Short implants (6 mm) installed immediately into extraction sockets: An experimental study in dogs

Key words: animal study, extraction socket, implant dentistry, short implants, hard tissue, soft tissues, peri-implant mucosa, osseointegration

Abstract

Aim: To evaluate the effect of implant length (6 mm vs. 11 mm) on osseointegration (bone-to-implant contact) of implants installed into sockets immediately after tooth extraction.

Material and methods: In six Labrador dogs, the pulp tissue of the mesial roots of $3_P_3$ was removed and the root canals were filled. Flaps were elevated bilaterally, the premolars hemi-sectioned and the distal roots removed. Recipient sites were prepared in the distal alveolus and a 6 mm or an 11 mm long implant was installed at the test and control sites, respectively. Non-submerged healing was allowed. After 4 months of healing, block sections of the implant sites were obtained for histological processing and peri-implant tissue assessment.

Results: No statistically significant differences were found between test and control sites both for hard and soft tissue parameters. The bone-to-implant contact evaluated at the apical region of the implants was similar as well. Although not statistically significant, the location of the top of the bony crest at the buccal aspect was more apical in relation to the implant shoulder at the test compared with the control sites ($2.0 \pm 1.4$ and $1.2 \pm 1.1$ mm, respectively).

Conclusions: Shorter implants (6 mm) present with equal osseointegration than do longer implants (11 mm).

Implants installed into alveolar sockets immediately after tooth extraction have been shown to yield predictable outcomes [e.g. Quirynen et al. 2007; Botticelli et al. 2008]. Furthermore, a recent systematic review (Lang et al. 2012) has established the fact that such implants present with similar survival rates (estimated annual failure rate: 0.82%) as conventionally placed implants. The use of this procedure reduces the number of surgical sessions and may also reduce the time between surgery and prosthetic delivery [Hämerle et al. 2004]. This technique, however, cannot prevent the physiological bone resorption that occurs after tooth extraction [e.g. Botticelli et al. 2004; Araújo et al. 2005; Lang et al. 2012].

For this placement modality (type 1; Hämerle et al. 2004), the need for implants that are longer than the remaining extraction sockets has been propagated under the assumption that implant stability may be guaranteed in the area beyond the apex of the extraction socket [e.g. Covani et al. 2004; Becker et al. 2011; González-Martín et al. 2012]. Because of the presence of anatomical structures such as the maxillary sinus or the inferior alveolar nerve, however, bone may not be available beyond the apex of the socket. Moreover, it was shown in experimental animals that immediate implants became osseointegrated irrespective of their length in relation to the extraction socket [e.g. Caneva et al. 2010b]. In these experimental studies, however, the length of the implants was at least of 10 mm.

Moreover, the use of short implants (6 mm) has been reported with good outcomes [e.g. ten Bruggenkate et al. 1998; Renouard & Nisand 2006; Rossi et al. 2010; Sun et al. 2011] and promising results have been published on the installation of short implants in comparison with alveolar bone augmentation techniques [Esposito et al. 2011; Felice et al. 2011]. However, the use of short implants (6 mm) in immediate installation has not been studied as yet. Hence, the aim of the present study was to compare the bone-to-implant contact of 6 mm osseointegrated implants with that of
11 mm long implants installed into sockets immediately after tooth extraction.

Material and methods

Clinical procedures

The protocol was approved by the institutional Ethic Committee for animal research. Six Labrador dogs (mean weight approximately 27–28 kg and mean age of about 2 years) were. During all surgical procedures, the animals were pre-anaesthetized with Xylazine® (1mg/kg intramuscular [i.m.] Ronpum®, Bayer, São Paulo, Brazil) and Ketamine® (15mg/kg i.m., Dopalens, Vetbrands, São Paulo, Brazil) and anaesthetized with Thionembutal® (20mg/kg intravenous [i.v.]) Tiopental®, Cristália, Itapira, Brazil). During the entire surgery, the animals inhaled O2 and were kept with an intravenous infusion of saline.

