Changes in Alveolar Bone Width Following Immediate Implant and Fresh Socket Preservation with Xenogeneic Gap-Filling Material Versus Guided Tissue Healing with Anatomical Tooth-Shaped Caps: A 3-Year Retrospective Case-Control Study

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This study aimed to calculate the 3-year dimensional change in crestal bone width when dental implants placed in postextraction sockets underwent two alternative techniques for alveolar preservation. Fresh sockets that had undergone immediate implant placement were categorized into one of two groups depending on the procedure type. For the xenogeneic biomaterial grafted (BG) group, the gaps between the metallic implant surfaces and the bony walls were filled with corticocancellous porcine bone; in the anatomical cap group, in which patients were treated with guided tissue healing (GTH), cross-linkable acrylic resin caps were immediately screwed on the implants. Absolute measurements of the alveolar width were performed on 3D images acquired before tooth extraction (thereby ensuring correct surgical treatment) and 3 years after surgery. Nonparametric statistics were performed, with the level of significance set at 1%. The results of 46 implants (placed in 36 patients) were analyzed, and 100% survival rates were reported for both groups at 3 years postsurgery. Minor swelling of treated areas was observed the first few days of healing, but neither mucositisides, dehiscence events, nor suppurations occurred. At 3 years postsurgery, loss in alveolar ridge width was higher for the BG group (–1.1 ± 0.6 mm) than for the GTH group (0.0 ± 0.3 mm); moreover, these changes were significantly different (P < .0001). This clinical and radiographic data analysis suggests that the implant sites that received a xenogeneic filling material were less effective in maintaining the preoperative alveolar bone width than sites that underwent GTH with immediate implants and anatomical tooth-shaped caps.


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packed into the bone-implant gap vs guided tissue healing (GTH) with tooth-shaped caps.

Materials and Methods

Patient Selection

The present retrospective analysis followed the Declaration of Helsinki and was approved by the Regional Ethical Review Board of the University of Pisa. Subjects were gathered from a pool of treated consecutive patients who underwent implant-supported rehabilitation at the Tuscan Stomatologic Institute between February 2017 and January 2018 and were then surveyed at the Department of Oral and Maxillofacial Surgery of the University of Pisa.

Patients were included if they met any of the following criteria: (1) needing maxillary anterior tooth extraction (second premolar to second premolar) due to root fracture, decay, endodontic lesion, or periodontal disease; (2) having intact alveolar bony walls after the extraction; (3) radiographic report of 4 mm of bone beyond the apex; (4) placement of an immediate implant in the postextraction socket; (5) subsequent placement of an implant-supported rehabilitation; (6) receiving either GTH treatment with anatomical tooth-shaped caps or socket preservation using a xenogeneic bone substitute compressed and firmly packed into the gap between the metallic surface and the innermost walls of the socket; and (7) preoperative (before tooth extraction thereby ensuring correct surgical treatment) and postoperative (36 months postsurgery) CBCT scans.

Subjects were excluded if they met any of the following criteria: (1) having a previous history of infections, dehiscences, or fenestrations in surgically treated areas; (2) heavy smoking habit (≥ 10 cigarettes/day); (3) report of excessive alcohol or drug use; (4) oral bruxism and/or parafunctional habits; (5) report of chronic systemic diseases.

All included patients signed a written informed consent form for the present analysis. One surgeon (U.C.) and one prosthodontist (R.C.) performed all surgeries and prosthetic treatments. Patient data were anonymized.

Surgical Procedure

Before surgery, 1 g amoxicillin was administered to each patient, followed by 1 g twice daily for 7 days. Local anesthesia was attained by injecting optocaine (20 mg/mL) with epinephrine (1:100,000). The maxillary tooth was extracted, attempting to preserve the socket as much as possible (no flap elevation) through the use of an electromagnetic device (Magnetic Mallet, Osseotouch). Before implant placement, the integrity of each socket was verified with a periodontal probe (PGF/GFS, Hu-Friedy). Immediate implants (Heredity, Kalodon) were positioned following the manufacturer’s advice. A surgical implant bed (extending at least 4 mm beyond the root apex) might ensure adequate primary stability. All implants were the same brand and had a progressive thread design, smooth 0.5-mm neck, and external hex. The implant platform was generally equicrestal in its facial aspect.

