A prospective, randomized-controlled clinical trial to evaluate bone preservation using implants with different geometry placed into extraction sockets in the maxilla

Key words: controlled clinical trial, dental implants, extraction socket, immediate placement, implant geometry

Abstract

Aim: The primary objective of this study was to determine the association between the size of the void established by using two different implant configurations and the amount of buccal/palatal bone loss that occurred during 16 weeks of healing following their installation into extraction sockets.

Material and methods: The clinical trial was designed as a prospective, randomized-controlled parallel-group multicenter study. Adults in need of one or more implants replacing teeth to be removed in the maxilla within the region 15–25 were recruited. Following tooth extraction, the site was randomly allocated to receive either a cylindrical (group A) or a tapered implant (group B). After implant installation, a series of measurements were made to determine the dimension of the ridge and the void between the implant and the bone walls. These measurements were repeated at the re-entry procedure after 16 weeks.

Results: The study demonstrated that the removal of single teeth and the immediate placement of an implant resulted in marked alterations of the dimension of the buccal ridge (43% and 30%) and the horizontal (80–63%) as well as the vertical (69–65%) gap between the implant and the bone walls. Although the dimensional changes were not significantly different between the two-implant configurations, both the horizontal and the vertical gap changes were greater in group A than in group B.

Conclusions: Implant placement into extraction sockets will result in significant bone reduction of the alveolar ridge.

In recent years, immediate implant placement after tooth extraction [Type 1 placement; Hämerle et al. 2004] has become a common clinical therapeutic approach. The outcome of this Type 1 placement has been reported to be as predictable as placing implants into healed sites [Chen et al. 2004]. A recent systematic review including ‘immediate implants’ [Quirynen et al. 2007] could identify only two prospective [Prosper et al. 2003] [Covani et al. 2004] and four retrospective studies [Schwartz-Arad et al. 2007] [Ashman et al. 1995] [Schwartz-Arad & Chaushu 1997; Huys 2001] [Bianchi & Sanfilippo 2004] that included data with a follow-up period of at least 4 years from implant placement or loading. Although ‘immediate implants’ exhibited a high survival rate, it was concluded that there was a lack of long-term clinical and radiographic data.

Histological studies regarding the incorporation of implants placed into extraction sockets or into healed ridges have

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documented that similar patterns of osseointegration occur in both humans [Wilson et al. 1998; Paolantonio et al. 2001] and animals [Amoroth et al. 1985; Barziyay et al. 1996; Karabuda et al. 1999]. However, an experiment in dogs [Araújo et al. 2005] showed that Type 1 placement of implants in post-extraction sockets was associated with marked osteoclastic activity that resulted in dimensional alterations (width and height) of the buccal and lingual socket walls.

In contrast, it was suggested that implant placement into an extraction socket may counteract the hard tissue resorption that occurs following tooth extraction [Dennisen et al. 1993; Watzek et al. 1995]. The validity of this hypothesis was questioned [Botticelli et al. 2004] in a clinical study, in which 21 implants were installed into extraction sockets in 18 patients. At surgical re-entry, after 4 months of healing, it was found that most marginal gaps that were present following implant placement were filled with newly formed hard tissue, but also that the buccal–lingual dimensions of the ridge were markedly reduced (buccal > 50%, lingual about 30%).

Often the placement of an implant immediately after tooth extraction is associated with a residual bone defect between the neck of the implant and the residual bone walls. The use of barrier membranes and grafting materials has been proposed to treat the residual peri-implant defects. The rationale for the use of regenerative procedures is to prevent the migration of cells from the connective and epithelial tissues into the gap between the implant surface and surrounding bone walls, thus favoring osteogenic cells in the bone-regenerative process [Paolantonio et al. 2001]. The use of these regenerative materials has been proposed depending on the size of this residual bone defect, and several authors have recommended a threshold of 1–2 mm of horizontal gap between the implant surface and the buccal bone wall to indicate the use of grafting or guided bone regeneration [Chen et al. 2007; Lang et al. 2007]. The validity of this ‘critical dimension’ has, however, never been demonstrated. Moreover, because this technique is being applied to the replacement of teeth in the maxillary anterior region, where esthetic outcomes are of great importance [Kan et al. 2003], these reported ridge alterations, mostly affecting the buccal bone wall, may have significant adverse effects on the final esthetic result [Evans & Chen 2008]. Some authors have attempted to counteract this resorptive process by applying grafting materials or other bone-regenerative techniques on the buccal bone wall [Covani et al. 2004; Fugazzotto 2005]. Results from recent clinical studies, however, demonstrate that in spite of using different regenerative approaches, buccal bone resorption occurs, although to a minor extent [Chen et al. 2007].

