Comparative Assessment of Bovine Versus Porcine Xenograft for Augmentation: A Randomized Prospective Cohort Study

Neel Bhatavadekar, BDS, MS, MPH
Yazad Gandhi, BDS, MDS
Ninad Padhye, BDS, MDS

This study compared the bone turnover and volume stability of bovine-derived xenografts (Cerabone) vs porcine-derived xenografts (MinerOss XP) in horizontal ridge augmentation (HRA) for veneer contour and extraction socket preservation (ESP), with a 6-month follow-up. Participants were divided into Group 1 (HRA + bovine), Group 2 (HRA + porcine), Group 3 (ESP + bovine), and Group 4 (ESP + porcine). Buccolingual ridge width was measured on CBCT scans at baseline and 6 months. Representative histologic core samples were taken from the ESP groups at 6 months. Each group comprised 10 subjects (40 subjects total). The buccolingual width for Groups 1 and 2 increased from 5.43 ± 1.82 mm and 5.75 ± 1.64 mm (P = .36) to 7.75 ± 1.91 mm and 8.75 ± 1.38 mm (P = .03), respectively. However, the buccolingual widths for Groups 3 and 4 decreased from 6.3 ± 1.26 mm and 6.74 ± 1.29 mm (P = .16) to 5.8 ± 1.21 mm and 6.61 ± 1.56 mm (P = .01), respectively. Significantly lower dimensional changes were noted in Group 4 at 6 months. Porcine xenografts serve as a stable biocompatible osteoconductive bone substitute and expand a clinician’s choice of bone grafts in dental applications. Int J Periodontics Restorative Dent 2022;42:789–796. doi: 10.11607/prd.6025

The alveolar bone undergoes a series of resorptive changes following tooth extraction, causing a loss of bone volume.1 Because an ideal functional and esthetic implant rehabilitation is dependent on the availability of sufficient alveolar bone volume and favorable architecture,2 various augmentative techniques and materials have been introduced to compensate for this loss of the alveolar bone.3 Among the available bone grafts, autogenous bone is considered to be a gold standard from a biological and histological aspect.4 However, its limited availability, donor site morbidity, and faster resorption rate have resulted in the popularity of other sources of bone grafts as well.5

Xenogeneic bone substitutes, particularly deproteinated bovine bone matrix (DBBM), have shown successful results in various periodontal and oral surgical procedures, including ridge preservation and buccal contour augmentation.6,7 However, concerns over potential bovine spongiform encephalopathy (BSE) transmission8 and possible religious conflicts for people of certain faiths9 have led to the development of porcine-derived bone substitutes.

Porcine bone, with a relatively lower zoonosis risk, has shown to have similar physiologic, anatomical, and genetic makeup to humans at

1 Private Practice, Pune, India.
2 Consultant Maxillofacial Surgeon, Saifee Hospital, Mumbai, India.
3 Private Practice, Andheri West, Mumbai; ITI Scholar, Queen Mary University and The London School of Medicine and Dentistry, The Royal London Dental Hospital, London, England.

Correspondence to: Dr Neel Bhatavadekar, 104 Serene Bay, Lane 6, Koregaon Park, Pune 411001, India. Email: dmeel1@gmail.com

Submitted September 20, 2021; accepted November 14, 2021. ©2022 by Quintessence Publishing Co Inc.
an ultrastructural level. Similar to bovine-derived grafts, the crystalline structure of porcine xenografts with a suitable calcium-to-phosphorous (Ca/P) ratio is comparable to human bone. However, despite its wide availability, there are limited data on the effectiveness of porcine-derived bone substitutes and how they compare to the commonly used bovine xenografts. Thus, this study prospectively compared the volume stability of bovine- and porcine-derived xenografts over a 6-month follow-up in a controlled cohort. As a secondary objective, histologic core analyses were performed in representative samples at the 6-month surgical reentry to assess de novo bone formation. To the present authors’ knowledge, this is the first study to compare the volume stability of these xenografts in humans.

