Establishment of the epithelial attachment and connective tissue adaptation to implants installed under the concept of “platform switching”: a histologic study in minipigs

Key words: biologic width, connective tissue adaptation, epithelial attachment, healing, oral implants, platform switching

Abstract

Aim: To validate the “platform switching” concept at oral implants with respect to the preservation of the alveolar crestal bone levels in an animal model.

Material & methods: Five minipigs received three implants each with a 0.25 mm implant/abutment mismatch and were placed flush (T0), 1 mm below (T1) and 1 mm above (T2) the alveolar bony crest, and as a control, one conventionally restored implant placed at the bone level. The implants were randomly inserted flapless into the mandible. Four months after implant insertion, the animals were sacrificed, and undecalcified block sections were obtained and used for histological analyses.

Results: The mean values for peri-implant bone resorption were 1.09 ± 0.59 mm (Control), 0.51 ± 0.27 mm (T0), 2.20 ± 0.65 mm (T1) and 1.70 ± 0.90 mm (T2), respectively. Statistically significant differences (P<0.05) were found among the test (T0, T1, T2) and the control sites.

Control implants presented an average biologic width length of 3.20 mm (± 0.33), with a connective tissue adaptation compartment of 1.29 mm (± 0.53) and an epithelial attachment of 1.91 mm (± 0.71).

T0, T1, and T2 implants presented with a mean biologic width of 1.97 mm (± 1.20), 2.70 mm (± 1.36) and 2.84 mm (± 0.90), respectively, with a connective tissue adaptation compartment of 1.21 mm (± 0.97), 2.12 mm (± 0.65) and 1.50 mm (± 0.70) and an epithelial attachment of 0.84 mm (± 0.93), 1.66 mm (± 0.88) and 1.35 mm (± 0.44), respectively.

Differences between the configurations were mainly associated with the length of the epithelial attachment. The epithelial attachment was significantly longer in the C sites than in T0, T1, and T2, respectively. However, no other differences between configurations were detected.

Conclusion: If the implants are positioned at the level of the alveolar bony crest, the platform-switching concept may have a minor impact on the length of the epithelial attachment (0.84 vs. 1.91 mm), while the connective tissue adaptation compartment remains relatively unaffected. Moreover, platform switching resulted in less resorption of the alveolar crest (0.58 mm).

The healing following implant installation of various systems has been documented in a variety of clinical studies. Specifically, the installation of two-piece implants healing in a submerged modality resulted in a crestal bone loss of 1.5–2.0 mm after 1 year of loading [Albrektsson et al. 1986]. Moreover, in experimental studies in dogs, a crestal bone remodeling with a resorption of 2 mm has been verified [Hermann et al. 1997].

In an attempt to minimize the crestal bone resorption, a concept of “platform switching” has been suggested [Lazzara and Porter 2006]. In essence, by reducing the diameter of the implant abutment in relation to the diameter of the implant body, the healing of the mucosal cuff around the abutment was to result in a smaller crestal bone resorption. This was anticipated owing to the fact that the inflammatory infiltrate encountered at the abutment/fixture interface in two-stage implants [Abrahamsson et al. 1996] would be located more coronally or more centripetal than in instances with an abutment/fixture interface located flush with the alveolar crest.

While a variety of clinical studies reported favorable outcomes with respect to the preserva-
tion of the crestal bone (for a review, see Atich et al. 2010), evidence for an advantage of the concept remains sparse and controversial. In fact, Becker et al. (2007, 2009) did not find any difference in buccal and palatal crestal resorption when comparing traditionally restored implants with those restored under a “platform-switching” concept after 4–24 weeks.

Moreover, 60 implants with non-matching platform designs were placed in dogs in either a submerged or a non-submerged healing modality. After 6 months, the mean bone loss was 0.52 and 0.44 mm, respectively [Cochran et al. 2009]. Furthermore, less crestal bone resorption in implants with mismatched platforms was identified (Weng et al. 2008). Also, in comparing two different implant designs with traditional or offset abutment/fixture configurations, less crestal bone loss occurred at those sites with non-matching abutment/fixture junctions [Berghlund et al. 2005].

