Immediate Augmentation of Compromised Extraction Sockets in Chronic Periodontitis Patients: 1-Year Results of a Case Series on Volumetric and Histologic Response

The present case series evaluated three-dimensional volumetric bone tissue changes and new bone formation in severely resorbed extraction sockets augmented with Bio-Oss collagen and a covering collagen membrane in nine chronic periodontitis patients. Healing was by secondary intention. After 12 months of healing, the augmentation procedure appeared not only to compensate for bone remodeling but also appeared to repair a significant portion of the buccal wall. The mineralized tissue filled the 91.49% ± 6.77% of the maximum volume for regeneration. Overall, a mean of 49.6% new bone, 27.1% residual graft material, and 23.3% connective tissue were detected. Int J Periodontics Restorative Dent 2019;39:245–251. doi: 10.11607/prd.3337

The three-dimensional (3D) bone resorption process following tooth extraction results in marked dimensional reduction of the alveolar bone, which may jeopardize prosthetically driven implant placement. There is significant evidence of the effectiveness of ridge-preservation treatment protocols in reducing the postoperative volumetric alteration of alveolar sockets with intact configuration, and buccal dehiscence/fenestration defects secondary to vertical root fracture or carious lesions. Scant information is available on the management of extraction sites with advanced bone loss as a consequence of severe periodontal lesions. In such anatomical conditions, augmentation procedures are required to restore appropriate ridge shape and dimensions. The placement of slowly resorbable bone grafting materials into damaged extraction sockets has been recommended.

Deproteinized bovine bone mineral (DBBM) has been successfully used both in the preservation of extraction sockets and in bone augmentation procedures. However, its slow resorption rate leads to very protracted or even no remodeling in the central part of the augmented sockets. As an alternative, a collagenous bovine bone matrix has been recently introduced (DBBM-C). The addition of porcine-derived collagen to the mineral...
matrix would seem to enhance cell adhesion and accelerate ingrowth, proliferation, and maturation of endothelial cells encouraging bone regeneration. However, data from the literature are controversial. A recent study demonstrated favorable ridge morphology for implant placement when buccal plate extraction socket defects were grafted with DBBM-C and recombinant human platelet-derived growth factor followed by coronal flap advancement to achieve primary closure.

In periodontally involved extraction sites, primary closure is often difficult to achieve because of the inadequate soft tissue volume. The placement of a resorbable collagen membrane, left partially exposed, in combination with DBBM-C to maintain space for bone regeneration may be a promising combination. Collagen barriers show proangiogenic qualities, semipermeability, and early wound stabilization.

Therefore, the aim of this case series was to evaluate the efficacy of an immediate ridge reconstruction procedure involving the use of DBBM-C and collagen membrane in the management of periodontitis-damaged alveolar sockets by using 3D volumetric cone beam computed tomography (CBCT) and histomorphometric data.

Materials and Methods

This case series study was conducted from March to July 2015. A total of 9 healthy subjects (5 males and 4 females, mean age 52.9 ± 9.6 years) were consecutively recruited from among generalized chronic periodontitis patients seeking care at the Section of Periodontology, C.I.R. Dental School of the University of Turin, Italy. The selected patients signed informed consent, previously approved by the Institutional Ethics Committee (protocol no. 695/2015).

All patients had been treated for severe periodontal disease and required extraction of at least one tooth in the maxillary or mandibular anterior region (incisors, canines, or premolars) as a consequence of advanced periodontal lesions. The discrepancy between the buccal and lingual walls of the periodontitis-damaged sockets had to be at least 35% on the basis of clinical examination and intraoral radiography. Subsequent implant therapy was planned for the extraction sites.

Patients with significant medical conditions and smokers were excluded. Hopeless teeth caused by trauma, endodontic failures, or prosthetic reasons were also excluded from the study.

