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Immediate implant placement may represent a possible treatment plan for single tooth restoration. This study evaluated the insertion of osseointegrated implants in intact fresh extraction sockets in the anterior maxilla. The bone-to-implant gap was accurately grafted with a bovine bone mineral prior to implant engagement, and an immediate screw-retained restoration was delivered. After 3 months, the provisional crown was replaced with the definitive ceramic crown. Marginal bone levels remained stable after 1 year. The horizontal ridge dimension was also evaluated at three levels using CBCT scans after 1 year. The horizontal width of the postextraction crest was well preserved independently from the thickness of the buccal bone plate at baseline. Int J Periodontics Restorative Dent 2019;39:633–641. doi: 10.11607/prd.4183

Following tooth extraction in the esthetic area, immediate implant placement and restoration may represent a reliable therapeutic option to shorten the treatment time and provide patients with an immediate fixed prosthetic rehabilitation. However, this option challenges the postextraction-socket remodeling that leads to various amounts of bone volume resorption. Studies reported 30% to 50% reductions in the horizontal ridge width after 4 to 12 months of spontaneous healing, and systematic reviews confirm that the alveolar ridge undergoes a mean horizontal reduction of 3.79 mm (range: 29% to 63%) and a mean vertical reduction of 1.24 mm (range: 11% to 22%) within 6 months after tooth extraction. Additional studies have demonstrated that implant placement in the fresh extraction socket fails to prevent the physiologic remodeling of the ridge. Clinical reports have demonstrated high survival rates of immediate implants, and these may also be associated with an increased risk for buccal bone dehiscence and marginal tissue recession, which may compromise the esthetic outcome. In fact, it has been reported that the thickness of the buccal and palatal bone walls and the dimension of the bone-to-implant gap may influence the bone fill of the gap itself, both in the vertical and...
horizontal components, as well as the remodeling of the socket walls.\textsuperscript{10}

To this end, the literature suggests that alveolar ridge preservation can maintain the three-dimensional (3D) osseous volume of the alveolar ridge\textsuperscript{11–13} and support delayed implant placement.\textsuperscript{14} At the same time, placing of a graft material into the bone-to-implant gap at immediate implants also seems to compensate for the modeling and remodeling process of the socket walls and promote bone formation.\textsuperscript{15,16}

For these reasons, increased interest in the hard tissue management of immediate implants is shown in recent literature, as both grafting of the bone-to-implant gap and delivery of an immediate restoration seem to improve the final esthetic outcomes.\textsuperscript{17–19} The majority of the conducted clinical studies have provided clinical and conventional radiologic evaluations, but there is a lack of knowledge on the fate of the volume of the alveolar ridge following immediate implant placement. Cone beam computed tomography (CBCT) is suitable for this specific 3D diagnosis in implant dentistry,\textsuperscript{20} providing a quantitative method to compare alveolar ridge remodeling following ridge preservation procedures.\textsuperscript{13}

The aim of the present study is to describe the radiologic alterations over a 1-year period of the alveolar ridge at immediately placed anterior maxillary single-tooth implants. Soft tissue evaluation will be reported in a separate paper.\textsuperscript{21}

**Materials and Methods**

Twenty consecutive adult patients undergoing dental treatment at a private periodontal practice in Torino, Italy and requiring single-tooth extraction in the anterior maxilla (premolar to premolar) were enrolled in this study. The study population consisted of 7 males and 13 females, mean age 58.5 ± 11.03 years (range: 34 to 75 years). The integrity of the soft tissue contour at the facial aspect of each tooth was verified at the time of enrollment (absence of gingival recession), and bone sounding was used to detect the presence of intact bone walls. The reasons for extraction included crown/root fracture, endodontic treatment failure, and advanced caries. Patients with acute periodontal or periapical infections were not included. The systemic exclusion criteria were existence of metabolic bone disease, current pregnancy, history of radiotherapy or chemotherapy for malignancy in the past 5 years, history of autoimmune disease, and drug consumption that could interfere with implant therapy. Patients who smoked more than 10 cigarettes per day were also excluded, and those who smoked 10 or fewer cigarettes per day were requested to stop smoking for 2 weeks before and after surgery. In all patients, a comprehensive periodontal examination was performed, followed by oral hygiene professional care and instructions, with scaling and root planing if indicated, to ensure a healthy periodontal environment. The study protocol was approved by the PROED ethical committee (Torino, Italy). The study was conducted in accordance with Helsinki Declaration of 1975, as revised in 2008. All study participants accepted the proposed treatment plan (tooth extraction followed by immediate implant placement with grafting of the bone-to-implant gap and immediate restoration) and provided written informed consent. All measurements were performed by a single person (A.R.) different from the surgeon (D.C.). A blinded examiner (L.T.) evaluated all measurements.