Minimal crestal bone loss after a short period of loading (1–6 months) was also confirmed histologically in case reports [Degidi et al. 2008; Luongo et al. 2008].

A more recent animal study with an abutment/implant mismatch of 0.25 mm [Raffone et al. 2011] failed to document statistically significant differences in alveolar crest resorption between mismatched and matched abutments. Hence, the positive suggested effects of mismatched abutments on the establishment of the soft and hard tissue dimensions at implants remain controversial.

The purpose of the present study was to validate the “platform-switching” concept at oral implants with respect to the preservation of the alveolar crestal bone levels in an animal model.

Material and methods

Five coetaneous minipigs with a permanent dentition were selected from the same lineage. The animals were treated and housed according to law regulations in force in Italy [D.L. 116/92] and in the European Community [2007/526/CE 18 June 2007] at the laboratories of the Section of Agriculture Animal Husbandry Department of Animal Science and the Faculty of Veterinary Medicine, University of Milan, Italy.

Surgical treatment

All animals were pre-anesthetized with xylazine [1 mg/kg intramuscular (i.m.) Ronpums, Bayer, Munich, Germany] and ketamine [15 mg/kg i.m. Dopalen, Vetbrands, Brazil] and anesthetized with thionembutal [20 mg/kg intravenously (i.v.) Tiopental, Marvecs Pharma Services, Mesina, Italy]. During the entire surgery, the animals inhaled O₂ and were maintained on an i.v. infusion of saline.

Before the surgical procedures, the sites were divided into test and control sites. A randomization list was provided by a statistician unaware of the study protocol using a random number generator utility. The surgeon was informed of the allocation of each animal shortly before implant insertion, by unsealing a closed envelope.

Four implants, 8.9 mm in length and 4.3 mm in diameter, were flaplessly placed in the mandible of each animal. The implants (Global, Sweden & Martina, Due Carrare, Italy) yielded a rough surface [ZirTi; zirconium sandblasted acid etched] and were positioned in native bone mesial and distal to the canine tooth. Two implants were installed flush with the mesiodistal level of the alveolar bony crest [Fig. 1], while the other two were placed 1 mm above or below that level, respectively.

One of the implants inserted flush with the bony crest received a matching diameter abutment, while diameter reduced, mismatched abutments, 3.8 mm in diameter, were affixed to the remaining three implants, resulting in a mismatch of 0.25 mm. The abutments did not interfere with the occlusion.

At the end of the surgery, an antibiotic prophylaxis (Amoxicillin) was administered for 5 days, and a soft diet was provided. Daily washings of the experimental sites with chlorhexidine (0.12%) were performed until sacrifice.

All animals were sacrificed after 4 months of healing. The mandibles were block resected, and each specimen was coded and sent at the BoNetwork in S. Raffaele Hospital of Milan, Italy, for histological processing.

Histological preparation

Individual bone blocks containing implants and the surrounding soft and hard tissues were fixed in 4% formaldehyde, followed by dehydration in a series of graded ethanol, and finally embedded in resin [LR Whites hard grade, London Resin Company Ltd, Berkshire, UK]. The blocks were cut in a mesio-distal plane, using a diamond band saw fitted in a precision slicing machine (BS 310, Exakt, Apparatebau, Norderstedt, Germany), and then ground to ultra-fine grains using a precision grinder (400 CS, Exakt, Apparatebau, Norderstedt, Germany).

The sections were stained with a modified Goldner Trichrom staining combined with the count of osteoclasts following TRAP staining.

The dimensions of the peri-implant tissues were evaluated, and the following landmarks were identified [Fig. 2]:

IAJ, Implant Abutment Junction; PM, Free mucosal margin; JE, Epithelial-connective junction; B, Most coronal bone-to-implant contact.