Tapered or root-shaped implants are frequently used in Type 1 procedures. Such implants are designed with wide cone-shaped marginal and narrower cylindrical apical portions with the aim of filling the space between the titanium rod and the residual bone walls. Recent evidence from animal studies [Araújo et al. 2006], however, has shown that the presence of a narrow space between the implant and the severed socket wall may not prevent bone loss occurring following tooth extraction. Hence, there is a risk that the surface of such wide implants may become exposed to the mucosa during healing and that this, in turn, may compromise treatment outcomes.

The primary objective of this study was to determine the association between the size of the void established by using two different implant configurations and the amount of buccal/palatal bone loss occurring during healing following implant installation into extraction sockets. This was accomplished by determining alterations of the horizontal and vertical dimensions of the buccal and palatal void and surrounding bone structures at placement and after initial healing (16 weeks after implant placement).

Material and methods

Study design

The study was designed as a prospective, randomized-controlled parallel-group multicenter study documenting the response of two implants with different configurations in the treatment of subjects in need of one or more single implants replacing teeth to be removed in the maxilla. Four centers are involved in the current clinical study, namely, Department of Periodontology and fixed Prosthodontics, University of Berne, Switzerland, Department of Periodontology, Universidad de Complutense, Madrid, Spain, Department of Periodontology, Institute of Odontology at Sahlgrenska Academy, University of Gothenburg, Sweden, and Institute Franci, Padova, Italy. The study protocol, as well as the informed consent forms, were approved by the human review boards from the respective participating institutions.

This clinical trial was registered at [Clinicaltrials.gov.: http://clinicaltrials.gov/ct2/show/NCT00711282?term=NCT00711282&rank=1]

Study population

Adult [≥ 18 years of age] subjects in need of one or more implants replacing teeth to be removed in the maxilla within region 15–25 were included if they fulfilled the following criteria:

- Presence of at least 20 teeth with expected functional occlusion after restoration.
- Presence of an intact extraction socket following removal of the natural tooth defined by:
  - An anatomy suitable for both cylindrical and conical/cylindrical implants.
  - A marginal border of the facial bone crest that deviated ≤ 2 mm from that of the expected normal location of the site/region.
  - A potential facial fenestration at least 3 mm apical of the marginal bone crest.

Subjects were excluded if they indicated the presence of any of the following:

- Untreated rampant caries and uncontrolled periodontal disease.
- Absence of adjacent (mesial and/or distal) natural tooth root.
- Uncontrolled diabetes or any other systemic or local disease or condition that would compromise post-operative healing and/or osseointegration.
- Need for systemic corticosteroids or any other medication that would compromise post-operative healing and/or osseointegration.
- Unable or unwilling to return for follow-up or unlikely to be able to comply with study procedures according to investigators’ judgment.
Smokers with a cigarette consumption in excess of 10 cigarettes, or equivalent, per day during the healing period.

Treatments
Before implant placement, the selected tooth was carefully extracted with the use of a periosteum. In the removal of multi-rooted teeth, sectioning of the tooth in a mesial/distal dimension was accomplished with a high-speed hand-piece and an appropriate burr.

Provided the extraction socket met the inclusion criteria, the site was allocated to either treatment group A (Test) or B (Control). An independent randomization schedule was generated for each center in blocks and designed to ensure a balanced distribution of treatments. In each center, the randomized treatment code was available in closed non-transparent envelopes.

Fig. 1 presents the randomization and treatment allocation flow chart.

Two types of implant configurations were used (Fixture Microthread™ OsseoSpeed™, Astra Tech AB, Mölndal, Sweden). Such implants [Fig. 2] are available in four diameters, 3.5, 4, 4.5, and 5 mm, based on their cervical diameter. Two of the implants, the 3.5 and 4 mm variety, are cylindrical (group A). The 4.5 and 5 mm implants are cylindrical in the apical portion while the cervical portion is tapered [conical] (group B). The apical diameter is 3.5 mm on the 4.5 implants and 4 mm on the 5 implant.

The implants were placed in accordance with the guidelines described in the Astra Tech Manual™ ‘Surgical Procedures.’

After implant insertion, a gap occurred between the implant surface and the hard tissue walls of the extraction socket. This defect could be present at the buccal, mesial, palatal and distal aspects of the implant. In order to describe the size of the defect, the following landmarks were defined (Fig. 3):

- Surface of implant (S).
- Rim of implant (R).
- Top of the bone crest (C).
- Inner border of the bone crest (IC), 1 mm apical of C.
- Outer border of the bone crest (OC), 1 mm apical of C.
- Base of the defect (D).

