Alveolar Ridge Preservation on Maxillary Molars Using Solvent Dehydrated Bone Allograft and d-PTFE Membrane: A CBCT and Histologic Human Pilot Study

Hachimia Fahes, DDS1
Carole Chakar, DDS, MSc, PhD1
Nabil Ghosn, DDS, MScD2
Nadim Mokbel, DDS, MSc, PhD1

The purpose of this study was to evaluate vertical and horizontal alveolar resorption after the extraction of eight single maxillary molars using solvent-dehydrated bone allograft (Puros) covered with a nonresorbable membrane for ridge preservation. At implant placement 4 months later, ridge dimensions were measured clinically and radiographically and compared to baseline, and a histologic analysis was performed. The mean buccal height decreased by 1.51 mm at midpoint, 0.88 mm mesially, and 1.16 mm distally. The implants were placed without additional ridge augmentation, and six of eight required an internal sinus elevation. Within the limits of this study, this technique succeeded in preserving the alveolar bone. Int J Periodontics Restorative Dent 2021;41:e27–e35. doi: 10.11607/prd.4632

The loss of a single molar is regarded as a common cause of a nonphysiologic occlusion resulting from the tipping of neighboring teeth and the extrusion of opposing teeth. In addition, the buccal bone plate height reduction is greater in the molar region (−13.11%) compared to anterior sites (−5.5%). Sinus pneumatization (1.04 ± 0.67 mm) has also been observed after extraction of a maxillary molar. In order to minimize this resorption, alveolar ridge preservation (ARP) has been introduced, with solid evidence from several systematic review supporting its effectiveness. Solvent-dehydrated bone allograft (SDBA) is a mineralized allograft product aiming to preserve the collagen matrix, porosity, trabecular pattern, and mineral composition of the original bone. The high-density cross-linked polytetrafluoroethylene (d-PTFE) membrane has many advantages, including blockage of bacteria due to its low porosity (2 µm), its ability to remain exposed, conservation of keratinized gingiva, and easy removal. In the present pilot study, SDBA + d-PTFE membrane was selected as the ARP technique after extraction of a single maxillary molar. To the present authors’ knowledge, this is the first study that focuses on this technique. The aim is to evaluate the horizontal and vertical resorp-

1Department of Periodontology, Faculty of Dental Medicine, Saint Joseph University, Beirut, Lebanon.
2Department of Oral and Maxillo-Facial Radiology, Saint Joseph University, Beirut, Lebanon.

Correspondence to: Dr Hachimia Fahes, Abdallah Hajj Street, Ghobeiry 1002, Baabda, Lebanon. Email: hachimia.fahes@net.usj.edu.lb

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tion (clinically and radiographically) after ARP (T1, baseline), implant feasibility, the need for further augmentation, and the 4-month (T2) histomorphometric analysis results.

Materials and Methods

This study was designed as a pilot prospective study. Ethics approval was obtained from the Saint Joseph University Ethics Committee (USJ-2017-90). Seven patients with nine maxillary molars were recruited from the Department of Periodontology. After ARP, one patient dropped out. Thus, a total of eight molars were extracted.

The following inclusion criteria were applied: (1) ≥ 18 years of age; (2) no systemic or local conditions presenting a contraindication to extraction and implant placement; (3) patient requiring extraction of one maxillary molar with subsequent implant placement; (4) postextraction residual ridge height (from the ridge crest to the inferior border of maxillary sinus) ranging between 4 and 8 mm, measured on retroalveolar radiographs; (5) no pathologic conditions of the maxillary sinus; and (6) good oral hygiene (Plaque Index < 20%) and absence of active periodontitis.

The following exclusion criteria were applied: (1) presence of systemic disease (uncontrolled diabetes) or bone metabolic disorder; (2) history of malignancy, radiotherapy, or chemotherapy in the past 5 years; (3) smoking > 10 cigarettes/day; (4) women who were pregnant or lactating; (5) allergy to the materials to be used; and (6) alcoholism or drug addiction. Clinical and radiographic vertical ridge changes were the primary outcome measures. Secondary outcomes were the clinical and radiographic horizontal ridge changes and the percentage of mineralized tissue, analyzed histomorphometrically.

