Influence of implants with different sizes and configurations installed immediately into extraction sockets on peri-implant hard and soft tissues: an experimental study in dogs

Abstract

Aim: To study the influence on the healing of soft and hard peri-implant tissues when implants of different sizes and configurations were installed into sockets immediately after tooth extraction.

Material and methods: Transmucosal cylindrical implants, 3.3 mm in diameter in the control sites, and conical 5 mm in diameter in the test sites, were installed into the distal socket of the fourth mandibular premolars in dogs immediately after tooth extraction. After 4 months, the hard and soft tissue healing was evaluated histologically.

Results: All implants were integrated in mineralized mature bone. Both at the test and control sites, the alveolar crest underwent resorption. The buccal bony surface at the implant test sites (conical; 3.8 mm) was more resorbed compared with the control sites (cylindrical; 1.6 mm). The soft tissue dimensions were similar in both groups. However, in relation to the implant shoulder, the peri-implant mucosa was located more apically at the test compared with the control sites.

Conclusion: The present study confirmed that the distance between the implant surface and the outer contour of the buccal alveolar bony crest influenced the degree of resorption of the buccal bone plate. Consequently, in relation to the implant shoulder, the peri-implant mucosa will be established at a more apical level, if the distance between the implant surface and the outer contour of the alveolar crest is small.

Several clinical [e.g. Botticelli et al. 2004; Covani et al. 2004; Sanz et al. 2010] as well as 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, 2010b, 2010c, 2010d, 2011a, 2011b; Covani et al. 2010; Barone et al. 2011) have demonstrated that implant installation into the alveolus immediately after tooth extraction did not result in the maintenance of the buccal bony wall at its original level.

This type of implant installation may be affected by a number of factors, such as a flapless installation [Blanco et al. 2008; Caneva et al. 2010a] or the use of bone fillers with or without concomitant membrane coverage [Caneva et al. 2010b, 2011a, 2011b]. The positioning of the implant within the extraction socket appears to be another important factor influencing the final outcome [Caneva et al. 2010c, 2010d; Tomasi et al. 2010]. A multilevel multivariate analysis [Tomasi et al. 2010] performed on data from a multicenter clinical study on implants placed immediately after tooth extraction [Sanz et al. 2010] revealed that the more buccally an implant was installed, the less the implant surface was covered by bone and soft tissue after 4 months of healing.

Moreover, the importance of the positioning of implants into the extraction socket was elaborated in experimental studies in dogs [Caneva et al. 2010c, 2010d]. In these experiments, implants were placed in different positions with respect to the buccal/lingual alveolar bony walls [Caneva et al. 2010c], or implants had different sizes and configurations [Caneva et al. 2010d]. In both studies, one implant was closer to the buccal alveolar bony crest compared with that placed in the contralateral side of the mandible. After 4 months of healing, the buccal...
surface of the former implant was covered less by bone compared with the latter implant. This, in turn, means that the more lingual the buccal surface of the implants was placed, the less the surface was exposed. Unfortunately, none of the experimental studies mentioned evaluated the adaptations of the soft tissues encountered in relation to the alveolar bone.

Hence, the aim of the present experiment was to study the influence of implant installation into sockets immediately after tooth extraction on the healing of soft and hard peri-implant tissues with implants of various sizes and configurations.

Material and methods

The research protocol was submitted to and approved by the local Ethical Committee for Animal Research (University of the State of São Paulo, Brazil).

Clinical procedures

Six Labrador dogs (each approximately 22 kg and with a mean age of 2 years) were used. During surgical procedures, the animals were pre-anesthetized with Acepran® (0.05 mg/kg; Univet-vetnil, São Paulo, Brazil), sedated with Zoetil® 10 mg/kg [Virbac EUA] and Xilazina® (1 mg/kg; Cristália, São Paulo, Brazil), and complemented with Ketamine®, [¼ of dose of 10 mg/kg; Cristália]. During the entire surgery, the animals were kept with an intravenous infusion of sterile saline.