After implant installation, the size of the defect for the buccal and palatal aspects was characterized by the following dimensions measured to the nearest millimeter using a periodontal probe [Hu-Friedy Diagnostic Probe UNC, UNC15 Quilix, Hu-Friedy Mfg. Co Inc., Chicago, IL, USA] (Figs 4–7):

- S to IC, constituting the horizontal defect distance, i.e. the width of the gap between the implant surface and the bone crest (S–IC buccal and S–IC palatal) [Fig. 4].
- S to OC, the horizontal distance between the implant surface and the outer surface of the bone crest (S–OC buccal and S–OC palatal) [Fig. 4].
- R to D constituting the vertical defect distance from the rim of the implant to the base of the defect (R–D buccal and R–D palatal) [Fig. 5].
R to C, the vertical distance between the rim of the implant to the top of the bone crest (R–C buccal and R–C palatal). This measure could be assigned a positive or a negative value depending on whether R was located apical of (positive) or below (negative) (Fig. 6) the bone crest (C).

The thickness of the buccal and palatal bone walls was measured 1 mm apical of the top of the bone crest. This was measured to the nearest half millimeter using a caliper instrument (Iwanson caliper, DP720, Bontempi snc, Bolonia, Italy) (Fig. 7).

All measurements were carried out by well-trained calibrated examiners independent from the surgeons placing the implants.

Following the installation, the stability of the implant was clinically assessed. The appropriate healing abutments were subsequently installed (Healing Abutment or Healing Abutment Zebra, Astra Tech AB). The soft tissues were then adapted and sutured to allow semi-submerged healing.

After surgery, mouth rinsing with chlorhexidine 0.1 % or 0.12 %, twice daily for 10 days, was prescribed, together with the recommended medication prescribed by the surgeon [such as analgesics, anti-inflammatory compounds or antibiotics].

No implant-supported temporary restorations were used during the first 4 months.

Seven days after implant placement, the patients returned and the sutures were removed.

At 16 weeks after implant placement, the patient returned for the re-entry procedure. The healing abutment was removed and full-thickness flaps were elevated. Implant stability was examined and the remaining size of the defect was recorded in the manner described following the implant installation (Figs 5–6). Prosthetic restorations were delivered 22 weeks after implant placement and periapical radiographs were taken to record baseline interproximal bone levels. Each patient was placed in a 3-year follow-up program, including the following examinations at yearly visits: implant stability, bleeding index, soft tissue level [mid-buccal and papilla] and radiographic bone levels. In addition, adverse events and adverse device effects [complications] were recorded. This paper reports on the 16-week follow-up data only.

**Statistical methods**

The null hypothesis is that the reduction in the thickness of the buccal bone plate following resorption in the outer surface of the crest is constant irrespective of the
size of the void established by using different implant geometries. A void between the titanium surface and the inner aspect of the socket will allow formation of a stable coagulum, the proper maturation of which will be followed by hard tissue formation. The use of a conical/cylindrical implant (Control – group B) obviously reduced the size of the void. The assumption is that a cylindrical implant (Test – group A), by providing more space for the coagulum, will have a positive effect on the preservation of the bone and that this in turn will result in less marked decrease of the S to OC dimension. With this assumption, the sample size was calculated using the results from an earlier study [Botticelli et al. 2004] that also assessed the horizontal distance from the implant surface to the other surface of the bone crest at 4 months after implant installation. They reported a 56% reduction of this distance. The assumption was that this reduction, when a cylindrical implant was used (Test), would be 20% less. Assuming an intra-patient standard deviation of the change of 0.9 mm in both groups and 80% power, together with a foreseen dropout of 8%, 120 patients needed to be included.

Demographics and other baseline characteristics were presented by means of descriptive statistics. Continuous variables were presented by means of number of observations \( N \), minimum \( \text{min} \), median, maximum \( \text{max} \), mean and standard deviation \( \text{SD} \) and discrete variables by frequency and percentage.

Inter-group comparisons were performed using Student’s t-test. A two-sided \( P \)-value of \( P \leq 0.05 \) was considered to be statistically significant.

Results

Fig. 1 presents the study population. It consisted of 108 subjects, 104 treated, 95 randomized and 93 subjects who remained in the study at re-entry [16 weeks, Fig. 1]. In these 93 subjects, 99 implants had been placed: 50 in group A and 49 in group B. The 93 randomized subjects were distributed as follows: 25 in Center 1, 37 in Center 2 and 31 in Center 3. Four subjects discontinued before treatment. Nine subjects did not meet the inclusion/exclusion criteria. Two subjects discontinued before the re-entry procedure at 4 months. Six subjects had two randomized implants, one in each subject was excluded by tossing a coin. Hence, a total of 93 implant sites in 93 subjects were included in the analysis [45 in group A and 48 in group B].

The demographic and key baseline characteristics of the study subjects, including implant diameter, reason for extraction, smoking during healing and thickness of the buccal bone walls, are summarized in Table 1. In general, the baseline characteristics of the two groups were similar. Mechanical [primary] implant stability [lack of mobility, when the healing abutment was applied] was obtained in 97% of the cases.