Treatment Procedure

At patient screening, supragingival scaling and root planing were performed. Extractions were performed atraumatically using mainly periottes, rarely with elevators. All molars were separated before extraction with a Zekrya surgical bur. The socket was debrided to remove granulation tissue. An individualized stent was fabricated for each patient with a fixed occlusal position. During the 4-month study period, no treatment affecting the occlusion was allowed. The stent included two metallic wires extending mesially and distally to the extracted molar (Fig 1). The bone graft used was a corticocancellous SDBA (Puros, RTI Biologics) with a particles size of 0.25 to 1.0 mm. The bone substitute was packed and compressed into the socket after rehydration, and a d-PTFE membrane (Cytoplast TXT-200 singles, Osteogenics Biomedical) was applied to cover the grafted site via minimal tunneling (< 3 mm). A hidden-X suture was utilized to stabilize the membrane with a resorbable poly(glycolide-co-L-lactide) braided suture (Novosyn, B. Braun; Fig 2). No primary closure was intended. Antibiotics (1 g amoxicillin twice daily for 1 week) and analgesics (50 mg diclofenac potassium twice daily for 3 to 5 days) were prescribed. Subjects were instructed to rinse twice daily for 1 minute with 0.12% chlorhexidine digluconate. Sutures were removed 10 to 14 days after surgery. All subjects were recalled at 6 weeks for membrane removal and at 3 months for wound-healing evaluation and professional supragingival plaque control.

The implant (NobelReplace CC, Nobel Biocare) was placed at
4 months postsurgery (T2). Before starting the drilling sequence, one bone core biopsy sample was taken from each patient (n = 6) at the middle of the extraction site using a trephine bur (Hager & Meisinger) for histologic analysis, with 2.5-mm and 3.5-mm diameters (internal and external, respectively), extending to a depth of 4 to 5 mm. Subsequently, the sites were finalized using the standard implant preparation protocol suggested by the implant manufacturer. When needed, an internal sinus elevation was performed with angled and tapered osteotomes. The implants were then placed at the middle of the preserved sites, in partly native and partly regenerated bone, and the flaps were sutured. The same postoperative medication was prescribed.

Clinical measurements included: (1) the buccal bone plate thickness at T1 (day of extraction and socket preservation), measured with a caliper; (2) the distance from the metallic wire...
to the most coronal point midbuccally, midpalatally, mesially, and distally at T1 and T2 (4 months after ARP, at implant placement), measured with a periodontal probe (UNC 15, Hu-Friedy); (3) the socket width (buccal to palatal aspects) at T1 and T2; and (4) the amount of internal sinus elevation at T2.

Radiographic Measurements

Patients were scanned with a VGi CBCT machine (NewTom). Scan data were saved in DICOM (Digital Imaging and Communications in Medicine) format, and reorientation of images were performed using NNT Workstation software (version 5.6, QR). For each patient, the pre- and postoperative DICOM images were imported and loaded simultaneously into the ITK-SSNAp software (version 3.6.0). The two CBCT scans were then aligned using the manual and automatic registration modules. The software allowed a direct comparison of the 2D sections between T1 and T2 while maintaining the same alignment.

Bone Width

Buccal bone width measurements were taken at three levels on the vestibulopalatal section of each site, maintaining the parallelism with the occlusal and mesiodistal reference planes as follows (Fig 3):

- $W_0T1/2$: bone width at T1 and T2 at the crest level
- $W_3T1/2$: bone width at T1 and T2, 3 mm apical to the postoperative crest level
- $W_6T1/2$: bone width at T1 and T2, 6 mm apical to the postoperative crest level

Bone Height

Buccal and palatal vertical bone height measurements were taken at three points (middle, mesial, and distal) on the vestibulopalatal section of each site. For first molar sites, the section between the mesial surface of the second molar and distal surface of the second premolar was chosen as the main (middle) section. The mesial and distal sections were chosen 4 mm from the main section. For second molar sites, the main (middle) section was chosen at 5 mm from the distal surface of the first molar, and the mesial and distal sections 4 mm from the main section. For each section, the most coronal point of the sinus floor was located, and a line parallel to the horizontal plane was drawn in order to determine the apical measurement point; the line was labeled “SF.” The most coronal point of the buccal/palatal plate was located, and the measurements were taken perpendicular to horizontal plane at the SF level (Fig 3):

- $BHT1/2$ and $PHT1/2$: midpoint buccal and palatal heights at T1 and T2, respectively

![Fig 3 Slice section of a CBCT scan taken at 4 months. (a) $BHT2$ and $PHT2$ represent the height of the buccal and the palatal bone plate, respectively, taken at the midpoint. $SF$ represents the most coronal point of the sinus floor. (b) $W0T2$, $W3T2$, and $W6T2$ represent the horizontal width of the extraction socket at the crest and at 3 and 6 mm apical to the crest, respectively.](image)
mBHT1/2 and mPHT1/2: 4 mm mesial to the midpoint at T1 and T2, respectively