One representative clinical case, from the pool of patients enrolled in the study, is shown in Figs 1 and 2.

Before surgery, a surgical template was fabricated for each patient in order to provide a prosthetically driven implant positioning (slightly palatal for incisors and canines, centric to the occlusal plane for premolars) able to leave at least a 2-mm–wide bone-to-implant gap on the buccal side.

All tooth extractions were performed using a minimally invasive flapless procedure. Local anesthesia (4% articaine plus epinephrine 1:100,000) was administered before the teeth were gently luxated with periotomes (Carda #1 and Carda #2, Omnia) and then extracted using extraction forceps. Maximum care was taken to minimize trauma to the socket walls. If needed, granulation tissue was removed by careful debridement of the socket and rinsed with saline solution, and the integrity of the alveolar walls was detected using a periodontal probe. The inner epithelium was also excised, using a 15-C blade (Kai), from the sulcus entrance and the junctional epithelium.
in order to expose the underlining connective tissue. At this time, using the surgical stent as reference, an osteotomy was performed to prepare for implant placement (Bone Level Tapered, Straumann) according to the manufacturer’s surgical protocol, with the exception that the final drill was used at a low speed (200 rpm) in order to underprepare the surgical site and improve implant primary stability. The apical portion of the osteotomy engaged the triangle of bone apical and palatal to the apex of the root. The implant platform was located subcrestally, approximately 1 mm apical to the margin of the buccal bone wall. A total of 20 tapered bone-level implants, with a highly hydrophilic surface (Bone Level Tapered Roxolid SLActive, Straumann) were inserted. Implant diameters were 3.3, 4.1, or 4.8 mm, while implant lengths were 10, 12, or 14 mm.

Before implant placement, in order to assure perfect 3D grafting around the implant threads leaving no voids, a specifically designed bone plugger (Cardaropoli set, Omnia) was used to fill the anticipated bone-to-implant gap with a deproteinized bovine bone mineral (Cerabone, Botiss). Specific attention was paid not to leave xenograft granules inside the previously prepared implant bed, using a depth gauge inserted into the implant site while grafting the anticipated gap. Implants were then screwed into the surgical sites until final seating. All implants reached a final insertion torque ≥ 35 Ncm.

Provisional polymethyl methacrylate screw-retained abutments were inserted, and the connection screws were seated. In each case, the provisional acrylic crown was

![Fig 1](a) Lateral and (b) occlusal intraoral views at baseline. (c) The tooth was extracted with a minimally invasive flapless approach. (d) After implant site preparation, the future bone-to-implant gap is filled with a bone substitute, leaving an adequate space for implant insertion. (e) The osseointegrated implant has been inserted with full contact to the surrounding biomaterial. (f) Enamel matrix derivative is placed on top of the biomaterial granules, in contact with the surrounding soft tissues. (g) An immediate temporary crown is delivered right after implant placement. (h) Lateral and (i) occlusal intraoral views at the 1-year follow-up.
luted to the provisional abutment using a light-cured composite resin, refined and polished chairside, and finally screwed on the implant at 15 Ncm. The composite resin below the free gingival margin was molded in order to create a fully contoured provisional crown with subgingival contours that duplicated the state prior to extraction. Before seating the provisional crown, a biologic mediator made of enamel matrix derivative (Emdogain, Straumann) was applied in contact with the soft tissues of the fresh socket. Occlusion was adjusted in order to avoid any functional loading. Antibiotic therapy with 1 g amoxicillin plus clavulanate potassium (every 12 hours) was prescribed for 6 days. Ibuprofen (600 mg) was also prescribed but assumed only on demand. The patients were asked to use a 0.2% chlorhexidine gluconate mouthrinse every 8 hours for 14 days.