All implant sites except two healed uneventfully. In one site the patient reported pain after surgery and at one site the clinician reported the occurrence of swelling and inflammation at suture removal. The following complications were reported at re-entry: incomplete buccal bone fill [1 site], incomplete buccal bone fill and implant mobility [1 site] and loss of the entire buccal bone wall [1 site]. Bone regeneration was used in the first two cases and the implant was explanted in the third situation.

The dimensional alterations that occurred during healing are reported in Tables 2–5.

Dimension S–OC (Table 2)
The mean reduction of S–OC during the 16 weeks that followed implant installation was 1.2 and 1.0 mm (groups A and B) at the buccal aspect and 0.6 and 0.4 mm in groups A and B at the palatal aspect. This represents a 43% and 30% buccal and an 18% and 11% palatal reduction in groups A and B. These differences between the two groups were not statistically significant.

Dimension S–IC (horizontal gap) (Table 3)
The horizontal gap underwent marked changes during healing at both the buccal and the palatal aspects of the implant. Thus, on the buccal aspect, the reduction amounted to 1.6 (80%) and 1.4 mm (63%) (groups A and B), while on the palatal aspects, the change amounted to 0.9 (70%) and 0.4 mm (58%), respectively. The reductions in the gap size, both in the buccal and the palatal aspects, were

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### Table 1. Baseline characteristics of the study sample

<table>
<thead>
<tr>
<th>Treatment group</th>
<th>A (n = 45)</th>
<th>B (n = 48)</th>
<th>Total (n = 93)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (n and % of subjects)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>28 (62%)</td>
<td>20 (42%)</td>
<td>48 (52%)</td>
</tr>
<tr>
<td>Female</td>
<td>17 (38%)</td>
<td>28 (58%)</td>
<td>45 (48%)</td>
</tr>
<tr>
<td>Age (years)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>50.4 (13.1)</td>
<td>51.8 (13.5)</td>
<td>51.1 (13.2)</td>
</tr>
<tr>
<td>Median</td>
<td>51</td>
<td>53</td>
<td>52</td>
</tr>
<tr>
<td>Range</td>
<td>19–73</td>
<td>23–80</td>
<td>19–80</td>
</tr>
<tr>
<td>Smoking during healing (n and % of subjects)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>31 (69%)</td>
<td>31 (65%)</td>
<td>62 (67%)</td>
</tr>
<tr>
<td>Yes</td>
<td>14 (31%)</td>
<td>17 (35%)</td>
<td>31 (33%)</td>
</tr>
<tr>
<td>Teeth extracted (n and % of subjects)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central incisor</td>
<td>5 (11%)</td>
<td>5 (10%)</td>
<td>10 (11%)</td>
</tr>
<tr>
<td>Lateral incisor</td>
<td>9 (20%)</td>
<td>10 (21%)</td>
<td>19 (20%)</td>
</tr>
<tr>
<td>Canine</td>
<td>3 (7%)</td>
<td>7 (15%)</td>
<td>10 (11%)</td>
</tr>
<tr>
<td>First and second premolars</td>
<td>28 (62%)</td>
<td>26 (54%)</td>
<td>54 (58%)</td>
</tr>
<tr>
<td>Main reason for extraction (n and % of subjects)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trauma</td>
<td>5 (11%)</td>
<td>5 (10%)</td>
<td>10 (11%)</td>
</tr>
<tr>
<td>Caries/endodontic</td>
<td>33 (73%)</td>
<td>30 (63%)</td>
<td>63 (68%)</td>
</tr>
<tr>
<td>Periodontitis</td>
<td>6 (13%)</td>
<td>10 (21%)</td>
<td>16 (17%)</td>
</tr>
<tr>
<td>Other</td>
<td>1 (2%)</td>
<td>3 (6%)</td>
<td>4 (4%)</td>
</tr>
<tr>
<td>Thickness of buccal bone wall</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>1 (0.5)</td>
<td>0.9 (0.5)</td>
<td>1 (0.5)</td>
</tr>
<tr>
<td>Median</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Range</td>
<td>0.5–2</td>
<td>0.5–3</td>
<td>0.5–3</td>
</tr>
<tr>
<td>Implant diameter (n and % of subjects)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.5</td>
<td>1 (2%)</td>
<td>0 (0%)</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>4</td>
<td>44 (98%)</td>
<td>0 (0%)</td>
<td>44 (47%)</td>
</tr>
<tr>
<td>4.5</td>
<td>0 (0%)</td>
<td>42 (88%)</td>
<td>42 (45%)</td>
</tr>
<tr>
<td>5</td>
<td>0 (0%)</td>
<td>6 (12%)</td>
<td>6 (6%)</td>
</tr>
</tbody>
</table>
between surgery and re-entry (16 weeks) as described by changes of the dimension R–D

Table 2. Crestal bone resorption that occurred in groups A and B between surgery and re-entry (16 weeks) as described by changes of the dimension S–OC