Materials and Methods

This parallel, two-arm, multi-centric prospective study was approved by the Institutional Review Board of the Ethical Committee of M.A. Rangoonwala Dental College (MCES/EC/520/2018) in agreement with the 1975 Declaration of Helsinki, revised in 2013. Patients were recruited from two private clinical practices between February 2019 and December 2020, either requiring horizontal ridge augmentation (HRA) for veneer contour or extraction socket preservation (ESP). Participants were recruited for the study if they met the following inclusion criteria: (1) aged 21 years or older; (2) missing teeth (> 6 weeks following extraction) requiring only horizontal contour bone augmentation (for HRA), or endodontically treated teeth without signs of periodontal inflammation requiring extraction (for ESP); (3) ≥ 10 mm of vertical alveolar bone height; (4) the tooth to be extracted had buccal/labial alveolar bone ≥ 1 mm thick; and (5) adequate interocclusal restorative space was available for implant-supported rehabilitations. Patients who met any of the following exclusion criteria were removed from the study: (1) age > 55 years; (2) having uncontrolled diabetes mellitus; (3) smoking habit (more than 5 cigarettes/day); (4) inability to maintain optimal oral hygiene during the study period; and (5) geographically located far away (thus limiting follow-ups and records).

Two commercially available xenogeneic bone grafts (bovine and porcine) were used for the study. The bovine- and porcine-derived bone grafts for this study were Cerabone (Botiss) and MinerOss XP (BioHorizons), respectively, with particle sizes of 0.25 to 1 mm. Within each treatment group (HRA or ESP), patients were randomized by a flip of a coin to receive either bovine (Cerabone) or porcine (MinerOss XP) graft. Study participants were thus divided as follows: HRA + Cerabone (Group 1), HRA + MinerOss XP (Group 2), ESP + Cerabone (Group 3), and ESP + MinerOss XP (Group 4).

CBCT scans were taken prior to patient enrollment to ensure they met the inclusion criteria. Buccolingual ridge width (Groups 1 and 2) or alveolar crestal bone width (Groups 3 and 4) was measured on the CBCT scans, and this reading was considered as the baseline. A standard sample size calculation determined that a minimum of 8 subjects per group (32 subjects total) were required for the difference between the horizontal width dimensions to be statistically significant when α = .05 and P < .01, and the power was set at 80%, as determined by Bae et al.

Surgical Protocol

HRA for Veneer Graft

All participants gave a written informed consent prior to enrollment in the study. Following local anesthesia, a full-thickness mucoperiosteal flap was reflected until it was 3 mm apical to the horizontal osseous defect. Implant osteotomy was performed to reach the desired dimensions, and an implant was placed with sufficient primary stability. Decortication was performed using a small, round, carbide drill around the site to be augmented. Depending on the subject’s group, the particular bone graft (Cerabone or MinerOss XP) was veneered on the buccal or labial surface in an incremental manner. A trimmed bi-phasic cross-linked collagen membrane (Mem-Lok, BioHorizons; 15 × 20 mm) was placed over the grafted site, extending 2 to 3 mm apical to the buccal/labial defect. Primary closure of the surgical site was then attained using 4-0 Vicryl sutures.
(Ethicon, Johnson & Johnson). Figure 1 shows the HRA surgical procedure.

ESP

Following written informed consent and local anesthesia, a full-thickness mucoperiosteal flap was reflected to approximately 3 mm apical to the alveolar crest. The tooth was then extracted with minimal trauma to avoid buccal/labial fenestration or dehiscence. The socket was debrided using curettes with copious saline irrigation. Depending on the subject’s group, the bone graft (Cerabone or MinerOss XP) was condensed in the socket incrementally for complete apico-coronal fill. In case of a deficient buccal cortical plate, the socket was covered with a Mem-Lok membrane. The buccal/labial flap was mobilized through periosteal scoring, and primary closure was attained using 4-0 Vicryl sutures. Figure 2 shows the ESP surgical procedure.

Postsurgical Care

All patients received postoperative instructions, a course of amoxicillin (500 mg orally every 8 hours for 7 days), and nonsteroidal anti-inflammatory drugs as needed. Subjects were instructed to rinse with 10 mL of 0.2% chlorhexidine gluconate mouthrinse twice a day for 15 days. Sutures were removed 10 days postsurgery. At the 6-month follow-up, CBCT scans were taken, and the horizontal dimensions were noted.