As described previously (Caneva et al. 2010d), the pulp tissue of the mesial roots of the 4P4 was removed, and the root canals were measured using a UNC 15™ calipers (Castroviejo, KLS Martin Group). A recipient site was prepared, and a titanium implant of 3.3 mm in diameter and 11.5 mm in length [Premium®, Sweden & Martina] with a rough surface [DES, dual engineered surface, Sweden & Martina] was installed. The implant was positioned in the center of the alveolus [Fig. 1a], with the margin of the rough surface placed flush to the alveolar bony crest, so that the machined collar of the implant [0.8 mm in height] was exposed above the bony crest (Fig. 1b). The following clinical landmarks were identified: implant shoulder (IS), the top of the bony crest (C), the base of the remaining defect (D), and the surface of the implant (S). The following distances were measured using a UNC 15™ probe (Hu-Friedy): the horizontal distance between S and C (S-C), and the vertical distance between IS and D (IS-D), parallel to the long axis of the implant.

A healing abutment was affixed to the implant, and the flaps were mobilized and sutured to allow a non-submerged healing. 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, Campinas, Brazil] and antibiotics [Pentabiotic®, 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 euthanized 4 months after surgery.

The same surgical procedures and measurements were performed in the left side of the mandible. However, the implant placed was conical, and filled almost the entire extraction socket [Kohno® Straight DES 5 mm wide, 11.5-mm long, Sweden & Martina] (Fig. 1c). The rough margin of the implant was placed flush with the buccal alveolar crest, as well as with the machined collar of the implant [0.8 mm in height] exposed above the bony crest [Fig. 1d]. The flaps were subsequently sutured to allow a non-submerged healing. 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, Campinas, Brazil] and antibiotics [Pentabiotic®, Fort Dodge Animal Health].

Photographs illustrating the clinical aspect after the placement of the implants within the distal extraction sockets of the mandibular premolars. (a) Occlusal view identifying the central positioning of the cylindrical implant. (b) Buccal view identifying the positioning of the rough/smooth surface limit of the cylindrical implant flush to the alveolar crest. (c) Occlusal view identifying the positioning of the conical implant filling the entire alveolus. (d) Buccal view identifying the positioning of the rough/smooth surface limit of the conical implant flush to the alveolar crest.

Table 1. Coronal diameter and depth of extraction sockets and width of the buccal and lingual bone walls at 1 and 3 mm from the alveolar crest

<table>
<thead>
<tr>
<th></th>
<th>Coronal diameter</th>
<th>Depth</th>
<th>Width at 1 mm</th>
<th>Width at 3 mm</th>
</tr>
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<tr>
<td></td>
<td>m-d</td>
<td>b-l</td>
<td>b-l</td>
<td>b-l</td>
</tr>
<tr>
<td>Test</td>
<td>5 ± 0.7</td>
<td>5.2 ± 0.4</td>
<td>13.5 ± 1.5</td>
<td>14.5 ± 0.9</td>
</tr>
<tr>
<td>Control</td>
<td>5.1 ± 0.5</td>
<td>5.1 ± 0.5</td>
<td>13.2 ± 0.9</td>
<td>14.3 ± 0.8</td>
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</tbody>
</table>

Mean values and standard deviations (SD) in millimeters. m-d, mesial-distal; b-l, buccal-lingual; b, buccal; l, lingual.

Fig. 1. Photographs illustrating the clinical aspect after the placement of the implants within the distal extraction sockets of the mandibular premolars. (a) Occlusal view identifying the central positioning of the cylindrical implant. (b) Buccal view identifying the positioning of the rough/smooth surface limit of the cylindrical implant flush to the alveolar crest. (c) Occlusal view identifying the positioning of the conical implant filling the entire alveolus. (d) Buccal view identifying the positioning of the rough/smooth surface limit of the conical implant flush to the alveolar crest.
applying overdoses of Thiopental® (Cristalia Ltd, Campinas, Brazil).