As described previously (Caneva et al. 2010a), the pulp tissue of the mesial roots of \( \text{P}_2 \) was removed, the root canals filled with gutta-percha and root canal cement [Mtwo®, Endopocket®, Epfill®, Sweden & Martina, Due Carrare, Padova, Italy]. The crowns were subsequently restored with composite (Ado-Cure Carrare, Padova, Italy). The crowns were heath abutment was affixed to the implant (Fig. 1b), and the flaps were mobilized and sutured to allow a non-submerged healing using interrupted Vicryl™ 4-0 sutures [Johnson & Johnson, São José dos Campos, Brazil]. The same surgical procedures and measurements were performed in the left side of the mandible. However, a shorter implant [6 mm long, Astra Tech, Osseospeed®, Göteborg, Sweden] with the same diameter (4 mm) was placed (test site).

After the surgeries, the animals were given a vitamin compound [Potenay®, Fort Dodge Animal Health, Campinas, Brazil], anti-inflammatory/analgesic drugs (Banamine®, Schering-Plough Animal Health) and antibiotics [Pentabiotico®; Fort Dodge Animal Health]. The animals were kept in kennels and on concrete runs at the university’s field laboratory with free access to water and feed of moistened balanced dog’s chow.

A daily inspection of the wounds for clinical signs of complications and healing abutment cleaning was performed. The animals were killed 4 months after the surgery applying an overdose of Thiopental® (Cristália Ltd, Campinas, Brazil) and were perfused with a fixative [4% formaldehyde solution] through the carotid arteries.

Histological preparation

Individual bone blocks containing the implant and the surrounding soft and hard tissues were fixed in 4% formaldehyde solution followed by dehydration in a series of graded ethanol solutions, and finally embedded in resin [LR White® hard grade; London Resin Company Ltd, Berkshire, UK]. The blocks were cut in a bucco-lingual plane using a diamond band saw fitted in a precision slicing machine [Exakt®; Apparatebau, Norderstedt, Germany] and then reduced to a thickness of about 50 μm using a cutting-grinding device [Exakt®; Apparatebau].

The histological slides were stained with Stevenel’s blue and alizarin red and examined under a standard light microscope for histomeric analysis.

Histological evaluation

In a Nikon Eclipse 50i microscope (Nikon Corporation, Tokyo, Japan) at a magnification of ×100, the following landmarks were identified (Fig. 2): the implant shoulder (IS), the most coronal bone-to-implant contact (B), the top of the adjacent bony crest (C), the top of the peri-implant mucosa (PM), the apical portion of the barrier (junctional) epithelium (aJE).

The following measurements of the hard and soft tissues were performed parallel to the long axis of the implant: the vertical distance between IS and B (IS-B), IS and C (IS-C), etc.
PM and B [PM-B], and PM and aJE [PM-aJE]. The horizontal distance between IS and C (GAP) was measured as well. The vertical distances between PM-C, aJE-B and PM-IS were subsequently calculated. The linear distance between PM and aJE (PM-aJE surface) and between aJE and B (aJE-B surface) were also measured following the surface of the abutment/implant unit (Fig. 2). The amount of bone-to-implant contact [BIC% total] was evaluated around the alveolar crest surface between the most coronal bone-to-implant contact (B) at the buccal and lingual aspects. BIC% was also evaluated at the apical portion of the implant [BIC% apical].

Data analysis
Mean values and standard deviations as well as 25th, 50th [median] and 75th percentiles were calculated for each outcome variable. The primary variable was BIC% total and BIC% apical. Differences between test (short implants) and control (long implants) sites were analyzed using Wilcoxon signed rank test using PASW Statistics 19 [SPSS Inc., Chicago, IL]. The level of significance was set at \( \alpha = 0.05 \).

Results

Clinical evaluation
The dimensions of the alveolar extraction sockets are reported in Table 1. The buccolingual dimensions were 4.2 ± 0.3 and 4.8 ± 0.8 mm at the test and control sites, respectively. The difference did not reach statistical significance. The width of the buccal alveolar bony crest 1 mm below the top of the crest was lower at the test compared with the control sites. The difference was statistically significant.