• dBHT1/2 and dPHT1/2: 4 mm distal to the midpoint at T1 and T2, respectively

Histomorphometric Analysis

The biopsy samples were removed from the trephines and immediately stored in 10% formalin. The specimens were dehydrated in a graded series of alcohol rinses (24 hours each in 70%, 95%, and 100% alcohol, respectively) and xylene, then embedded in a methyl-methacrylate resin (with benzoyl peroxide and dibutyl phthalate) for several days until solidification. After polymerization, the specimens were sectioned with a microtome along their longitudinal axis; 80-µm sections were obtained. After polishing, sections were stained with Giemsa (methylene blue, eosin, and Azure B) and Paragon (fuchsin and toluidine blue). The slides were examined using a microscope (BX43F, Olympus) equipped with a digital video camera (U-LH100HG, Olympus). Areas of mineralized and fibrous tissue were measured using an imaging program (Fiji, ImageJ, National Institutes of Health) by calculating the total number of pixels per component and the total number of pixels in the total surface.17 Vital bone is defined by visualization of osteocytes within lacunae of mineralized tissue; residual graft as lamellar mineralized tissue with empty lacunae; and connective tissue as the absence of the above categories and the presence of fibrous tissue (Fig 4).

Statistical Analysis

SPSS for Windows (version 25.0, IBM) was used for statistical analyses of the data. The level of significance was set at $P < .05$. The normality distribution of continuous variables was assessed with Shapiro-Wilk tests. Parametric tests were performed for variables normally distributed. Nonparametric tests were performed when variables were not normally distributed. Wilcoxon and paired Student t tests were performed to compare continuity within time points (T1 and T2), and the mean variation within time for each clinical and radiologic measurement was obtained. Repeated measure analysis of variance or Friedman test were calculated for statistical significance within bone levels.

Results

Six patients (4 men and 2 women) aged 52.33 ± 7.89 years (range: 39 to 60 years) were included in the study. Eight implants were placed in first or second molar sites. The reason for extraction was caries (87.5%) or periodontal disease (12.5%).

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This study revealed a significant decrease in mean clinical crest width from T1 to T2 (0.88 mm; \( P = .008 \)). The mean stent distance significantly increased by 2.13 mm on the buccal aspect (\( P = .041 \)), by 1.38 mm on the palatal aspect (\( P = .026 \)), by 1.38 mm on the mesial aspect (\( P = .017 \)), and by 2.62 mm on the distal aspect (\( P = .011 \); Table 1). The variation was greatest on the distal side; no significant difference was found within levels (\( P = .412 \)).

Radiographically, the W0T1/2 decreased significantly by 2.35 (\( P = .012 \)). It also decreased significantly by 1.25 mm at 3 mm apically (\( P = .012 \)) and by 0.46 mm at 6 mm apically (\( P = .043 \)). The variation was significantly greater at the crest, intermediate at 3 mm apically, and lower at 6 mm apically (\( P = .036 \); Table 2).

The mean BHT1/2 decreased significantly over time (by 1.69 mm; \( P = .001 \)), as did dBHT1/2 (by 1.16 mm; \( P = .006 \)) values (Table 3).

The mean PHT1/2 decreased significantly over time (by 1.69 mm; \( P = .001 \)), as did dBHT1/2 (by 1.39 mm; \( P = .002 \)). The difference between mPHT1 and mPHT2 was not significant (\( P = .222 \); Table 4). The mean variation of measurement at T2 was not significantly different between palatal and buccal height (\( P > .05 \)).

In the six biopsy samples obtained, the connective tissue comprised a mean ± SD of 35.47% ± 15.39% of the sample, and the mean mineralized tissue was 64.53% ± 15.39% (Table 5).
Discussion

The present study compared CBCT measurements of the ridge width and height after ARP (T1) and at implant placement after 4 months (T2). A flapless technique was chosen, as it was mentioned more favorably in a recent systematic review. In the present study, the mean buccal plate thickness at the crest level was 0.8 ± 0.46 mm, and a thin buccal wall is associated with higher alveolar bone resorption even after ARP. Radiographically, it was found that W0T1/2 was the most affected (2.35-mm decrease). The resorption at 3 and 6 mm apical to the crest level was less pronounced (1.25-mm and 0.46-mm decreases, respectively). These results are in agreement with a randomized controlled clinical trial (RCT) where width variations decreased from the coronal to apical level. Another study found that initially damaged sockets have width resorption of 2.3 mm at 1 mm below the ridge crest compared to 3.9 mm for unassisted sockets (P = .021).