**Histologic 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 with a diamond band saw fitted in a precision slicing machine (Exakt®, Apparatebau, Norderstedt, Germany) and then reduced to a thickness of approximately 50 μm using a cutting-grinding device (Exakt®, Apparatebau).

The histologic slides were stained with toluidine blue and examined under a standard light microscope for histometric analysis.

**Histologic evaluation**

In a Nikon Eclipse 50i microscope (Nikon Corporation, Tokio, Japan) at a magnification of ×100, the following landmarks were identified [Fig. 2a–c]: the shoulder of the implant (IS), the most coronal bone-to-implant contact (B), the top of the adjacent bony crest (C), the implant surface at the buccal aspect at the top of the threads (S), the outer contour of the alveolar bony crest (OCbc), the top of peri-implant mucosa (PM), the apical termination of the barrier (junctional) epithelium (aJE), and the outer contour of the alveolar crest, including soft tissue (OCst).

The following measurements were performed [Fig. 2a–c]: the vertical distance between IS and C (IS-C) and IS and B (IS-B), the amount of bone-to-implant contact (BIC%) around the implant evaluated from B to the apical termination of the implant, the vertical distance between PM and B (PM-B) and aJE and B (JE-B).

The distance between the coronal margin of the rough surface (M) and B (M-B), and the distance M-C were calculated by subtracting 0.8 mm of the machined implant collar from the measurements IS-B and IS-C respectively. The distance PM-aJE and PM-IS were also calculated using the other parameters measured.

The width of the alveolar bony crest was measured from S to OCbc at the IS level and then, apically, at each subsequent millimeter, up to 5 mm (S-OCbc, Fig. 2b). The width of the peri-implant mucosa was also measured from S to OCst at the IS level and then coronally, up to 2 mm, and apically, up to 3 mm, at each subsequent mm (S-OCst, Fig. 2c).

![Fig. 2. Diagrams depicting the landmarks for the histologic evaluation. (a) PM: margin of the peri-implant mucosa; IS: implant shoulder; M: coronal limit of rough/smooth implant surface, located 0.8 mm below IS, aJE: apical termination of the barrier (junctional) epithelium; B: most coronal bone-to-implant contact location; C: top of the alveolar crest projected onto the implant surface. (b) Buccal width of the bony crest. S: the implant surface at the top of the threads (yellow dotted line); OCbc: the outer contour of the alveolar bony crest (red dotted line). The width of the alveolar bony crest was measured from S to OCbc at the IS level and then, apically to it, at each subsequent mm, up to 5 mm (S-OCbc). (c) Buccal width of the peri-implant mucosa. S: the implant surface at the top of the threads (yellow dotted line); OCst: the outer contour of the soft tissue (red dotted line). The width of the peri-implant mucosa was also measured from S to OCst at the IS level and then coronally, up to 2 mm, and apically, up to 3 mm, at each subsequent mm (S-OCst).](Image 285x595 to 493x725)

The percentage of mineralized bone determined in an area from the implant surface to a parallel line at a distance of approximately 1 mm from S was also assessed between B and the apical termination of the implant. Thus, a lattice [density 50 μm] was superimposed over this tissue area (magnification ×200).

**Data analysis**

Mean values and standard deviations (SD) in millimeters. IS-C, distance between IS (implant shoulder) and C (top of alveolar bony crest); IS-D, distance between IS and D (base of the remaining defect); B, buccal; l, lingual.

| Table 2. Clinical measurements of residual defects at test and control sites at implants installation |
|-----------------------------------|-----------------|------------------|------------------|
|                                  | S-C             | IS-D             |
|                                   | b               | l                |
| Test                              | 0.1 ± 0.2       | 0.1 ± 0.2        | 0.4 ± 0.9        | 0.6 ± 1.3 |
| Control                           | 0.9 ± 0.3       | 0.9 ± 0.3        | 4.2 ± 1.6        | 4 ± 1.5  |

Mean values and standard deviations (SD) in millimeters. IS-C, distance between IS (implant shoulder) and C (top of alveolar bony crest); IS-D, distance between IS and D (base of the remaining defect); B, buccal; l, lingual.