In the biomaterial grafting (BG) group, the gaps between the metallic implant surface and the innermost bone walls of the socket were filled with corticocancellous porcine bone (Gen-Os, OsteoBiol Tecnos). The bone substitute underwent careful preoperative hydration before insertion into the gap; once soaked in blood and after a gentle compression, the material could fill the space. Then, a collagen sheet (Condress, Abiogen Pharma) was used to fully cover the socket and blood clots and was secured with silk sutures (Fig 1).

In GTH group with preformed anatomical caps (made with one-package, cross-linkable acrylic resin; GTH, Kalodon), the caps were screwed on the implants after surgery, avoiding biomaterial between the implant surface and alveolar walls (Fig 2). The healing caps should mimic the natural tooth being replaced as much as possible. For each patient, the caps were modified by an additive procedure to imitate or copy the form and appearance of natural extracted teeth, and to sustain the unsupported mucosa of the extraction socket. Fresh photo-polymerizing resin material could be stuck to the preformed cap when it was smaller than the fresh extraction socket; after adaptation to the gingival margin, the material was cured and polished with a rubber wheel. When caps were too large, an inverted cone bur (Integra Miltex) was employed to
discard excess material, provide a buccal orientation, and accomplish slightly rounded circumferential margins. Finally, the cap was torqued following the manufacturer’s recommendations (Fig 2). Sutures were removed 5 to 7 days after surgery.

Prosthetic Procedure

After 2 months, new implant-impression coping was used to correctly identify the emergence profile. The master cast was made according to the functional impression and the restorative treatment plan. Appropriate final restoration (cemented or screwed) was fabricated 4 months after placement (Fig 1).

Radiographic Examination

Preoperative and postoperative 3D radiographic scans (GXCB-500, Gendex) were acquired using the same setting for each scan: 120 kV, 0.0031 amp-second, 0.008 mm³ isotropic voxels, 8.72-cm field of view, and a resolution of 125 voxels/mm³. Before linear measurements, the data were modified as per Crespi et al.¹⁶

Computed tomography cross-sections were acquired, and the coronal portions of the implants were reviewed. Alveolar width (AW) was determined using a fused cross-sectional image parallel to the implant, measured 1 mm below the implant neck platform as the length between the most protruding facial point to the most palatal one (Fig 3). The buccal gap between buccal bone and implant surface was measured in the same fused cross-sectional image in the same direction as the line measuring AW (Fig 3).

The change in width was given by the equation:

\[ \text{AW}_{\text{bsl}+\text{y}} = \text{AW}_{\text{y}} - \text{AW}_{\text{bsl}} \]

where \( \text{AW}_{\text{bsl}} \) and \( \text{AW}_{\text{y}} \) were the AW at baseline (preoperative) and 3 years postsurgery, respectively.

Statistical Analysis

A matrix laboratory performed all the statistics (Statistics Toolbox, MatLab 7.11, The MathWorks). Neither
Gaussian distribution nor homoscedasticity was verified within and among groups. The null hypothesis was that there would be no differences (H0) between the GTH group and the BG group. Friedman test was employed as a nonparametric analysis of variance test. To compare the differences between follow-up times (matched data), paired comparisons were performed by Wilcoxon signed-rank test. The unmatched data (between procedures) were compared by Wilcoxon rank-sum test. Outcome description and dispersion used means ± standard deviations (up to the first decimal place). The level of significance was set at .01.