<table>
<thead>
<tr>
<th>S–OC</th>
<th>A (N = 45)</th>
<th>B (N = 48)</th>
<th>P</th>
<th>A + B (N = 93)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buccal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At surgery</td>
<td>3.1 ± 1.2</td>
<td>3 ± 1.1</td>
<td>0.64</td>
<td>3 ± 1.1</td>
</tr>
<tr>
<td>At 16 weeks</td>
<td>1.9 ± 1.2</td>
<td>2 ± 1.2</td>
<td>0.53</td>
<td>1.9 ± 1.2</td>
</tr>
<tr>
<td>Difference</td>
<td>1.2 ± 0.9</td>
<td>1 ± 1.1</td>
<td>0.26</td>
<td>1.1 ± 1</td>
</tr>
<tr>
<td>Mean % reduction</td>
<td>43 ± 34</td>
<td>30 ± 39</td>
<td>0.08</td>
<td>36 ± 37</td>
</tr>
<tr>
<td>Median % reduction</td>
<td>40</td>
<td>33</td>
<td></td>
<td>37</td>
</tr>
<tr>
<td>Palatal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At surgery</td>
<td>2.5 ± 0.8</td>
<td>2 ± 0.9</td>
<td>0.0074*</td>
<td>2.2 ± 0.9</td>
</tr>
<tr>
<td>At 16 weeks</td>
<td>1.9 ± 0.8</td>
<td>1.6 ± 0.8</td>
<td>0.08</td>
<td>1.8 ± 0.8</td>
</tr>
<tr>
<td>Difference</td>
<td>0.6 ± 0.9</td>
<td>0.4 ± 0.7</td>
<td>0.23</td>
<td>0.5 ± 0.8</td>
</tr>
<tr>
<td>Mean % crest reduction</td>
<td>18 ± 37</td>
<td>11 ± 35</td>
<td>0.34</td>
<td>14 ± 36</td>
</tr>
<tr>
<td>Median % crest reduction</td>
<td>33</td>
<td>0</td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

*Statistically significant.

Buccal and palatal measurements are reported separately (mean and SD).

Table 3. Change of the size of the horizontal gap and amount of gap fill in groups A and B between surgery and re-entry (16 weeks) as described by changes of the dimension S–IC

<table>
<thead>
<tr>
<th>S–IC</th>
<th>A (N = 45)</th>
<th>B (N = 48)</th>
<th>P</th>
<th>A + B (N = 93)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buccal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At surgery</td>
<td>2.1 ± 1.1</td>
<td>2.2 ± 1.2</td>
<td>0.67</td>
<td>2.1 ± 1.1</td>
</tr>
<tr>
<td>At 16 weeks</td>
<td>0.4 ± 0.7</td>
<td>0.8 ± 0.8</td>
<td>0.02*</td>
<td>0.6 ± 0.7</td>
</tr>
<tr>
<td>Difference</td>
<td>1.6 ± 1.1</td>
<td>1.4 ± 1.1</td>
<td>0.3</td>
<td>1.5 ± 1.1</td>
</tr>
<tr>
<td>Mean % gap fill</td>
<td>80 ± 31</td>
<td>63 ± 41</td>
<td>0.03*</td>
<td>71 ± 37</td>
</tr>
<tr>
<td>Median % gapfill</td>
<td>100</td>
<td>67</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Palatal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At surgery</td>
<td>1.4 ± 0.8</td>
<td>0.8 ± 0.9</td>
<td>0.001*</td>
<td>1.1 ± 0.9</td>
</tr>
<tr>
<td>at 16 weeks</td>
<td>0.5 ± 0.6</td>
<td>0.4 ± 0.6</td>
<td>0.47</td>
<td>0.4 ± 0.6</td>
</tr>
<tr>
<td>Difference</td>
<td>0.9 ± 0.9</td>
<td>0.4 ± 0.8</td>
<td>0.005*</td>
<td>0.6 ± 0.9</td>
</tr>
<tr>
<td>Mean % gap fill</td>
<td>70 ± 39</td>
<td>58 ± 46</td>
<td>0.29</td>
<td>66 ± 42</td>
</tr>
<tr>
<td>Median % gap fill</td>
<td>100</td>
<td>83</td>
<td></td>
<td>100</td>
</tr>
</tbody>
</table>

*Statistically significant.

Buccal and palatal measurements are reported separately (mean and SD).

