The aim of this study was to evaluate buccal-lingual bone remodeling after fresh socket implant placement and immediate loading at 3 years of follow-up by cone beam computed tomography (CBCT). A total of 96 implants were placed in fresh sockets in anterior maxillary regions and immediately loaded. The sockets were divided into two groups related to buccal bone thickness: group A, with a buccal bone thickness > 1 mm, and group B, with a thickness ≤ 1 mm. The CBCT scans were performed before tooth extractions and 3 years after implant placement, and measurements were assessed. At 3 years, all fresh sockets in both groups presented considerable buccal-palatal crestal reduction. In both groups, statistically significant (P < .05) bone loss was found between time points. There was no statistically significant difference in bone reduction between groups at 3 years of follow-up. Nevertheless, sockets with vertical axis presented more bone volume reduction than those with axis parallel to buccal bone after implant placement. Int J Periodontics Restorative Dent 2018;38:43–49. doi: 10.11607/prd.3074

To avoid alveolar bone collapse and maintain an excellent esthetic profile of tissue volume around implant-prosthetic restorations, different authors1−3 have placed dental implants with immediate loading in fresh extraction sockets (occlusal load applied to temporary crowns positioned immediately onto implants), reporting a survival rate of 100% with minimal crestal bone loss.

The peri-implant soft tissues setting, gingiva level, color, and texture are additional critical requirements for final implant esthetics.4−8 Hence, accurate evaluation of bone tissues around extraction sockets is a main concern before immediate implant placement.9 It was also observed, however, that the thickness of the buccal and palatal bony walls and the dimensions of the void (defect) between the implant and the bony walls of the socket significantly influenced bone fill in the horizontal and vertical components of these defects as well as the resorption that occurred at the socket walls.10

Demineralized freeze-dried bone allograft has been widely used to fill peri-implant defects in immediate implant placement.11−13 Other authors14 have suggested that filling allografts could inhibit bone formation.

However, all these clinical and animal studies were carried out using clinical and radiographic data,
CBCT seems especially suitable for diagnosis in implant therapy as it has been shown to improve the visibility of anatomical structures that cannot be clearly observed in intraoral panoramic radiographs or in clinical data. Pre- and postoperative CBCT has served as a quantitative method to compare alveolar ridge resorption or preservation following grafting procedures before implant placement to assess bone quantity and morphology.

Nevertheless, there are no data regarding bone remodeling in fresh socket implants at several years of follow-up, so the aim of this study was to evaluate buccal-lingual bone remodeling 3 years after fresh socket implant placement and immediate loading by CBCT.

Materials and Methods

Patient Selection

Between September 2010 and October 2011, 26 patients requiring extractions of one or more teeth in esthetic zones of the maxilla due to root fractures, caries, endodontic lesions, or periodontal disease were scheduled for the present study.

The following inclusion criteria were adopted for each patient: good health, no chronic systemic disease, presence of four bony walls of the alveolus, and presence of at least 4 mm of bone beyond the root apex.

Exclusion criteria were presence of a dehiscence or fenestration of the residual bony walls, coagulation disorders, signs of acute infection around the alveolar bone at the surgical site, heavy smoking (> 10 cigarettes per day), alcohol or drug abuse, and bruxism.

Implants were positioned and loaded immediately after tooth extraction. The patients included in this clinical study were treated by one oral surgeon and one prosthetic specialist in the Department of Dentistry, San Raffaele Hospital.

The study protocol was approved by the local institutional review committee, and all patients signed a written informed consent form for immediate implant loading.

Surgical Protocol

The patients received 1 g amoxicillin (Zimox, Pfizer Italia) 1 hour prior to surgery and twice a day for a week after the surgical procedure. Surgery was performed under local anesthesia (Optocain, Molteni Dental, 20 mg/mL with adrenaline 1:80,000).

Maxillary teeth in incisor, canine, and first premolar regions were extracted, maintaining the integrity of the socket and avoiding buccal and palatal flaps. A periodontal probe (PGF-GFS, Hu-Friedy) was used to verify the integrity of the four walls of the fresh sockets. All sockets showed the absence of fenestration or dehiscence, no regenerative procedures were performed in any sites, and no biomaterials were used to fill voids between the implant surface and alveolar walls.

Implant sites were prepared with standard drills following the palatal bony walls as a guide, and the apical portion of the implant was always placed at least 4 mm beyond the root apex; no countersinking was used.

The quality of alveolar bone was determined during surgery for each site and was predominantly classified as type 2 or 3, according to Lekholm and Zarb.