Results

Patients were retrospectively selected without any randomization process and placed into one of two groups (GTH group or BG group) based on the surgical treatment they received. A single tooth per patient was randomly selected in a way that
made further subgroups statistically independent. A total of 40 patients (26 women, 14 men) with an average age of 50.3 ± 7.3 years (range: 36 to 65 years) were initially selected; 4 women were excluded due to CBCT data corruption. Out of the remaining 36 patients, 8 smoked < 10 cigarettes/day (4 women, 4 men). Of the 46 extracted maxillary teeth (Table 1), 42 underwent single intercalate extraction with healthy neighboring dentition. None of the case sheets reported any bone defect surrounding the extraction socket. In the GTH group, 28 healing caps were immediately placed on implants. In the BG group, the gaps between the metal surface and the bony wall of the 18 immediate implants were filled with a corticocancellous porcine bone substitute (Table 1 and Fig 1).

### Surgical and Prosthetic Procedures

At the 3-year follow-up, both groups had a 100% survival rate. Minor swelling of the healing sites was observed during same-day surgery, without mucositis or flap dehiscences. Four months later, either a screw- or cement-retained definitive metal-ceramic crown was secured to the implant. During the entire study period (3 years), no pain or prosthetic movement was reported. Definitive prosthetic contours were designed to mimic the shape of natural teeth, allowing an emergence profile that was as predictable as possible.

### Radiographic Evaluation

Patient gender and the implant site (ie, incisor, canine, or premolar) was checked to test the influence of these confounding factors on the AW change between GTH and BD groups. Friedman test revealed no significant influences on the changes between genders and among implant sites (Table 2).

Short-term GTH data suggested that there was no alveolar crestal width reduction. Both the

| Table 1 Descriptive Characteristics of Patients and Extraction Sites at Baseline |
|---------------------------------|--------|--------|
|                                 | GTH    | BG     |
| Size, n                         |        |        |
| Implants                        | 28     | 18     |
| Patients                        | 18     | 18     |
| Gender (F/M), n                 |        |        |
| Female                          | 11     | 12     |
| Male                            | 7      | 6      |
| Smoking habit, n                |        |        |
| Yes                             | 5      | 3      |
| No                              | 13     | 15     |
| Age, y                          |        |        |
| Mean ± SD                       | 49.5 ± 7.3 | 51.1 ± 8.0 |
| Range                           | 37.2–64.6 | 34.7–64.9 |
| Buccal gap, mm                  |        |        |
| Mean ± SD                       | 0.9 ± 0.9 | 0.7 ± 0.9 |
| Range                           | 0.0–3.1 | 0.0–2.7 |

BG = biomaterial grafting; GTH = guided tissue healing.

Wilcoxon rank-sum test for independent samples was used to compare buccal gaps between groups, resulting in a value of 0.4440.
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Table 2 Alveolar Width at Baseline and 3 Years with Related Changes for Both Groups