The percentage of mineralized bone determined in an area from the implant surface to a parallel line at a distance of approximately 1 mm from S was also assessed between B and the apical termination of the implant. Thus, a lattice [density 50 μm] was superimposed over this tissue area (magnification ×200).

**Results**

**Clinical measurements**

The coronal diameter and depth of the extraction sockets, as well as the width of the buccal and lingual bony walls at 1 and 3 mm from the top of the alveolar crest before implant installation are reported in Table 1.

The distances S-C and IS-D measured clinically after implant installation are reported in Table 2. At the control site, S-C was 0.9 ± 0.3 mm whereas, at the test site, it was only 0.1 ± 0.2 mm. In fact, the buccal-lingual

![Fig. 3. Ground sections illustrating the healing after 4 months at the test (a) and control (b) sites. Toluidine blue, original magnification ×16. All implants were integrated in mature mineralized bone. The buccal bony wall, as well as the peri-implant mucosa were located more apically at the test compared with the control sites.](Image 397x105 to 567x235)
coronal dimension of the alveolus at the test sites (conical implant) was consistently slightly wider than the diameter of the implant.

The width of the buccal bony crest was similar at the test and control sites.

After 4 months of healing, all implants were clinically stable without signs of complications. During histologic processing, neither did artifacts occur, nor were there any tissue blocks destroyed. Hence, test and control sites yielded \( n = 6 \).

**Histologic evaluation of the hard tissue**

The implants at the histologic examination appeared to be well integrated into mature mineralized bone (Fig. 3a and b). Measurements are reported in Table 3 and illustrated in Fig. 4. The buccal bony wall at the test sites was more apically positioned after healing (3.8 ± 1.6 mm) compared with the control sites (1.6 ± 0.8 mm). The difference was statistically significant. The M-B at the test sites (3.8 ± 1.6 mm) was also longer than at the control sites (2.2 ± 0.3 mm), the difference being statistically significant as well.

The overall percentage of bone-to-implant contact was slightly higher at the control compared with the test sites. The difference was, however, not statistically significant. The overall percentages of mineralized bone adjacent to test and control implants were statistically greater at the test sites.

The mean values of S-OCbc at both the test and control sites after 4 months of healing are reported in Fig. 5. A more apical positioning of the bony crest was observed at the test compared with the control sites.

**Histologic evaluation of the soft tissue**

Measurements are reported in Table 4 and illustrated in Fig. 4. The soft tissue dimensions were similar at the test and control sites. The position of the peri-implant mucosa was, however, more apically located at the test compared with the control sites, yielding a statistically significant difference. This is graphically illustrated in the Fig. 6, reporting the mean values of S-OCst at both the test and control sites after 4 months of healing.