Histologic Processing

During the implant osteotomy preparation for patients who received ESP, a 2-mm–diameter trephine was first introduced to obtain a cylindrical bone biopsy sample (6 mm long). The sample was stored in a
10% neutral buffered formalin solution. Hydrochloric acid was used to decalcify the harvested samples, and the specimens were placed in a tissue processor (Tissue-Tek VIP 1000, Sakura Finetek USA). The samples were then embedded in paraffin wax using a paraffin embedder (Leica RM2155 automated microtome, Leica Microsystems) and sectioned to a thickness of 4 μm. The sections were stained with Harris hematoxylin-eosin (h&E). The slices were examined at ×20 to ×40 magnification (Vanox AH2, Olympus America), and vital bone was identified as the presence of osteocytes in mineralized tissue.

Statistical Analysis

The recorded data were entered in Microsoft Excel (version 2010) and tabulated. Data analysis was done using a Windows PC-based software (MedCalc Software, version 13.3.1). All testing was done with alpha = .05 (95% confidence intervals). Intergroup comparison was performed using unpaired Student t test, considering normality assumption and homoscedasticity. Differences beyond the 95% confidence intervals were regarded as statistically significant. The change in width was also evaluated as a percentage for HRA groups.

Results

A total of 40 patients (10 patients per group) participated in the study. There were no sample dropouts during the study period. The mean age of the subjects who underwent HRA and ESP were 40 ± 7.4 years and 42 ± 6.8 years, respectively. Few patients reported minor postoperative discomfort following the surgical procedure; the overall healing for all four groups was uneventful.

### Table 1 Buccolingual/Buccopalatal Width of the Alveolar Ridge

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>6 mo</th>
<th>Difference</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 (HRA + Cerabone)</td>
<td>5.43 ± 1.82 mm</td>
<td>7.75 ± 1.91 mm</td>
<td>2.32 ± 0.9 mm</td>
<td>&lt; .001*</td>
</tr>
<tr>
<td>Group 2 (HRA + MinerOss XP)</td>
<td>5.75 ± 1.64 mm</td>
<td>8.75 ± 1.38 mm</td>
<td>3.00 ± 1.2 mm</td>
<td>&lt; .001*</td>
</tr>
<tr>
<td>P</td>
<td>.36</td>
<td>.03</td>
<td>.06</td>
<td></td>
</tr>
<tr>
<td>Subjects, n</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

HRA = horizontal ridge augmentation.
Values are presented as mean ± SD.

*Statistically significant difference.

### Table 2 Alveolar Crestal Bone Width

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>6 mo</th>
<th>Difference</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 3 (ESP + Cerabone)</td>
<td>6.30 ± 1.26 mm</td>
<td>5.80 ± 1.21 mm</td>
<td>0.50 ± 0.2 mm</td>
<td>&lt; .001*</td>
</tr>
<tr>
<td>Group 4 (ESP + MinerOss XP)</td>
<td>6.74 ± 1.29 mm</td>
<td>6.61 ± 1.56 mm</td>
<td>0.13 ± 0.07 mm</td>
<td>&lt; .001*</td>
</tr>
<tr>
<td>P</td>
<td>.16</td>
<td>.01</td>
<td>&lt; .001*</td>
<td></td>
</tr>
<tr>
<td>Subjects, n</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

ESP = extraction socket preservation.
Values are presented as mean ± SD.

*Statistically significant difference.
the horizontal dimensions between Groups 1 and 2 ($P = .36$) and Groups 3 and 4 ($P = .16$) at baseline. The average baseline buccolingual width was 5.43 ± 1.82 mm for Group 1 and 5.75 ± 1.64 mm for Group 2, which increased to 7.75 ± 1.91 mm and 8.75 ± 1.38 mm, respectively, at 6 months (Fig 3). The average alveolar crestal bone width was 6.30 ± 1.26 mm for Group 3 and 6.74 ± 1.29 mm for Group 4, which decreased to 5.80 ± 1.21 mm and 6.61 ± 1.56 mm, respectively, at 6 months (Fig 4). Although the horizontal ridge dimensions at 6 months were greater for Group 2 than Group 1 ($P = .03$), and greater for Group 4 than Group 3 ($P = .01$), there was no statistically significant difference. From baseline, there was a 42.72% increase in horizontal ridge width for Group 1 and a 52.17% increase for Group 2. Alternatively, there was a 7.93% decrease in alveolar crestal bone width for Group 3 and a 4.98% decrease for Group 4. A statistically significant difference was noted when the change in dimensions (baseline to 6 months) was compared between Groups 3 and 4 ($P < .001$; Table 2).