Surgical Procedure

Following gentle tooth extraction, the alveolar socket was thoroughly curetted and the discrepancy between the buccal and lingual bone
was confirmed (Fig 1). After taking a CBCT scan of the unfilled socket, two vertical releasing incisions were made beyond the mucogingival junction. A buccal full-thickness flap was elevated and lingual tissues were undermined at least 10 mm beyond the alveolar crest margin. The socket was augmented by means of DBBM-C (BioOss Collagen, Geistlich Pharma) without heavy compaction to the most coronal bone peak level. A resorbable bilayer collagen membrane (Bio-Gide, Geistlich Pharma) was trimmed to cover the grafting material, placed in a double layer, and secured using pins approximately 3 mm over the bony walls. The flaps were relocated in their original position, leaving the central part of the membrane uncovered, and were secured by horizontal mattress sutures. A resin-bonded provisional pontic was used to replace anterior teeth, taking care to avoid any pressure on the underlying tissue.

**Maintenance Care Program**

All patients received antibiotics (amoxicillin and clavulanic acid 1 g to be taken 1 hour before and 12 hours after the surgical procedure) and analgesic medication (ibuprofen 600 mg, only if they experienced pain). Local plaque control was maintained by chlorhexidine 0.12% mouthrinse for 2 weeks. Sutures were removed at 2 weeks after surgery. Recall appointments were scheduled weekly during the first month and at 3-month intervals until the end of the study.

**Radiographic Volumetric and Linear Measurements**

CBCT scans (New Tom/NTVG; field of view = 153.3 mm width × 109.8 mm height; thickness = 0.3 mm; voxel size = 0.3 mm; voltage = 110 kV; 2 mA; 10 seconds) were taken immediately after tooth extraction and 12 months after socket augmentation. The patients were asked to wear a template of radiotransparent acrylic resin with aluminum radiopaque markers (high-precision balls, diameter 5 mm, Martin & C). The imaging procedure for 3D volumetric analysis was validated in a previous study. Briefly, all DICOM (Digital Imaging and Communications in Medicine) images were imported into Mimics 17.0 software (Mimics Innovation Suite), where bone and teeth were segmented by means of a mask creation tool, utilizing thresholds corresponding to their Hounsfield values. The 3D-rendered images of the volumetric reconstructions of the alveolar sockets were then generated and exported as STL files. The superimposition of the volumes of interest (VOI), corresponding to the alveolar sockets, was obtained by inserting reference points on the pre- and postoperative CBCT images that were appropriately realigned and fused. The middle and posterior reference points were identified according to Alsufyani et al. while the anterior landmarks were placed in the center of the aluminum spheres. By means of the rendering operation, it was possible to obtain the 3D volumetric reconstruction of the alveolar socket and to calculate its volume in mm³. The percentage of mineralized tissue at 12 months was determined in relation to the maximum volume for regeneration based on the preoperative height and width of the alveolar crest.

On the same CBCT images, linear measurements were made according to Jung et al. Three reference lines were drawn: a vertical line (parallel to the long axis of the socket, from the apex to the center of the sockets [C–C]) and two horizontal lines (perpendicular to line C–C, projecting from the most coronal portion and the most apical point of the alveolar socket). The following measurements were recorded at baseline and at 12 months with respect to these reference lines: thickness of the vestibular bone plate (VBP) at 1 mm, 3 mm, and 5 mm below the lingual bone crest (VBP-1, VBP-3, VBP-5) (only at baseline); height of the socket at the mid-vestibular (HV) and mid-lingual (HL) aspect; and horizontal ridge width at 1 mm, 3 mm, and 5 mm below the most coronal aspect of the crest (HW-1, HW-3, HW-5).

An experienced engineer made the measurements. In order to assess the intra-examiner reproducibility, five cases were randomly re-analyzed on two different occasions. The duplicate measurements differed by < 5%.

**Histologic Analysis**

Bone biopsy specimens were obtained from the center of prior extraction sockets at the time of implant placement by means of a
The sections were stained with toluidine blue/pyronine G (Sigma–Aldrich) and observed using a Nikon light microscope (Eclipse E600) equipped with a calibrated digital camera (DXM1200, Nikon).