After 3 months of healing, the immediate provisional restoration was disconnected and an impression was taken using an impression coping. To counteract the natural
tendency of the mucosal tissues to spontaneously collapse after removal of the provisional crown, a custom impression coping of the provisional restoration contours was made. After 2 weeks, screw-retained definitive ceramic crowns were delivered.

Radiologic Measurements

At implant placement (T0, for radiographic measurements) and 12 months postloading (T1), standardized digital intraoral radiographs were taken for each implant using the paralleling long-cone technique. Radiographs were saved and then acquired and evaluated using the ImageJ (National Institutes of Health) software. The software was calibrated for every single image using the known length of the implant. Linear measurements on the digital radiographs were performed by a single previously calibrated examiner (L.T.) using the measurement tool specifically designated into the software. Marginal bone level (MBL), intended as the distance from the interproximal bone to the reference point on the outer aspect of the implant shoulder, at the mesial (mMBL) and distal (dMBL) sides was measured and the mean MBL values were calculated.

CBCT Measurements

CBCT evaluation was performed using a 5 × 5–cm field of view and 90 µm cuts (CS 9300, Carestream), taking scans preoperatively before tooth extraction (T0, for CBCT measurements) and 1 year after loading (T1). The horizontal ridge width (HW) was measured at three levels: at the most coronal aspect of the crest (HW-0), 3 mm below the crest (HW-3) and 6 mm below the crest (HW-6). Also measured at T0, on a line perpendicular to the long axis of the root, was the buccal bone plate (BBP) thickness, at the same three levels: 0, 3, and 6 mm below.
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the crest (BBP-0, BBP-3, and BBP-6, respectively) (Fig 3). Changes between T0 and T1 were calculated and compared. To perform radiographic measurements and comparisons, CBCT scans at T0 and T1 were converted into 3D volumetric label maps (segmentations) using an open source software package (ITK-SNAP, version 3.4.0). Through segmentation, the anatomical regions of interest were defined. The corresponding voxels registration was performed, and 3D surface mesh models were obtained for quantitative and qualitative evaluations (3D Slicer, version 4.6.2). Volumetric measurements were performed using specific 3D software (CloudCompare, version 2.8).

Statistical Analysis

A power calculation before the study revealed that a sample size of 20 sites was necessary to detect a difference in bone ridge dimension of 0.5 mm after 1 year, assuming a maximum standard deviation of 0.7 mm using paired t test with 80% power and the level of significance at .05. Each parameter was evaluated at T0 and T1 by paired t test. Data were presented as mean values ± standard deviation.

All CBCT measurements were treated as continuous data. Statistical analysis was performed using Wilcoxon signed rank test and Kruskal Wallis test. Statistical significance was set with P < .05.

Results

All patients completed the study and all surgical procedures and prosthetic rehabilitations were performed as planned, without complications.

Radiological data, scored at T0 and T1, are reported in Table 1. Mean mMBL was 2.97 ± 1.25 mm at T0 and 2.38 ± 1.66 mm at T1, with a difference of 0.59 ± 0.88 mm (P < .05). At T0, mean dMBL was 2.44 ± 1.27 mm, while at T1 it was 2.18 ± 1.35 mm, with a difference of 0.26 ± 0.40 mm (P < .05). The total mean MBL, intended as an average value between mMBL and dMBL, at T0 was 2.70 ± 1.19 mm and at T1 was 2.28 ± 1.34 mm, with a difference of 0.42 ± 0.45 mm (P < .05).