After implant installation, the implant shoulder was located deeper in relation to the top of the lingual bony crest of 0.6 ± 0.5 and 0.6 ± 0.9 mm at the test and control sites, respectively [IS-C clinical; Table 2].

Small horizontal gaps [GAP clinical] occurred at the control sites between the implant surface and the inner contour of the alveolar bony crest (Table 2). At the test site, the horizontal GAP was minimal (0.1 mm). The difference to the control sites did not reach statistical significance.

During the healing period, no complications were observed and all implants were available for histological analysis.

Histological evaluation
No artifacts occurred during the histologic preparation; hence, test and control sites yielded an \( n = 6 \).

The implants appeared to be well integrated into mature bone (Fig. 3a and b). BIC % total was slightly higher at the test compared with the control sites (54.4 ± 14.2% and 49.0 ± 20.2% [Table 3]. The difference, however, was not statistically significant. The apical region of the implant presented with newly formed bone attached to the surface both at the test and control sites (Fig. 4a –d). The BIC%-apex was about 33% and 21% at the test and control sites, respectively. Again, the difference did not reach statistical significance.

Both at the test and control sites, the bony walls were partly resorbed at the buccal and lingual aspects (Table 3). The bony crest (C) as well as the most coronal bone-to-implant contact point (B) were located more apically at the test compared with the control sites. However, the differences did not reach statistical significance both at the buccal and lingual sites.

Small residual defects were detectable around the marginal portion of the implant [GAP, Table 3].

The soft tissues appeared to be well adapted around the neck of the implant and the healing abutment. No inflammatory infiltrates were found within the connective peri-implant tissue. The dimensions of the peri-implant mucosa were similar in both groups [Table 4].

When the straight vertical measurements [assessed in the long axis of the implant] of the peri-implant soft tissues were compared with the measurements assessed along the surface of the implant, statistically significant differences were revealed, with the latter assessment always being greater than the former [Table 4].

Discussion
The present experiment evaluated the influence on the healing of hard and soft tissues at short and long implants [6 mm vs. 11 mm] installed into sockets immediately after tooth extraction.

A slightly higher, though not statistically significant, osseointegration was found at the

![Fig. 3](image-url) The implants appeared to be well integrated into mature bone. Stev enel’s blue and alizarin red stain. Original magnification ×16. A higher loss of the buccal alveolar bony crest was observed at the test [a] compared with the control sites [b].
test [short implants] compared with the control sites [54.4% vs. 49.0%]. This tendency of higher bone-to-implant contact for shorter implants may be due to the fact that the control implants were installed deeper into the alveolar bone reaching an area with higher trabecular alveolar bone density than the test implants that with their apical extension generally reached the center of the alveolar process. This region is usually of a looser trabecular morphology resulting in very little pressure being applied during implant installation. Consequently, bone formation may be initiated immediately without any prior resorption occasionally observed in dense alveolar bone (Berglundh et al. 2007a).

As the residual bony housing of the extracted tooth was similar in the test and the control sites [approximately 11 mm], the control implant filled the alveolus in its entire length, while the short test implant left a space of approximately 5 mm filled with coagulum after installation. Obviously, no pressure was applied to the apical outline of the test implant, while at the control sites, the apical outline of the implants was prepared into alveolar bone. Again, this difference in location of the tip of the implant may have influenced the osseointegration process. The fact that the proportion of bone-to-implant contact at the apical termination of the test implant was 33% vs. 21% at the apical termination of the control implants would support a concept of improved osseointegration in areas with looser trabecular bony.

Bone resorption was observed both at the marginal buccal and lingual aspects. This buccal resorption was about 2.0 and 1.2 mm at the test and control sites, respectively. Considering the initial positioning of the implant shoulder in relation to the lingual bony crest (Table 2), the corresponding lingual resorption was about 1.0 and 0.8 mm at the test and control sites, respectively.