<table>
<thead>
<tr>
<th>GTH</th>
<th>Size, n</th>
<th>AW_{bsl}, mm</th>
<th>AW_{3y}, mm</th>
<th>AW_{bsl} vs AW_{3y}</th>
<th>AW_{bsl+3y}, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients (n = 18)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall sites</td>
<td>18</td>
<td>8.3 ± 1.4</td>
<td>8.3 ± 1.3</td>
<td>0.1193&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.0 ± 0.3</td>
</tr>
<tr>
<td>Shapiro-Wilk test (P)</td>
<td>.1837&lt;sup&gt;c&lt;/sup&gt;</td>
<td>.3062&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td>.0009&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Brown-Forsythe test</td>
<td>1.92</td>
<td>1.78</td>
<td></td>
<td>0.10</td>
<td></td>
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<tr>
<td>Implants (n = 28)</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Maxillary incisor</td>
<td>9</td>
<td>7.4 ± 0.7</td>
<td>7.4 ± 0.7</td>
<td>0.4258&lt;sup&gt;a&lt;/sup&gt;</td>
<td>–0.1 ± 0.2</td>
</tr>
<tr>
<td>Maxillary canine</td>
<td>7</td>
<td>8.9 ± 1.4</td>
<td>8.7 ± 1.4</td>
<td>0.0313&lt;sup&gt;a&lt;/sup&gt;</td>
<td>–0.2 ± 0.2</td>
</tr>
<tr>
<td>Maxillary premolar</td>
<td>12</td>
<td>8.7 ± 1.1</td>
<td>8.9 ± 1.1</td>
<td>0.8906&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.1 ± 0.4</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>BG vs GTH</th>
<th>Size, n</th>
<th>AW_{bsl}, mm</th>
<th>AW_{3y}, mm</th>
<th>AW_{bsl} vs AW_{3y}</th>
<th>AW_{bsl+3y}, mm</th>
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<tr>
<td>Overall sites</td>
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<td>8.0 ± 1.2</td>
<td>6.9 ± 1.2</td>
<td>0.0003&lt;sup&gt;a&lt;/sup&gt;</td>
<td>–1.1 ± 0.6</td>
</tr>
<tr>
<td>Shapiro-Wilk test (P)</td>
<td>.0938&lt;sup&gt;c&lt;/sup&gt;</td>
<td>.1845&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td>.0505&lt;sup&gt;c&lt;/sup&gt;</td>
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<tr>
<td>Brown-Forsythe test</td>
<td>1.49</td>
<td>1.32</td>
<td></td>
<td>0.39</td>
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<td>Implants (n = 18)</td>
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<tr>
<td>Maxillary incisor</td>
<td>9</td>
<td>7.5 ± 0.9</td>
<td>6.5 ± 0.8</td>
<td>0.0195&lt;sup&gt;a&lt;/sup&gt;</td>
<td>–0.9 ± 0.7</td>
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<tr>
<td>Maxillary canine</td>
<td>4</td>
<td>8.2 ± 0.4</td>
<td>6.6 ± 0.6</td>
<td>0.1250&lt;sup&gt;a&lt;/sup&gt;</td>
<td>–1.4 ± 0.6</td>
</tr>
<tr>
<td>Maxillary premolar</td>
<td>5</td>
<td>8.8 ± 1.8</td>
<td>7.6 ± 1.8</td>
<td>0.0625&lt;sup&gt;a&lt;/sup&gt;</td>
<td>–1.2 ± 0.5</td>
</tr>
</tbody>
</table>

AW = alveolar width; AW_{bsl} = baseline AW (preoperative); AW_{3y} = AW at 3 years; AW_{bsl+3y} = changes from preoperative to 3 years; BG = biomaterial grafting group; GTH = guided tissue healing group.
One tooth per patient was randomly selected for independent comparison. Statistically significant values are in bold.
Results of Brown-Forsythe test (variance): F = 14.4278; df1 = 5; df2 = 102; P < .0001.
Analysis of variance and results of Friedman test for the outcomes AW_{bsl} vs AW_{3y} (gender interaction): df = 1; MS = 24; chi-square = 1.8690; P = .1716. For the AW_{bsl} vs AW_{3y} (tooth interaction): df = 2; MS = 12.60; chi-square = 2.0187; P = .3645.
*aWilcoxon signed-rank test for matched samples.
*bWilcoxon rank-sum test for independent samples.
*cShapiro-Wilk test significance.

Preoperative and 3-year AWs were 8.3 mm with a change of 0.0 ± 0.3 mm (Table 2). Significant differences were found between preoperative (8.0 ± 1.2 mm) and postoperative (6.9 ± 1.2 mm) bone width for overall teeth of BG group (P = .0003). A significant difference (P < .0001) was also found between the width reduction of the GTH group (0.0 ± 0.3 mm) and the BG group (–1.1 ± 0.6 mm) (Fig 4).

When tooth-site predictor was investigated, significant differences were registered between the two procedure groups just for premolar and canine areas; bone width changes were significantly higher (P ≤ .0061) for the BG group (–1.4 ± 0.6 mm for canines and –1.2 ± 0.5 mm for premolars) than those measured for GTH group (–0.2 ± 0.2 mm for canines and 0.1 ± 0.4 mm for premolars). No other
differences were significant in the subgroup analyses.