The sockets were divided into two groups related to buccal bone thickness: group A had a buccal bone thickness > 1 mm, and group B had a bone thickness ≤ 1 mm. Titanium implants were titanium plasma sprayed and had a rough surface, a body with a progressive thread design (Outlink, Sweden & Martina), a smooth collar of 0.5 mm, and external hexagon implant-abutment junctions (Fig 1). The implant platform was placed at the level of the buccal crest.

Each patient received one to five dental implants, according to the number of extraction sites, and immediate loading was performed with implant insertion torque ≥ 35 Ncm. No flap was raised in all cases. Chlorhexidine 0.2% mouthrinse was prescribed twice daily for the next 15 days.

Prosthetic Protocol

Immediately after the surgical procedure, all patients received metal temporary abutments and temporary crowns were cemented. All temporary crowns were in full contact in centric occlusion, making the occlusal surfaces flat and reducing horizontal relations. All patients followed a soft diet (avoiding bread and meat) for 2 months (Fig 1).
Follow-up Evaluation

Follow-up visits were performed by a dental hygienist twice a year after implant insertion.

Success criteria for implant survival were presence of implant stability, absence of a radiolucent zone around the implants, no mucosal suppuration, and no pain.16,17

Radiographic Examination

The CBCT scans in this study were performed with a device dedicated to dental and maxillofacial imaging (Gendex GXCB-500, Gendex Dental Systems). Free i-CAT Vision viewing and sharing software was applied. Scans 1 mm thick were obtained at 120 kV and 30.89 mAs, with a resolution of 0.2 voxels for 23 seconds and a diameter of $8.5 \times 8.5$. A CBCT cross-sectional projection was extrapolated and analyzed at the longitudinal midportion of each examined socket.

Cone beam units use a divergent cone/pyramid-shaped beam to obtain multiple planar projections in a single rotation. These cone-shaped beams are similar to those of x-ray units used for two-dimensional radiography. This cone beam unit functions while the patient is seated.

CBCT examinations were performed before tooth extractions and 3 years later (Fig 2). The thickness of the bony walls was measured 1 mm apical of the top of the alveolar crest.

The alveolar bone measurements were assessed from the most coronal, buccal, and palatal bone in which the alveolar crest was identified. The alveolar bone margins were considered the most coronally located point of the alveolar bone of the buccal and palatal sides of the socket. For buccal-palatal width assessment, one line was drawn from the palatal to the buccal side at 1 mm apical to the top of the alveolar crest (Fig 2). Before tooth extractions and 3 years after implant placement, measurements were acquired and changes were evaluated. The CBCT scans for each patient were then transferred to a blinded radiologist for evaluation. The radiologist measured twice. The intraexaminer error was calculated by comparing the first and second measurements with paired t test at a significance level of 5%. No statistically significant difference was calculated between values.

Statistical Analysis

Data were presented as mean ± standard deviation. Comparisons between group A and group B and intragroup comparisons over time were performed by Student t test. $P = .05$ was considered the threshold for statistical significance.

Results

A total of 26 patients, 18 women and 8 men, with a mean age of 48.8 years (range: 31 to 67 years) were enrolled in the present study. A total of 96 maxillary teeth in incisor, canine, and first premolar regions were extracted, maintaining the integrity of the socket (Table 1), and
implants were immediately placed in the fresh sockets. Of the implants, 45 had a diameter of 4.10 mm and a length of 13 mm, and 51 had a diameter of 3.75 mm and a length of 13 mm. At the CBCT measurements before teeth extraction, 35 sites were scheduled in group A and 61 sites in group B.

**Surgical and Prosthetic Procedures**

After a 36-month follow-up period, a survival rate of 100% was reported for all implants. There was no patient withdrawal in either group. Minor swelling of gingival mucosa was present in the first days after the surgical procedures, and no mucositis or flap dehiscences with suppuration were found. The final ceramic-fused-to-metal restorations were cemented 6 months after implant placement. No pain or final prosthesis mobility was registered at 36 months of follow-up (Fig 3).

**Table 1 Extracted Teeth and Implants Dimensions and Positions**

<table>
<thead>
<tr>
<th>Implant position</th>
<th>Implant size (mm)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.75 × 13</td>
<td>4.1 × 13</td>
</tr>
<tr>
<td>Incisor (n)</td>
<td>35</td>
<td>23</td>
</tr>
<tr>
<td>Canine (n)</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>Premolar (n)</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Total (n)</td>
<td>51</td>
<td>45</td>
</tr>
</tbody>
</table>

Fig 2 Group A: Cone beam computed tomography (CBCT) before surgery (a to d) and 3 years after implant placement (e to h) showing the CBCT measurement technique. For buccal-palatal width assessment, a line was drawn from the palatal to the buccal side 1 mm apical to the top of the alveolar crest.