The resorption of the alveolar bony crest after installation of implants immediately into extraction sockets has been documented in several clinical [e.g., Botticelli et al. 2004; Sanz et al. 2010] and experimental studies [e.g., Araújo et al. 2005; Botticelli et al. 2006; de Sanctis et al. 2009; Vignoletti et al. 2009; Caneva et al. 2010a,b, 2012]. It is important to emphasize that the positioning of the implant within the extraction socket influences both the buccal and the lingual bony crest resorption. In an experiment in dogs [Caneva et al. 2010a], implants were installed into the distal alveoli of the third premolars immediately after tooth extraction. In the control sites, the implants were placed in the center of the alveolus while, at the test sites, the implants were installed more lingually and apically. After 4 months of healing, less buccal bone resorption had occurred at the test compared with the control sites. However, more lingual bone resorption was observed at the test compared with the control sites. While at the control sites the buccal bone resorption was larger compared with lingual aspects, the resorption at the test sites was similar for the two aspects. This, in turn, means that the positioning of the implant affects bone resorption both buccally and lingually.

In the present experiment, more buccal bone resorption was observed at the test compared with the control sites [difference 0.8 mm], even though this difference was not statistically significant. This outcome may be explained by the various coronal sizes of the extraction sockets. A smaller initial buccal gap was observed at the test compared with the control sites. Moreover, the width of the bony crest was smaller at the test compared with the control sites. This resulted in a lower distance between the implant surface and the outer contour of the bony.

The distance of the implant surface in relation to the outer contour of the bony

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**Table 3. Histological measurements of the hard tissue after 4 months of healing**

<table>
<thead>
<tr>
<th></th>
<th>IS-B</th>
<th>IS-C</th>
<th>GAP</th>
<th>BIC%</th>
</tr>
</thead>
<tbody>
<tr>
<td>b</td>
<td>2.60(1.30)</td>
<td>2.02(1.44)</td>
<td>0.11(0.21)</td>
<td>54.4(14.2)</td>
</tr>
<tr>
<td>l</td>
<td>1.07(0.84)</td>
<td>0.37(0.71)</td>
<td>0.44(0.66)</td>
<td>33.1(26.6)</td>
</tr>
<tr>
<td>b</td>
<td>2.14(1.50)</td>
<td>0.88(0.50)</td>
<td>0.00(0.12)</td>
<td></td>
</tr>
<tr>
<td>l</td>
<td>0.50(0.35)</td>
<td>-0.05(0.63)</td>
<td>0.12(0.19)</td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>2.92(1.15)</td>
<td>1.60(0.63)</td>
<td>0.01(0.35)</td>
<td></td>
</tr>
<tr>
<td>l</td>
<td>1.12(0.83)</td>
<td>0.83(0.35)</td>
<td>0.19(0.33)</td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>3.69(0.83)</td>
<td>3.30(0.93)</td>
<td>0.09(0.35)</td>
<td></td>
</tr>
<tr>
<td>l</td>
<td>1.65(0.93)</td>
<td>3.30(0.93)</td>
<td>0.35(0.42)</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>Mean (SD)</td>
<td>1.67(1.02)</td>
<td>0.23(0.34)</td>
<td>49.0(20.2)</td>
</tr>
<tr>
<td>Percentiles</td>
<td>0.84(0.65)</td>
<td>0.21(0.83)</td>
<td>0.42(0.47)</td>
<td>20.9(16.6)</td>
</tr>
<tr>
<td>25th</td>
<td>1.02(0.69)</td>
<td>0.68(0.12)</td>
<td>0.00(0.17)</td>
<td></td>
</tr>
<tr>
<td>50th</td>
<td>1.79(0.81)</td>
<td>1.23(0.22)</td>
<td>0.03(0.19)</td>
<td></td>
</tr>
<tr>
<td>75th</td>
<td>2.27(1.04)</td>
<td>1.86(0.45)</td>
<td>0.43(0.50)</td>
<td></td>
</tr>
</tbody>
</table>

Mean values, standard deviations (SD) and 25th, 50th (median) and 75th percentiles. b, buccal; l, lingual; IS, implant shoulder; B, coronal end of osseointegration; C, top of alveolar bony crest; S, implant surface; PM, top of the peri-implant mucosa; aJE, apical portion of the junctional epithelium; BIC, bone-to-implant contact.