**Discussion**

Statistically significant differences were seen between the two groups, and thus the null hypothesis was rejected. The embryologically derived bundle bone generally underwent complete resorption if it ceased to support the tooth that was extracted. Because the buccal plate mainly consisted of very thin bundle bone, it was common for that to undergo extreme negative remodeling, possibly resulting in a huge loss of volume. On the contrary, the wide lamellar bone at the lingual aspect experienced a lower vertical reduction.17 The correlation between soft tissue shrinkage and hard tissue remodeling after tooth extraction and preoperative alveolar ridge phenotype has been verified previously.6–8 Particularly, Chappuis et al in two different works6,8 suggested that the lower the facial bone wall thickness (thin wall phenotype; ≤ 1 mm), the greater the degree of bone loss following extraction, with a median horizontal loss of 0.8 mm. Additionally, the way a clinician places an implant (with an appropriate implant dimension and position), in combination with the preoperative angulation of the pristine tooth to be extracted, could also be a significant factor in good buccal bone preservation.7

To prevent alveolar collapse, it is common practice for clinicians to fill the void between the implant and the postextraction socket walls with bone substitute materials to counteract, to some extent, the progressive volumetric reduction of the buccal bony plate.17

Sanz et al18 reported that, in the grafted areas, distances between the implant and the buccal bone decreased to 1.1 mm, whereas the gaps in the ungrafted sites amounted to 1.6 mm. Furthermore, it was observed that the loss in the whole width of the buccal–palatal ridge dimension and the buccal bony plate was significantly less pronounced in grafted (–11%) than in nongrafted (–16%) groups. Moreover, the grafting technique did not seem to improve the gap closure. This was a result that could be achieved for both the esthetic zone (ie, the anterior maxilla) and nonesthetic areas, albeit to a lesser extent. To some degree, the observations of the present study were in line with those reported by Araújo et al.19 Some studies suggested that an implant might be inserted at least 3 mm away from the innermost bone wall.20–23 This distance should prevent buccal bone loss in the early stages. This was successfully proven in a clinical study24 in which it was rationally possible to assume that the alveolar integrity was completely maintained during the prosthetic steps.

The results of the present paper suggest that preformed anatomical healing caps not only shored up the gingival tissue but also prevented the alveolar ridge collapse. The idea was to develop an anatomically harmonious abutment, allowing for a more predictable final restoration as well as preservation of the socket.

**Fig 4** Box and whisker plot of the alveolar width at baseline and 3 years, as well as the preoperative buccal gap, for GTH and BG groups. Pairwise statistical comparisons were performed: Wilcoxon signed-rank test assessed changes in time, from preoperative to the 3-year follow-up (*); Wilcoxon rank-sum test assessed changes between groups (*).
by capturing the anatomy present at the time of extraction.9,10 Sealing a fresh-socket implant site with a custom-made tooth-form provisional abutment that reproduced the exact shape of the extracted tooth’s emergence profile could be a simple yet unique way to preserve pristine alveolar dimension, as supposed by Menchini-Fabris et al.23

The possible occurrence of an over-contraction could explain the myofibroblastic pathophysiology of high dimensional shrinkage of the alveolar crest.25 In the GTH group, there was neither an augmentation nor a diminution of the alveolar ridge width. In the alveolus, myofibroblasts induced a contraction of buccal bone within the gap as the preformed caps tried to maintain the volume of the osseomucogingival complex, without inducing a stress process into the tissues surrounding the gap.26–28

As described in the present study, the gap between the metallic implant surfaces and the alveolar bony walls was filled with newly formed bone. Preformed anatomical caps presented a good treatment option that combined the natural abutment’s emergence profile and improved-fit features over stock abutments, as both features could guide soft tissue contouring.29,30

Mimicking the implant emergence profile according to natural dentition required high clinical dexterity, which involved extra cost and increased the operating time.28,30

Currently, there were no standard tools to establish the proper shape, dimension, and orientation of the implant emergence profile that could help clinicians fabricate a healing abutment in an objective, fast, and easy manner. The present clinical and radiographic study suggested that GTH with fabricated anatomical caps seemed to be more effective in maintaining the proerative socket contour than sites preserved with xenogeneic material compressed and firmly packed into the gap between the metallic surface and the innermost socket walls. As shown by negligible bone width change, full preservation of the volume and tissue contours at the facial aspect could be expected for the GTH group.

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References