Histomorphometric measurements were performed at ×10 magnification using a stereological method.

Statistical Analysis

Data were expressed as mean ± SD. Changes of radiographic parameters over the experimental period were analyzed with Student paired t test. Statistical analyses were conducted using SPSS version 24.0 for Mac (IBM). P < .05 was considered statistically significant.

Results

Radiographic Measurements

All patients underwent a single tooth extraction and completed the 1-year observation period. Most of the hopeless teeth were in the maxilla (77.8%), 55.6% were incisors, and 44.4% premolars.

Table 1 presents radiographic parameters over the experimental period. At baseline, six out of the nine alveolar sockets displayed complete loss of the buccal bone wall at the –3-mm level, and three sockets at the –5-mm level. No healing complications were noted in any of the treated sites.

At 12 months posttreatment, the augmentation procedure was effective in preserving the vertical height at the lingual crest (HL), and in achieving a vertical reconstruction of the buccal wall (HV) in all treated sockets with a gain of 2.91 ± 1.08 mm (P < .001). A statistically significant horizontal shrinkage of –2.57 ± 1.32 mm was evident at the 1-mm level (HW-1), whereas a small increase in the horizontal width of 0.30 ± 0.96 mm was observed in the apical region (HW-5). At this time point, the mineralized tissue filled the 91.49% ± 6.77% of the possible volume for regeneration (P = .010). This bone volume deficiency of 8.51% was within the 3-mm crestal zone of the buccal wall.

All treated sites allowed the placement of implants (3.5 mm to 4 mm in width) without further bone regenerative therapy. At the time of flap elevation, a bone-like tissue was depicted into the augmented sites. All implants were stable after placement (Fig 2). Representative images of 3D-rendered CBCT volumes from extraction sites at baseline and 12 months are shown in Fig 3.

Histomorphometric Measurements

After 12 months of healing, the grafted particles were still present without any inflammatory infiltrate (Fig 4). At higher magnification, lamellar bone tissue appeared organized in trabeculae, the biomaterial was well integrated with woven bone, and blood vessels were evident in the marrow spaces. Woven bone occupied 20.8% ± 10.8% of the area, lamellar bone 28.8% ± 7.7%, connective tissue 23.3% ± 13.7%, and Bio-Oss 27.1% ± 11.6%.

Table 1  Linear and Volumetric Parameters (Mean ± SD) at Baseline and 12 Months After the Augmentation Procedure Based on CBCT Imaging

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Baseline</th>
<th>12 months</th>
<th>Difference</th>
<th>P value</th>
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<tbody>
<tr>
<td>VBP-1 (mm)</td>
<td>0</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>VBP-3 (mm)</td>
<td>0.25 ± 0.39</td>
<td>–</td>
<td>–</td>
<td>–</td>
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<tr>
<td>VBP-5 (mm)</td>
<td>0.67 ± 0.48</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>HW-1 (mm)</td>
<td>8.20 ± 1.03</td>
<td>5.63 ± 1.13</td>
<td>–2.57 ± 1.32</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>HW-3 (mm)</td>
<td>7.76 ± 0.62</td>
<td>6.88 ± 1.14</td>
<td>–0.88 ± 0.89</td>
<td>.021</td>
</tr>
<tr>
<td>HW-5 (mm)</td>
<td>6.94 ± 0.90</td>
<td>7.24 ± 1.45</td>
<td>0.30 ± 0.96</td>
<td>.227</td>
</tr>
<tr>
<td>HV (mm)</td>
<td>2.52 ± 1.88</td>
<td>5.44 ± 1.43</td>
<td>–2.91 ± 1.08</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>HL (mm)</td>
<td>6.79 ± 1.38</td>
<td>7.30 ± 1.22</td>
<td>0.51 ± 1.41</td>
<td>.306</td>
</tr>
<tr>
<td>Volume (mm³)</td>
<td>219.16 ± 87.09</td>
<td>199.41 ± 81.79</td>
<td>–19.75 ± 18.85</td>
<td>.010</td>
</tr>
</tbody>
</table>

Positive values = gain of tissue; negative values = loss of tissue; SD = standard deviation; VBP = thickness of vestibular wall (at 1, 3, and 5 mm from the top of the crest); HW = horizontal width (at 1, 3, and 5 mm from the top of the crest); HV = mid-buccal height; HL = mid-lingual height.