Fig 3 (a) The final abutments 6 months after implant placement. (b) Ceramic restoration at 36 months.
Radiographic Evaluation

All fresh sockets presented a considerable buccal-palatal bone reduction in both groups after 3 years (Table 2). In group A, mean bone width before extraction was 8.03 ± 1.45 mm, and 7.56 ± 1.40 mm 3 years after implant placement. A statistically significant ($P < .05$) bone loss was found between time points. In group B, mean bone width before extraction was 7.45 ± 1.22 mm, and 6.78 ± 1.13 mm 3 years after implant placement. A statistically significant ($P < .05$) bone loss was found between time points. However, there were not statistically significant differences between groups A and B over time ($P > .05$).

More buccal-palatal bone loss was observed when the dental alveolus had a vertical axis (Figs 4a and 4b). When the alveolus axis was relatively parallel to the buccal bone, the insertion of the implant axis maintained the same direction and the bone collapse was reduced, which was also the case in the thin bone group (Figs 4c and 4d).

Furthermore, it was reported implants placed closer to buccal bone lost more bone volume (Fig 4e). Conversely, implants placed near the palatal surface presented the best bone volume maintenance (Fig 4d).

### Table 2 Mean Bone Levels Before Extraction and at 3 Years After Implant Placement

<table>
<thead>
<tr>
<th>Mean bone level (mm)</th>
<th>Before extraction</th>
<th>3 y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>8.03 ± 1.45</td>
<td>7.56 ± 1.40</td>
</tr>
<tr>
<td>Group B</td>
<td>7.45 ± 1.22</td>
<td>6.78 ± 1.13</td>
</tr>
</tbody>
</table>

Discussion

This CBCT study reported a considerable bone volume reduction in all fresh sockets after implant placement and immediate loading at the 3-year follow-up. There were no statistically significant differences between groups A and B over time ($P > .05$).

These results demonstrated that a different rationale may induce bone tissue remodeling following immediate implant placement into extraction sockets.
The present CBCT data demonstrated no statistically significant difference in buccal-lingual bone reduction between the two groups, contrasting with other data\textsuperscript{10,19,20} obtained via clinical measurements. Tomasi et al\textsuperscript{10} reported a series of clinical measurements in extraction sites immediately after implant placement and at reentry 4 months later. The authors showed that the thickness of the buccal-palatal bony crest markedly influenced the bone fill that occurred in the defect between the implant surface and the socket walls. Thus, sites with thick bony walls presented more bone fill than did sites with a thin alveolar crest.

Moreover, it was observed that the amount of bone fill on the buccal and palatal aspects was similar and dependent on the thickness of the alveolar crest.

In the present study, CBCT revealed that the implant axis in the extraction socket appears to be of utmost importance for treatment outcomes. Analysis showed that the further to the palatal side of the alveolus the implant was placed, the less horizontal bone reduction occurred after 4 months of healing.\textsuperscript{10} These data were confirmed by Araujo et al,\textsuperscript{22} who demonstrated that by placing the implants into the extraction socket in a lingual position, the large buccal gap that occurred between the titanium device and the bone wall during healing became filled with bone. The implant became fully integrated into the bone. Similar results were recently demonstrated in another study in which the immediate positioning of the implant into the extraction socket approximately 1 mm deeper than the level of the buccal alveolar crest, and in a lingual position in relation to the center of the alveolus, was able to reduce or eliminate exposure of the implant above the alveolar crest.\textsuperscript{23}

Cone beam sections revealed that the anatomy of the socket was important for bone volume adjustment. Dental sockets with vertical axes presented more bone volume reduction than those with an axis parallel to the buccal bone after implant insertion.

Data obtained in this study suggests that clinicians should consider the bone anatomy and the relationship between the alveolar direction and buccal bone profile. Attention must be given to correct implant placement in fresh sockets, since the implant must be placed as palatal as possible to avoid the buccal bone wall. Furthermore, a multilevel model identified age and smoking as patient-related factors that may influence bone remodeling outcomes.\textsuperscript{24–28}

Conclusions

The clinician must evaluate many concerns in the decision-making process regarding fresh socket implant procedures.

Acknowledgments

The authors reported no conflicts of interest related to this study.

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