*P < 0.05 between test and control.*

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**Fig. 4.** The apical region of the implants presented newly formed bone attached to the surface, both at the test and control sites. Stevenel’s blue and alizarin red stain. (a) Apical portion of a test implant (short). Original magnification about x16. (b) Larger magnification of the apical region (originally x40). (c) Apical portion of a control implant (long). Original magnification about x16. (b) Larger magnification of the apical region (originally x40).
Crest (OC; Botticelli et al. 2004) has been recognized as an important factor affecting the final position of the bucco-lingual bony walls in respect to the implant margin (Caneva et al. 2010a,b, 2012; Ferrus et al. 2010; Sanz et al. 2010; Tomasi et al. 2010; ). In an experiment in dogs (Caneva et al. 2010b), larger implants that filled completely the alveolus were compared with narrower implants installed in the center of the extraction sockets. This, in turn, means that the surface of the implant was closer to the outer contour of the bony crest (OC) at the test compared with the control sites. After 4 months of healing, a higher degree of bony crest resorption was observed at the wider compared with the narrower implant sites, both at the buccal and lingual aspects. A similar experiment subsequently performed in dogs (Caneva et al. 2012) confirmed these findings.

The difference of the distances IS-B and IS-C between test and control sites should be considered with caution because of the fact that the dimensions of the alveoli were slightly different. For this reason, these two distances were not considered as primary outcome variables. The use of a randomized side selection (right or left) as test or control sites might have decreased the influence of this confounding factor. The BIC% performed between the two references points B (most coronal bone-to-implant contact) at the buccal and lingual aspects was used as primary outcome variable.

Assessing the height of the mucosal cuff in two ways (vertical and surface assessment) revealed significant differences irrespective of the length of the implants installed. The surface measurements were always larger than the vertical measurements. It is noteworthy to realize that the majority of these differences are found within the connective tissue adaption to the implant rather than in the area of the barrier (junctional) epithelium, the latter yielding a dimension of typically 2.0–2.5 mm (Berglundh et al. 2007b). The differences between the connective tissue adaptation measurements assessed by the two different methods has to be explained on the basis of the geometry at the implant shoulder.

### Table 4. Histological measurements of the soft tissue after 4 months of healing

<table>
<thead>
<tr>
<th>Vertical no.</th>
<th>PM-B</th>
<th>PM-aJE</th>
<th>aJE-B</th>
<th>PM-B</th>
<th>PM-aJE</th>
<th>aJE-B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test</td>
<td>Mean (SD)</td>
<td>4.97 (1.12)</td>
<td>3.30 (0.69)</td>
<td>2.19 (0.68)</td>
<td>2.78 (1.02)</td>
<td>2.02 (0.84)</td>
</tr>
<tr>
<td></td>
<td>50th</td>
<td>4.75</td>
<td>4.92</td>
<td>4.75</td>
<td>5.00</td>
<td>5.00</td>
</tr>
<tr>
<td></td>
<td>75th</td>
<td>5.62</td>
<td>5.62</td>
<td>5.62</td>
<td>5.62</td>
<td>5.62</td>
</tr>
<tr>
<td>Control</td>
<td>Mean (SD)</td>
<td>4.75 (1.10)</td>
<td>3.37 (0.51)</td>
<td>2.39 (0.61)</td>
<td>2.02 (0.84)</td>
<td>1.91 (0.84)</td>
</tr>
<tr>
<td></td>
<td>75th</td>
<td>5.62</td>
<td>5.62</td>
<td>5.62</td>
<td>5.62</td>
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</tr>
</tbody>
</table>

Mean values, standard deviations (SD) and 25th, 50th (median) and 75th percentiles. b, buccal; l, lingual; IS, implant shoulder; B, coronal end of osseointegration; C, top of alveolar bone crest. 5.

P < 0.05. No differences statistically significant were found between test and control sites. All differences between vertical and surface measurements were statistically significant (P < 0.05).
which—in the implants installed in the present study—followed a concept of “platform switching”.

In conclusion, the present study showed that comparable osseointegration was obtained at short (6 mm) compare to long implants (11 mm) installed into sockets immediately after tooth extraction.

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References