*These parameters were recorded only at baseline.
Discussion

This study was designed to verify the effectiveness of an immediate reconstructive procedure in severely periodontitis-damaged sockets by means of a 3D analysis of radiographic and histologic 12-month healing. Preoperative and postoperative CBCT scans were digitally superimposed and analyzed, thus allowing accurate estimations of the volume and contour modifications by using Mimics software.20

Twelve months after extractions, grafted sockets exhibited a mean vertical increase of buccal bone plate of 2.91 ± 1.08 mm along with a mean horizontal width change of −2.57 ± 1.32 mm in the cervical area. Comparable results were obtained in studies on socket preservation procedures with horizontal bone loss from 1.2 to 3.5 mm2,3 when clinically measured, and from 1.4 to 2.1 mm on CBCT imaging2,3,21-23

Limited information is available on volumetric bone changes. Previous volumetric studies on CBCT imaging showed at 6 months a reduction in volume of 9.9% and 23.8% for intact extraction sites24 and dehiscence sockets,25 respectively, using bovine-derived xenograft covered with porcine collagen barrier24 or resorbable poli-L-lactide device.25 In the current study, the mineralized alveolar tissue filled the
91.49% ± 6.77% of the possible volume for bone regeneration based on baseline size of the defects and allowed implant placement without further bone regenerative therapy.

The use of a slowly resorbable grafting material covered by a secured resorbable membrane may explain these favorable outcomes.\(^6,26,27\)

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The healing was by secondary intention. The early stabilization of blood clot and graft particles was guaranteed by the flap design without peristomal incisions as well as by the collagen membrane applied in double layers over the damaged socket and secured with pins.

Mixed data are available on the rates of resorption of DBBM-C and new bone formation in humans. Some authors reported small amounts of newly formed bone in four-wall sockets after 3 to 7 months.\(^8,28\) Nevins et al found comparable results in compromised sockets.\(^13\) Conversely, Alkan et al observed remaining Bio-Oss particles mainly in the coronal area of intact sockets at the 3-month evaluation.\(^29\)

The present data showed a mean of 27% residual graft particles and 49% new vital bone at 12 months. A process of osseointegration was evident in all biopsies, and woven bone was observed surrounding grafts, with bridges of newly formed bone between xenograft particles. In a review article of ridge preservation studies, the amount of newly formed bone ranged between 18% and 64% and the residual DBBM particles between 20% and 30% at 6 to 9 months.\(^26\) Conversely, Fugazzotto observed the almost complete resorption of the graft material after 12 to 13 months of healing.\(^30\)

Conclusions

The placement into periodontitis-damaged extraction sockets of a slowly resorbable xenograft with a secured covering collagen mem-

Fig 4  Microphotographs from two Bio-Oss Collagen grafted sockets: histologic view after 12 months of healing (×100 magnification, left) and higher magnification (×200) of selected sites (right). Grafted particles (in dark brown) appeared surrounded by new woven bone, and the interface between biomaterial and new bone matrix was closed. Osteoid matrix, woven bone, and lamellar bone are stained with different shades of blue. Toluidine Blue and Pyronine Y staining.
brane, even with open healing, reduces the degree of ridge contraction, ultimately achieving comparable results to those obtained with conventional ridge preservation techniques in intact sockets. Further studies with higher patient numbers and long-term follow-ups are needed to validate this procedure.

Acknowledgments

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References