HW-0 averaged 8.41 ± 1.19 mm at T0 and 7.82 ± 1.12 mm at T1, corresponding to a difference of 0.59 ± 0.47 mm (6.82% ± 5.33%). HW-3 amounted to 8.90 ± 1.32 mm at T0 and to 8.48 ± 1.42 mm at T1, resulting in a difference of 0.49 ± 0.36 mm (5.63% ± 4.41%). HW-6 averaged ± 1.66 mm at T0 and to 8.74 ± 1.72 mm at T1, corresponding to a difference of 0.43 ± 0.32 mm (4.87% ± 3.66%). Accordingly, preservation of the horizontal width of the alveolus after tooth extraction and immediate implant placement was 93.18% ± 5.33% at HW-0, 94.37% ± 4.41% at HW-3, and 95.13% ± 3.66% at HW-6.

Fig 5 CBCT images of two clinical cases, demonstrating both (a, b) thin and (c, d) thick periodontal biotypes. Maxillary lateral incisors (a, c) before tooth extraction, showing the respective buccal bone plate, and (b, d) 1 year after implant placement. The width of the alveolar ridge is preserved in both thin and thick biotypes.
The thickness of the buccal bone plate was analyzed at the same three levels and averaged 0.84 ± 0.36 mm (at BBP-0), 1.06 ± 0.66 mm (at BBP-3), and 0.89 ± 0.81 mm (at BBP-6) at baseline (Table 2). No correlation was found between the initial thickness of the buccal bone plate and the remodeling of the alveolar ridge at 0 mm (Rho = –0.166, P = .484), 3 mm (Rho = 0.422, P = .064), or 6 mm (Rho = 0, P = .999) (Table 2, Fig 4).

Discussion

This study was designed to evaluate the healing of soft and hard tissues following tooth extraction and immediate implant placement with provisional restoration. All parameters were evaluated after 12 months of healing (Fig 5).

The procedure described here proposes a one-stage approach to shorten the overall treatment time. For the interest of the patients, a fixed provisional crown is immediately delivered at the end of the surgery. This improves the esthetic outcome and psychologic acceptance and eliminates the need for a second-stage surgery or for wearing a removable provisional prosthesis in an area of high esthetic relevance. Consequently, the morbidity is significantly reduced.

From a biologic point of view, the fresh extraction socket heals simultaneously to implant osseointegration. The accurate grafting of the bone-to-implant gap creates a clinical situation comparable to what usually happens following a ridge preservation procedure but with simultaneous implant placement. At the end of the healing period, the spontaneous remodeling of the postextraction site has been compensated by the bone fill of the gap, preserving more than 90% of the original volume of the alveolar ridge, as seen from CBCT measurements.

Within the limits of this clinical research, the data presented here support the statement that accurately grafting the bone-to-implant gap plays a key role in preserving the buccolingual remodeling of the postextraction ridge. The novel approach describes the possibility of grafting the distance before implant placement, assuring a perfect adaptation of the xenograft granules around the implant threads.

The stability of the marginal bone levels and the survival rates are comparable to those of implants inserted in a completely healed ridge and to the positive findings reported in literature for immediate implants.

Immediate implant placement does not prevent bone resorption per se, and marked volume alterations are often reported at the end of the healing period. The extent of bone volume loss varies depending on baseline thickness of the buccal bone plate at the treatment area. The thickness of the buccopalatal bony crest markedly

### Table 1 Radiographic Examination of Ridge Dimensions

<table>
<thead>
<tr>
<th>Measuring point</th>
<th>Baseline (mm)</th>
<th>1 y (mm)</th>
<th>T0 to T1 (mm)</th>
<th>T0 to T1 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>mMBL</td>
<td>–2.97 ± 1.25</td>
<td>–2.38 ± 1.66</td>
<td>–0.59 ± 0.88</td>
<td></td>
</tr>
<tr>
<td>dMBL</td>
<td>–2.44 ± 1.27</td>
<td>–2.18 ± 1.35</td>
<td>–0.26 ± 0.40</td>
<td></td>
</tr>
<tr>
<td>mean MBL</td>
<td>–2.70 ± 1.19</td>
<td>–2.28 ± 1.34</td>
<td>–0.42 ± 0.45</td>
<td></td>
</tr>
<tr>
<td>HW-0</td>
<td>8.41 ± 1.19</td>
<td>7.82 ± 1.12</td>
<td>0.59 ± 0.47</td>
<td>6.82 ± 5.33</td>
</tr>
<tr>
<td>HW-3</td>
<td>8.90 ± 1.32</td>
<td>8.48 ± 1.42</td>
<td>0.51 ± 0.34</td>
<td>5.88 ± 4.13</td>
</tr>
<tr>
<td>HW-6</td>
<td>9.17 ± 1.66</td>
<td>8.74 ± 1.72</td>
<td>0.43 ± 0.32</td>
<td>4.87 ± 3.66</td>
</tr>
</tbody>
</table>