Table 4. Change of the size of the vertical gap and amount of gap fill in groups A and B between surgery and re-entry (16 weeks) as described by changes of the dimension R–D

<table>
<thead>
<tr>
<th>R–D</th>
<th>A (N = 45)</th>
<th>B (N = 48)</th>
<th>P</th>
<th>A + B (N = 93)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buccal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At surgery</td>
<td>6.5 ± 3.1</td>
<td>8.3 ± 3.5</td>
<td>0.0092*</td>
<td>7.5 ± 3.4</td>
</tr>
<tr>
<td>At 16 weeks</td>
<td>1.8 ± 2.1</td>
<td>2.7 ± 2.9</td>
<td>0.066</td>
<td>2.3 ± 2.6</td>
</tr>
<tr>
<td>Difference</td>
<td>4.8 ± 3.6</td>
<td>5.6 ± 4.1</td>
<td>0.3</td>
<td>5.2 ± 3.9</td>
</tr>
<tr>
<td>Mean % gap fill</td>
<td>69 ± 40</td>
<td>65 ± 37</td>
<td>0.64</td>
<td>67 ± 39</td>
</tr>
<tr>
<td>Median % gap fill</td>
<td>88</td>
<td>78</td>
<td></td>
<td>83</td>
</tr>
<tr>
<td>Palatal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At surgery</td>
<td>4.2 ± 3.7</td>
<td>2.8 ± 3</td>
<td>0.045*</td>
<td>3.4 ± 3.4</td>
</tr>
<tr>
<td>At 16 weeks</td>
<td>1.2 ± 1.8</td>
<td>1.1 ± 1.3</td>
<td>0.92</td>
<td>1.1 ± 1.6</td>
</tr>
<tr>
<td>Difference</td>
<td>3 ± 3.4</td>
<td>1.6 ± 2.9</td>
<td>0.036*</td>
<td>2.3 ± 3.2</td>
</tr>
<tr>
<td>Mean % gap fill</td>
<td>70 ± 43</td>
<td>58 ± 50</td>
<td>0.29</td>
<td>65 ± 46</td>
</tr>
<tr>
<td>Median % gap fill</td>
<td>88</td>
<td>75</td>
<td></td>
<td>80</td>
</tr>
</tbody>
</table>

*Statistically significant.

Buccal and palatal measurements are reported separately (mean and SD).

significantly greater in group A than in group B (P < 0.05).

Dimension R–D (vertical defect) (Table 4)

During the 16 weeks of healing, the vertical defect depth was markedly reduced on both the buccal and the palatal aspects of the extraction socket. The reduction at the buccal aspect varied between 4.8 mm (69%) and 7.6 mm (65%) in groups A and B, while the corresponding reductions at the palatal aspect were 3.0 mm (70%) and 1.6 mm (58%). Differences between groups were not statistically significant.

Dimension R–C (vertical crest reduction) (Table 5)

The reduction of the height of the marginal bone crest was more pronounced at the buccal than at the palatal aspect of the extraction site (1.0 vs. 0.5 mm). There was, however, no difference between groups A and B regarding this outcome variable.

Discussion

The present clinical study demonstrated that the removal of single teeth resulted in a marked reduction of the buccal–lingual dimension of the alveolar ridge at the pristine edentulous site. This is in agreement with data reported previously in both retrospective (e.g. Pietrokovski & Massler 1967; Pietrokovski et al. 2007) and prospective studies (Schropp et al. 2003) in humans. In a recent experiment, using a canine model, Araujo et al. [2005] showed that the reduction of the dimension of an extraction site was the result of [i] replacement of bundle bone with woven bone from the inner portion and [ii] substantial resorption of the outer and crestal portions of the buccal–lingual socket walls. The outcome of short-term experiments suggested [e.g. Blanco et al. 2008, Fickl et al. 2008] that the dimensional change that occurred following tooth extraction was at least in part the effect of the preparation of full-thickness flaps that was performed in conjunction with surgery. Recently, in a dog study, single teeth were either removed following flap elevation or in a flapless procedure [Araujo & Lindhe 2009]. In biopsies sampled after 6 months of healing, the authors observed that similar amounts of hard tissue loss had occurred irrespective of the procedure used during tooth extraction. In other words, ridge alterations that occur following tooth removal are mainly the result of the loss of the tooth and its function.

The present study also documented that the placement of an implant in the fresh extraction socket (Type I placement; Hämmerle et al. 2004) failed to prevent the buccal–lingual ridge contractions that apparently always take place following
tooth loss. This confirms findings from a clinical study [Botticelli et al. 2004]. It was observed that 4 months after the removal of single teeth (maxillary and mandibular canines and premolars) and immediate implant placement, the buccal–lingual dimension of the marginal portion of the edentulous sites was substantially reduced (about 2.8 mm or 40%). In the current study, the corresponding ridge reduction at 4 months was somewhat smaller (1.6 mm or about 25%) than that reported by Botticelli et al. [2004]. The reason for this discrepancy in treatment outcome is presently not understood, but may be related to the larger number of patients and sites treated as well as the larger number of clinicians who were involved in the present clinical trial.