The following linear measurements were performed parallel to the long axis of the implant: IAJ-B, Bone remodeling, PM-JE, Epithelial width, JE-B, Connective width. Hence, the vertical biologic width was considered as the sum of PM-JE and JE-B.

The 20 samples were divided into four groups, according to the randomization: (i) Implants inserted flush with the bony level and restored using matching diameter abutments (control); (ii) Implants inserted flush with the bony level and restored according to the platform-switching concept (Test); (iii) Implants inserted 1 mm subcrestally and restored according to the platform-switching concept (Test); and (iv) Implants inserted 1 mm supracrestally and restored according to the platform-switching concept (Test).

Mesial and distal aspects were measured and mean values were calculated.

Data analysis

Statistical analysis was performed applying the SPSS software package (SPSS Inc., Chicago, IL, USA). Differences in the means between the groups were analyzed using the Mann–Whitney U Test. The level of significance was set at \( \alpha = 0.05 \).

As specified under the randomization protocol, T₀−₁ and T₀+₁ implants were placed 1 mm above and 1 mm below the alveolar crest, respectively. The baseline measurements of the distance between the IAJ and B were adjusted for the implants placed 1 mm supracrestally to reveal bone resorption values.

Results

The post-operative healing was uneventful in all animals. No complications such as allergic reaction to medications, abscesses or infections were observed throughout the entire study period.

Two implants [one of the Test and one of the T₀+₁] were excluded from analysis owing to artifacts that occurred during histological processing. Hence, a total of 18 specimens were avail-
able for analysis. Mesial and distal measurements were averaged.

**Peri-implant bone remodeling**

As described in Table 1, the marginal bone resorption encountered was as follows: (i) the Control = 1.09 ± 0.59 mm; (ii) the Test = 0.51 ± 0.27 mm; (iii) the $T_{-1} = 0.50 ± 0.46$ mm; and (iv) the $T_{-1} = 1.30 ± 0.21$ mm. The differences between Control and Test as well as $T_{-1}$ were statistically significant ($P = 0.028$).

**Biologic width**

In Table 1, the data of the soft tissue dimensions are reported. At the Control, the biologic width averaged 3.20 ± 0.33 mm with a connective tissue adaptation compartment of 1.29 ± 0.53 mm and an epithelial attachment of 1.91 ± 0.71 mm (Figs 3 and 4).

At Test implants, a mean biologic width of 1.97 ± 1.20 mm, with a connective tissue adaptation compartment of 1.21 ± 0.96 mm and an epithelial attachment of 0.83 ± 0.92 mm, was noted (Fig. 5). At $T_{-1}$ implants, the biologic width averaged 2.84 ± 0.90 mm, with a connective tissue adaptation compartment of 1.49 ± 0.69 mm and an epithelial attachment of 1.35 ± 0.44 (Fig. 6).

**Table 1. Histometric measurements (n = 5)**

<table>
<thead>
<tr>
<th></th>
<th>Mean values</th>
<th>SD</th>
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<tbody>
<tr>
<td>Control PM-JE</td>
<td>1912</td>
<td>715</td>
</tr>
<tr>
<td>Control JE-B</td>
<td>1290</td>
<td>535</td>
</tr>
<tr>
<td>Control biologic width</td>
<td>3202</td>
<td>335</td>
</tr>
<tr>
<td>Control B-IAJ</td>
<td>1085</td>
<td>591</td>
</tr>
<tr>
<td>Control resorption</td>
<td>1085</td>
<td>591</td>
</tr>
<tr>
<td>Test PM-JE</td>
<td>839</td>
<td>925</td>
</tr>
<tr>
<td>Test JE-B</td>
<td>1210</td>
<td>966</td>
</tr>
<tr>
<td>Test biologic width</td>
<td>1970</td>
<td>1206</td>
</tr>
<tr>
<td>Test B-IAJ</td>
<td>510</td>
<td>273</td>
</tr>
<tr>
<td>Test resorption</td>
<td>510</td>
<td>273</td>
</tr>
<tr>
<td>$T_{-1}$ PM-JE</td>
<td>1346</td>
<td>442</td>
</tr>
<tr>
<td>$T_{-1}$ JE-B</td>
<td>1496</td>
<td>698</td>
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<tr>
<td>$T_{-1}$ biologic width</td>
<td>2842</td>
<td>906</td>
</tr>
<tr>
<td>$T_{-1}$ B-IAJ</td>
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<td>876</td>
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<tr>
<td>$T_{-1}$ resorption</td>
<td>501</td>
<td>461</td>
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</tbody>
</table>