T0 = baseline; T1 = 1 year; MBL = marginal bone level; mMBL = mesial MBL; dMBL = distal MBL.

Horizontal ridge width (HW) at three levels (0, 3, and 6 mm) below the most coronal aspect of the crest were measured.

### Table 2 Thickness of BBP Measured at 0, 3, and 6 mm Below the Buccal Bone Crest

<table>
<thead>
<tr>
<th>Measuring point</th>
<th>BBP at T0 (mm)</th>
<th>HW T0 to HW T1 (mm)</th>
<th>Spearman rank correlation coefficient (BBP/HW-3, T0 to T1)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.84 ± 0.36</td>
<td>0.59 ± 0.47</td>
<td>–0.166</td>
<td>.484</td>
</tr>
<tr>
<td>3</td>
<td>1.06 ± 0.66</td>
<td>0.51 ± 0.34</td>
<td>0.412</td>
<td>.071</td>
</tr>
<tr>
<td>6</td>
<td>0.89 ± 0.81</td>
<td>0.43 ± 0.32</td>
<td>0.000</td>
<td>.999</td>
</tr>
</tbody>
</table>

T0 = baseline; T1 = 1 year; BBP = buccal bone plate; HW = horizontal ridge width. The correlation between BBP at baseline and horizontal remodeling of the ridge height (HW T0 to HW T1) at 3 different levels 1 year postsurgery was analyzed using Spearman rank correlation coefficient.
influences the bone fill that occurs in the distance between the implant surface and the socket walls.10 It is of crucial importance to understand the dynamics of healing in tooth extraction sites25,26 in order to counteract these alterations and achieve predictable treatment outcomes.

Filling the peri-implant gap with a biomaterial promotes bone formation and compensates for the postextraction modeling and remodeling of the socket bony walls.16,17,19 In a randomized controlled clinical trial evaluating immediate implant sites after an observation period of 12 months, the untreated control sockets demonstrated significantly greater reductions in ridge height and width compared to the test sockets, in which the peri-implant gap was grafted with a bone substitute. While the control sites lost more than 20% of the original width, the test sites had only 8% reduction.16

The positive influence of ridge preservation around immediate postextraction implants has also been described in an experimental study. The use of a xenograft to fill the bone defects around the implants resulted in a bone-to-implant contact level located more coronal than the untreated control sites.27 In the present study, enamel matrix derivative was applied in contact with marginal mucosa to enhance wound healing due to its capability to gain soft tissue density.28

The literature also evidences the importance of protecting and containing the bone graft during the healing phase. In this context, a provisional restoration seals the peri-implant tissues in the fresh extraction socket, preserving the original ridge contour. Survival rates of immediate implants are equivalent to those of delayed implants despite the reduced number of clinical procedures,29 and placing a bone graft in the bone-to-implant gap reduces the amount of bone contour changes.19

Conclusions

Within the limits of the present study it can be concluded that:

Immediate implant placement with immediate restoration represents a suitable protocol for the rehabilitation of intact postextraction sites, providing positive survival rates and stability of the marginal bone levels;

An accurate grafting of the bone-to-implant gap is shown to compensate for marginal bone remodeling and to maintain the original volume of the bone ridge of intact sockets;

The preservation of the horizontal width of the postextraction crest is independent from the thickness of the buccal bone plate at baseline.

Acknowledgments

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References