Histologic analysis showed new bone formation predominantly in the apical section of the biopsy samples (Fig 5). Woven bone with isolated islands of lamellar bone was noted. The graft material was in direct contact with the newly formed lamellar bone in both bovine and porcine groups. The trephine bone biopsy sections stained with h&e showed the presence of mature trabecular bone, which exhibited osteocytes and some residual graft bone particles (average: 10.01% in porcine, 11.48% in bovine). However, this difference was not statistically significant. A minimal inflammatory component was noted in both groups. In the coronal sections of the biopsy samples, the graft
particles were surrounded by connective tissue composed of fibroblasts, collagen fibers, and blood vessels.

Discussion

The present study compared the clinical, radiographic, and histologic outcomes of HRA and ESP using bovine and porcine xenografts. These procedures are often performed to achieve adequate bone dimensions in order to facilitate implant placement in a prosthetically driven position. Analysis of the primary outcomes showed no significant clinical or histologic differences between the two xenografts at 6 months.

ESP has been shown to stabilize the coagulum within the socket and counteract the reduction of hard tissue volume.16 However, even after applying ESP techniques, a complete preservation of the preextraction ridge dimensions cannot be expected, as postextraction healing is characterized by significant contour changes due to osseous resorption, particularly in the horizontal plane.17 Likewise, the present study showed an average crestal ridge width loss of 4.98% and 7.93% in porcine and bovine ESP groups (Groups 4 and 3), respectively; these results are similar to ones reported in a randomized trial by Lai et al.18 However, an average ridge width loss of 41.6% has been shown in unassisted socket healing.19,20 In the present study, although both ESP groups showed comparable results, the differences between the baseline and 6-month dimensions showed statistical significance. The MinerOss XP group showed statistically significantly less dimensional change following ESP (0.13 ± 0.07 mm; Group 4) compared to the Cerabone group (0.5 ± 0.2 mm; Group 3).

In agreement with the literature,21–23 the present study indicated non-inferior results of porcine-derived xenografts as compared to DBBM and allogeneic bone substitutes. A few factors that determine the resorption process of xenogeneic grafts are the pore size, morphology, and percentage and the connection between pores and the granulometry.24,25 Porcine-derived bone grafts are noted to have a higher percentage of pore connectivity as compared to DBBM, and this is said to result in a greater degree of graft particle resorption.26 Porcine-derived xenografts have a similar structure to human bone and are biocompatible.27 The Ca/P ratio of MinerOss XP (1.63 to 1.66) is close to that of human bone (1.68 to

Fig 5  Representative histologic core sections from the (a) bovine and (b) porcine ESP groups. In Fig 5a, the blue arrows indicate graft material, and the red arrows indicate new bone formation.
The anorganic structure provides a natural scaffold and mechanical support to counteract the tissue changes. Additionally, BSE transmission could potentially be avoided by using porcine-derived xenografts.

The present study does have its share of limitations. Histologic assessment of HRA subjects in addition to ESP subjects would have provided a broader perspective on the amount of vital bone regenerated. Additionally, the absence of a negative control group, in whom unassisted socket healing could have been compared to the ESP groups, was a limitation of the present study. However, from prior literature, it is known that the average bone loss would have been much greater, and thus it was deemed unethical.

From an operator’s perspective, MinerOss XP was found to be more hydrophilic and showed a higher wettability than Cerabone, thus improving its handling characteristics. Higher wettability usually corresponds with better protein adsorption and cellular behavior. Furthermore, during the augmentation procedures, the texture of the porcine xenograft permitted denser packing of the biomaterial using gentle pressure.

Conclusions

The current findings suggest that statistically significantly lower dimensional changes were noted 6 months after ESP using a porcine-derived xenograft. Histologic analysis of the graft cores showed the presence of mature trabecular bone exhibiting osteocytes, and similar residual bone particles were found in both porcine and bovine groups. Based on the present results, the porcine-derived graft used herein is a biocompatible osteoconductive bone substitute and expands a clinician’s choice of bone graft in dental applications.

Acknowledgments

This study was supported with bone graft material (MinerOss XP and MemLok) by BioHorizons USA. The authors thank Dr Supriya Kheur for the histologic processing of samples.

References