*Histometric evaluation of soft and hard tissue structure. Mean values and standard deviation (SD) are reported in microns.

IAJ-B, bone remodeling; PM-JE, epithelial width, JE-B, connective width.

At $T_{-1}$ implants, the biologic width averaged 2.70 ± 1.36 mm, with a connective tissue adaptation compartment of 1.21 ± 0.64 mm.
The present study demonstrated that applying a platform-switching concept to the implant/abutment interface resulted in less marginal bone resorption after 4 months of healing than that encountered at implants with matching diameter abutments.

This outcome is in agreement with results from a variety of clinical (Canullo et al. 2009, 2010; Prosper et al. 2009; Vigolo & Givani 2009) as well as experimental studies (Weng et al. 2008; Cochran et al. 2009). In all those studies, the use of non-matching diameter implant abutments appeared to minimize the often observed marginal bone resorption (Atieh et al. 2010).

On the other hand, some reports do not agree with the outcomes of the present study. For instance, in a clinical study (Crespi et al. 2009), implants with two different abutment configurations were installed immediately after tooth extraction, and no differences in crestal bone resorption were identified between matched and mismatched abutment configurations. It has to be realized, however, that the implants were installed with the shoulder being placed at the level of the mesio-distal alveolar bone crest.

In experimental studies (Becker et al. 2007, 2009), implants were installed 0.4 mm supracrestally in edentulous alveolar bone crests in dog mandibles both with matched and mismatched implant abutments. No difference was found in the crestal bone level between matched and mismatched restorations up to 24 weeks following implant installation. The lack of any difference in alveolar crestal bone levels and in soft tissue dimensions may be attributed to the fact that the implants were placed coronal to the crestal bone level, thus eliminating any influence of mismatched implant abutments.

In the present study, it was further demonstrated that mismatched abutments of implants inserted flush with the bony crest allowed the establishment of a smaller biological width compared with matched abutment sites of implants with the same positioning. These data are also in agreement with outcomes from a dog study (Becker et al. 2007), which, after a healing period of 28 days, demonstrated a statistically significantly shorter epithelial attachment in sites with mismatched abutments compared with conventionally restored implant sites. However, recent dog studies failed to confirm these data (Becker et al. 2009, Baffone et al. 2011).

The difference in the outcomes of the various studies compared with those of the present study may be related to the different planes of sectioning applied in the histological preparations and to the supracrestal positioning of the implants in some instances.

The results of the present study were obtained from an animal model. Because of this, linear values of the peri-implant soft tissues should be considered with caution and not directly related to human equivalents. However, the proportional distribution of the peri-implant tissues found in the current experiment may provide reference values applicable to the human model.

In conclusion and within the limits of this study, the results of the present experiment suggest beneficial effects of mismatched (0.25 mm) abutments at implants, where the shoulder had been placed flush with the level of the alveolar crest. These effects include the preservation of approximately 0.5 mm crestal bony height concomitant with a shortening of the epithelial attachment of 1.1 mm and a maintained dimension of the supracrestal connective tissue adaptation compartment.

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Farronato et al. Biologic width after platform switching