical Devices, Giaveno, Italy). C) The XCBL graft was adapted and stabilized on the buccal aspect with titanium screws. The bony defect was then grafted with particulate autogenous bone graft and porcine hydroxyapatite. D) Closure of the flaps with horizontal mattress and simple interrupted sutures. E) Re-entry after 6 months with
the placement of two implants. F) Cone-beam computed tomography 6 months after the bone augmentation procedure. G) Cone-beam computed tomography 3 months after implant placement.

Figure 2. Staged horizontal bone augmentation with the described shell technique in the anterior maxilla. A) Pre-operative cone-beam computed tomography. B) Stabilization of the xenogeneic cortical bone lamina graft. C) the space between the graft and the ridge is filled with autogenous bone graft and porcine hydroxyapatite. D) Cone-beam computed tomography at the 6-month post. E) Re-entry with implant placement 6 months after the staged bone augmentation. Further bone augmentation was not necessary.

Figure 3. Histological section of an implant site 6 months after staged horizontal bone augmentation with the shell technique. A prefabricated stent was used to harvest a bone core from the newly regenerated tissue. The samples were fixed in 4% formalin for 24 hours. Then the samples were decalcified for 24 hours, immersed in alcohol 70%, dehydrated and then embedded in paraffin according to standard procedures (1).

A) Histological slide stained with H&E showing fragments of pristine bone (PB) with signs of remodeling, and a stromal tissue (ST) rich in inflammatory cells. It is possible to observe blood vessels (BV) adjacent to newly formed bone (NB) characterized by bone osteoid matrix and osteoblasts. (original magnification: 10x).

B and C) Histological slides stained with H&E showing remodeling of pristine bone (PB), stromal tissue (ST) rich in inflammatory cells, blood vessels (BV) adjacent to newly formed bone (NB) characterized by the apposition of lamellae (arrows). Several osteoblasts are visible in the osteoid matrix of the NB. (original magnification: 10x).

D) Histological slide stained with H&E showing an acellular graft particle (G) surrounded by stromal tissue. (original magnification: 10x).
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Table 1. Horizontal bone width measured 1-, 3- and 5-mm points apical to the bone crest at baseline and at the 6-month appointment after the bone augmentation procedure.

<table>
<thead>
<tr>
<th>Buccal bone level</th>
<th>HBW at T0 (mean ± SD) (mm)</th>
<th>HBW at T1 (mean ± SD) (mm)</th>
<th>HBW gain (mean ± SD) (mm)</th>
<th>p-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 mm</td>
<td>3.19 ± 0.99</td>
<td>7.98 ± 1.73</td>
<td>4.79 ± 1.64</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>3 mm</td>
<td>3.81 ± 1.09</td>
<td>9.40 ± 1.44</td>
<td>5.59 ± 1.51</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>5 mm</td>
<td>4.65 ± 2.02</td>
<td>10.44 ± 1.91</td>
<td>5.79 ± 2.53</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

Legend. HBW: horizontal bone width; T0: baseline; T1: 6-month follow-up; * p-value comparing HBW at T1 with HBW at T0.
Figures

Fig 1

Fig 2