In the current study, the hard tissue resorption that occurred during healing following tooth extraction and Type 1 implant placement was twice as large at the buccal as at the palatal aspect of the ridge [35% vs. 14%]. This is in agreement with the findings of Botticelli et al. [2004], who observed that the corresponding buccal hard tissue dimension amounted to 1.9 ± 0.9 mm while the change at the lingual/palatal aspect was considerably smaller (0.9 ± 0.6 mm). The data of the present study also corroborate findings by Pietrokovski & Massler [1967], who carried out measurements on casts of 149 dentate jaws in which one tooth was missing on one side while the contra-lateral tooth was present. Their measurements, which included both soft and hard tissues, indicated that tooth resorption following tooth loss in the maxillary incisor, canine and premolar region was much more pronounced in the buccal than in the palatal compartment of the alveolar ridge. The results of the present study also support observations of studies in dogs [Araújo et al. 2005]. In hemi-sectioned mandibular premolars, distal roots were extracted. In one quadrant, implants were placed into the post-extraction sockets (implant sites), while in the contralateral site, the sockets were left without additional therapy (coagulum sites). In biopsies sampled after 3 months of healing, it was observed that the buccal–lingual diminution that had occurred in the alveolar ridge at the implant and coagulum sites was similar. In this context, it should be observed that the buccal–lingual reduction occurred only in the marginal third of the extraction site [Araújo et al. 2008, Araújo & Lindhe 2009], i.e. in a location where the volume of the extracted root is large and the buccal/lingual bone walls are comparatively thin.

Following Type 1 implant placement, a marginal defect often occurs between the walls of the socket and the titanium device (e.g. Lang et al. 2007; Hämmerle et al. 1998; Wilson et al. [1998]; Botticelli et al. 2004). This defect is rapidly filled with a coagulum that is subsequently replaced with bone [Araújo et al. 2006]. In the current study, it was observed that the horizontal component of the buccal gap, which was 2.1 ± 1.1 mm at baseline, had reduced to 0.6 ± 0.7 mm [71%] at the 4-month re-entry examination interval. The corresponding percentage reduction of the palatal gap was similar and amounted to 66%. This change of the dimension of the marginal gap confirms the data presented by Botticelli et al. [2004]. They reported that the gap, which was on average 2.0 mm (buccal) and 1.5 mm (lingual) wider at baseline, had been reduced to 0.4 mm for both aspects at the re-entry assessments after 4 months.

In the present study, the degree of vertical bone fill (change R–D, buccal + palatal) that had occurred between baseline and 4 months amounted to about 60–70%. Also, this extent of defect reduction corroborates the findings of Botticelli et al. [2004] and illustrates that only minor marginal defects may remain 4 months after Type 1 treatment.

The primary objective of the present trial was to compare the ridge and gap alterations that occurred following Type 1 placement of implants with different configurations (cylindrical vs. conical/cylindrical), i.e. implants that, in the marginal portion, occupied different volumes of the extraction socket. In this context, it must be observed, however, that the vast majority of the implants used had a marginal diameter of either 4 mm (group A) or 4.5 mm (group B), i.e. a difference between the groups of only 0.25 mm in the buccal, palatal, mesial and distal directions.

Two variables (S–OC; buccal, palatal and R–C; buccal, palatal) were used to study dimensional changes of the ridge that occurred in the two treatment groups. It was observed that during the 4 months of healing, there was a marked horizontal contraction of the marginal ridge in both groups. In group A, S–OC (buccal + palatal) was reduced by 1.8 mm, with a similar change in group B (1.4 mm). Also, the ‘vertical’ reduction (R–C) of the buccal and palatal walls of the socket was similar in the two treatment groups and amounted to about 1 mm at the buccal and 0.5 mm at the palatal aspects. In other words, the reduction of the ridge that occurred following tooth extraction in the current study was apparently independent of the geometry of the implants used to substitute for the tooth.

During installation, implants were during installation obviously placed in the palatal part of the socket. This is evidenced by the fact that S–C buccal at the aspect was 2.1 mm (group A) and 2.2 mm (group B), while the corresponding dimension at the palatal aspect (S–C; palatal) was markedly smaller (1.4 mm group A and 0.8 mm group B). This also means that the buccal void at baseline was larger than the void at the palatal aspect and that consequently the space that potentially could be filled with hard tissue was larger buccally than palatally. Hence, it is not surprising to find that the amount of hard tissue fill was substantially larger at the buccal (1.6 and

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**Table 5. Change of the position of the marginal bone crest and amount of cresta resorption in groups A and B between surgery and re-entry (16 weeks) as described by changes of the dimension R–C**