**Discussion**

This study has confirmed that implants placed into the sockets immediately after tooth extraction did not prevent buccal bone resorption. This finding is in agreement with a series of clinical [e.g. Botticelli et al. 2004; Covani et al. 2004; Sanz et al. 2010] and experimental studies [e.g. Araujo et al. 2005; Botticelli et al. 2006; de Sanctis et al. 2009; Vignoletti et al. 2009; Caneva et al. 2010a, 2010b, 2010c, 2010d, 2011a, 2011b, Covani et al. 2010; Barone et al. 2011]. After 4 months of healing, the alveolar buccal bony crest at the sites of the conical implants (test) was more apically located compared with the control sites of the cylindrical implants (control). This is in agreement with a previous experimental study [Caneva et al. 2010d] in which smaller cylindrical and larger conical implants were compared as well. A more apical repositioning of the buccal bony crest was observed at the larger diameter implant sites compared with the smaller diameter implant sites. The results of the present study, however, are seemingly in disagreement with those obtained in a clinical study [Sanz et al. 2010] in which two groups of implants with different configurations, cylindrical and conical, were installed. After 4 months of healing, all implants were clinically stable without signs of complications.
healing, the buccal alveolar bony crest was located at a similar vertical level, both at the cylindrical and at the conical implant sites. It has to be realized, however, that the dimensions of the remaining gap between the implant surface and the socket wall as well as the width of the bony crest at the time of implant installation were quite similar between the two groups of implants. This, in turn, means that the outer contour of the buccal alveolar bony crest was also located at a similar distance from the surface of the implant. As opposed to that study, the outer contour of the buccal alveolar bony crest was located at a larger distance from the implant surface at the control compared with the test sites in the present study. In fact, while the width of the buccal bony plate was similar between the two implant sites, a virtually absent buccal gap could be observed at the test sites although, at the control sites, a gap of 0.9 mm existed. This relationship between the implant position within the socket and buccal resorption was presented in clinical (Ferrus et al. 2010; Sanz et al. 2010), as well as in a few experimental studies (Araújo et al. 2006; Caneva et al. 2010c, 2010d) on implants installed into sockets immediately after tooth extraction. A multilevel multivariate analysis (Tomasi et al. 2010) on data of the multicenter study mentioned above (Sanz et al. 2010) demonstrated that the closer the implant was to the buccal bony wall, the more the buccal bone was resorbed after 4 months of healing.

Despite the presence of a gap at the cylindrical implant [control] sites in the present study, the buccal bony level of the crest was more coronal compared with the test sites, where a gap was virtually absent at the time of implant installation.

The exposure of the implant surface at the test sites in the present experiment [3.8 mm] was higher compared with the results reported in a previous similar experiment in dogs [2.7 mm, Caneva et al. 2010d]. This may be explained by the larger distance of the outer contour of the buccal alveolar bony crest to the implant surface in the previous study compared with that of the present study. The clinical study on implants installed into sockets immediately after extraction (Ferrus et al. 2010) mentioned before, has shown that at sites with a width of the buccal bony crest $\geq 1$ mm, bone resorption was less compared with sites with a corresponding width $<1$ mm. In the present study, a very similar observation was made.

The distance between the coronal margin of the rough surface [M] and the most coronal bone-to-implant contact [B] was higher at the test compared with the control sites, yielding statistical significance only at the buccal site. This is in agreement with other experiments in dogs (Araújo et al. 2006; Caneva et al. 2010c, 2010d), where higher M-B values were reported at sites where the implant surface was close to the buccal bony wall.

While the difference between test and control sites with regard to bone-to-implant contact percentages [BIC %] was not statistically significant, the difference in mineralization of the surrounding bone reached statistical significance. The higher degree of mineralization at the test compared with the control sites may be explained by the larger diameter of the conical (test) implants, rendering the surface to be closer to the compact cortical bone of the mandible compared with the smaller cylindrical (control) sites.

In the present experiment, soft tissue dimensions were similar at both test and control sites. However, the peri-implant mucosa (PM) was located at different levels at the test and control sites, both buccally and lingually. In fact, at the test sites, PM was located apically to the implant shoulder [IS] whereas, at the control sites, PM was located coronally to IS. The difference in location was statistically significant. This is explained by the fact that the most coronal aspect of the bony crest was located more apically at the test sites, so that the soft tissue unit had shifted coronally as well. This is in agreement with another experimental study in dogs (Araújo et al. 2011) in which the location of the buccal peri-implant mucosa was positioned more apically in relation to the implant shoulder at the site where more buccal bone resorption had occurred.

In conclusion, the present study has confirmed that the distance between the implant surface and the outer contour of the buccal alveolar bony crest influenced the resorption of the buccal bone plate. If the implant surface is closer to the bony crest, a higher exposure of the implant surface has to be expected. Consequently, the peri-implant mucosal unit will be established at a more apical level at the test (larger conical implant) when compared with the control (smaller cylindrical implant) sites.

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