In the present study, the radiographic buccal height variation was –1.51 mm, –0.88 mm, and –1.16 mm at the midpoint, mesially, and distally, respectively. These findings are in agreement with a recent RCT: Maxillary and mandibular molars were preserved with freeze-dried bone allograft (FDBA) and d-PTFE, and the buccal plate resorption at the midpoint was 1.12 ± 1.60 mm, 1.11 ± 1.69 mm mesially, and 1.01 ± 1.85 mm distally. The control group showed a variation of –2.60 ± 2.06 mm at the midpoint, –3.01 ± 2.24 mm mesially, and –2.33 ± 1.72 mm distally, with statistically significant differences between the two groups. These findings suggest that ARP might have transformed the resorption into a more homogeneous bone loss rather than being accentuated buccally when unassisted.

All implants were placed successfully without the need for horizontal augmentation. Additionally, none of the sites needed an external sinus elevation, and two of eight sites did not need an internal sinus elevation. Of the present study sample, sinus pneumatization seems to be limited. This is in agreement with Lombardi et al., who found a mean 6-month sinus pneumatization of 0.69 ± 0.48 mm in the test group (synthetic nanohydroxyapatite and a collagen barrier) and 1.04 ± 0.67 mm in the control unassisted group (P = .15). Sinus pneumatization was also reduced after ARP in a study by Levi et al. The procedure was performed with demineralized bovine bone xenograft on maxillary second premolar and first and second molar sites. The mean change in the distance from the bone crest to the sinus floor was 0.32 mm in the study group and 1.26 mm in the control group (P < .0019). Regarding the present histomorphometric results, an average percentage of 64.53% was found for mineralized tissue and 35.47% for connective tissue. The mineralized tissue includes the newly formed bone and the residual graft. These two entities were hardly differentiated, due to the lack of advanced technologies and the sections’ thickness. Beck and Mealey compared the histologic measurements of the same SDBA at 3 and 6 months used in the present study and found 60.4% and 58.5%, respectively, of mineralized tissue, as well as 39.6% and 41.3%, respectively, of connective tissue. No statistical significance was found between the two timings. It is suggested that implant placement may be possible after 3 months of ARP.

Immediate implant placement is one procedure used to augment the posterior maxilla. Liu et al compared immediate implant placement with simultaneous transalveolar sinus elevation to delayed implantation with transalveolar sinus elevation with 1-year follow-up. After 1 year of loading, no statistically significant difference (P > .05) in vertical or horizontal changes were identified in the test group nor control group. Of the included molars, the height of the alveolar ridge to maxillary sinus was < 7 mm, or the

### Table 5 Mean Histomorphometric Measurements

<table>
<thead>
<tr>
<th>Tissue</th>
<th>n</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connective tissue</td>
<td>6</td>
<td>22.66%</td>
<td>62.74%</td>
<td>35.4667%</td>
<td>15.39305%</td>
</tr>
<tr>
<td>Mineralized tissue</td>
<td>6</td>
<td>37.26%</td>
<td>77.34%</td>
<td>64.5333%</td>
<td>15.39305%</td>
</tr>
</tbody>
</table>

One biopsy sample was taken per patient.
bone height from the septum to the maxillary sinus was > 4 mm. Another study by Checchi et al.\textsuperscript{\textregistered} suggested that immediate placement of 6.0- to 8.0-mm–diameter implants in molar extraction sockets yielded inferior esthetic outcomes (in terms of the Pink Esthetic Score) after 1 year of follow-up than results from ridge preservation with delayed placement of conventional 4.0- to 5.0-mm–diameter implants.

In the present study, no CBCT was taken prior to extraction in order to visualize the interradicular septa, and all roots appeared convergent on the preliminary radiograph. Otherwise, the advantages of the ARP technique with delayed implants include: implant placement in vital bone and in an ideal, prosthetically driven position; easily obtaining great primary stability; a decreased risk of membrane perforation; and no expectation of buccal long-term resorption. Long-term RCTs are required to prove the efficacy of immediate implantation in these cases of residual bone height 4 to 8 mm below the sinus.

**Conclusions**

The mean residual bone height at T2 was 7.33 mm buccally and 6.3 mm palatally, compared to 8 mm at T1. At T2, the mean W0T2 was 8.52 mm and W3T2 was 11.75 mm, compared to 10.87 mm and 13 mm at T1, respectively. These alveolar dimensions obtained at T2 allow the placement of relatively large implants in vital bone with minimal internal sinus elevation. Case selection is very important for the replacement of maxillary posterior teeth. A thorough examination of initial bone loss, buccal plate thickness, sinus floor curvature, level of root protrusion into the sinus, interradicular septa, bone level of adjacent teeth, and residual height under the sinus seem to be preliminary predictors of bone loss. These key factors will lead the clinician to choose an adequate procedure: unassisted socket, ARP, or immediate implant placement with simultaneous internal sinus elevation and grafting.

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**References**