<table>
<thead>
<tr>
<th></th>
<th>A (N = 45)</th>
<th>B (N = 48)</th>
<th>P</th>
<th>A + B (N = 93)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Buccal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At surgery</td>
<td>0.4 ± 1.1</td>
<td>0.1 ± 0.9</td>
<td>0.17</td>
<td>0.3 ± 0.1</td>
</tr>
<tr>
<td>At 16 weeks</td>
<td>−0.6 ± 1.7</td>
<td>−0.8 ± 2.2</td>
<td>0.53</td>
<td>−0.7 ± 1.9</td>
</tr>
<tr>
<td>Difference</td>
<td>−1 ± 1.7</td>
<td>−1 ± 2.2</td>
<td>0.96</td>
<td>−1 ± 2</td>
</tr>
<tr>
<td><strong>Palatal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At surgery</td>
<td>0.2 ± 1.6</td>
<td>0.2 ± 1.3</td>
<td>0.65</td>
<td>0.1 ± 1.4</td>
</tr>
<tr>
<td>At 16 weeks</td>
<td>−0.3 ± 1.1</td>
<td>−0.4 ± 1.3</td>
<td>0.67</td>
<td>−0.4 ± 1.2</td>
</tr>
<tr>
<td>Difference</td>
<td>−0.5 ± 1.6</td>
<td>−0.5 ± 1.4</td>
<td>0.91</td>
<td>−0.5 ± 1.5</td>
</tr>
</tbody>
</table>

Buccal and palatal measurements are reported separately (mean and SD).
References


References (2003) referred to above. They examined
of the extraction site was reduced, the
period. It was observed that whereas the
height of the buccal and lingual bone crests
of the extraction site was reduced, the
mesial and distal socket walls remained
unchanged. This finding is in agreement
with data from the study by Schropp et al. [2003] referred to above. They examined
tissue changes that occurred at the mesial
and distal septa between the extraction site
and adjacent teeth following single tooth
extraction and concluded that only minor
alterations took place at such interproximal
locations during a 12-month period of heal-
ing. The present findings are also in agree-
ment with the results obtained by Botticelli
et al. (2004), who demonstrated that less
change had occurred at mesial and distal
aspects of the socket than at buccal and
lingual portions 4 months following single
tooth extraction and Type 1 implant place-
ment.

The hard tissue changes that occurred in
the current clinical trial during the first 4
months of healing were quite substantial
but additional change may in fact occur
during later phases of tissue remodeling.
Thus, Schropp et al. (2003), who studied
ridge alterations following tooth extraction
on models (hard and soft tissues com-
bined), found that the contraction – in the
marginal 1/3rd of the ridge which, at the 3-
month interval, was 30% had increased to
50% after 12 months. In other words,
during the first 3 months, 3.6 mm of the
horizontal dimension was lost while during
the subsequent 9 months an additional
2.4 mm disappeared.

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Ridge augmentation for immediate postextraction
implants: a pilot study in dogs. The International

Lang, N.P., Tonetti, M.S., Suwan, J.E., Pierre Ber-
nard, J., Botticelli, D., Fournoumis, L., Hallund,
M., Jung, R., Laurell, L., Salvi, G.E., Shafer, D.
with transmucosal healing in areas of aesthetic
priority. A multicentre randomised-controlled
clinical trial I. Surgical outcomes. Clinical Oral
Implants Research 18: 188–196.

Paolantonio, M., Dolci, M., Scarano, A., d’Archivio,
D., di Placido, G., Tumini, V. & Piattelli, A.
(2001) Immediate implantation in fresh extraction
sockets. A controlled clinical and histological
review and proposed hierarchy of treatment selec-

Lang, N.P. (1998) Successful bone formation at
immediate transmucosal implants: a clinical
report. International Journal of Oral Maxillofa-

Consensus statements and recommended clinical
procedures regarding the placement of implants in
extraction sockets. International Journal of Oral

Huys, L.W. (2001) Replacement therapy and the
immediate post-extraction dental implant. Im-

Immediate placement and provisionalization of
maxillary anterior single implants: 1-year prospec-
tive study. The International Journal of Oral &
Maxillofacial Implants 18: 1–19.

Kababuda, C., Sandalli, P., Yalcin, S., Steflik, D.E.
& Parr, G.R. (1999) Histologic and histomorpho-
metric comparison of immediately placed hydro-
xyapatite-coated and titanium plasma-sprayed
implants: a pilot study in dogs. The International

Barzilay, I., Graser, G.N., Iranpour, B., Natiella, J.R.
& Proskin, H.M. (1996) Immediate implantation
of pure titanium implants into extraction sockets
of Macaca fascicularis. Part II: histologic obser-
vations. The International Journal of Oral & Max-

Barzilay, I., Graser, G.N., Iranpour, B., Natiella, J.R.
& Proskin, H.M. (1996) Immediate implantation
of pure titanium implants into extraction sockets
of Macaca fascicularis. Part II: histologic obser-
vations. The International Journal of Oral & Max-

replacement by immediate implant and connec-
tive tissue graft: a 1–9-year clinical evaluation.