INFLUENCE OF INTERIMPLANT DISTANCES AND PLACEMENT DEPTH ON PAPILLA FORMATION AND CRESTAL RESORPTION: A CLINICAL AND RADIOGRAPHIC STUDY IN DOGS

Arthur B. Novaes Jr, DDS, MScD, DSc; Raquel R. M. Barros, DDS, MScD; Valdir A. Muglia, DDS, MScD, DSc; Germana J. Borges, DDS

Among the factors that contribute to the papilla formation and crestal bone preservation between contiguous implants, this animal study clinically and radiographically evaluated the interimplant distances (IDs) of 2 and 3 mm and the placement depths of Morse cone connection implants restored with platform switch. Bilateral mandibular premolars of 6 dogs were extracted, and after 12 weeks, the implants were placed. Four experimental groups were constituted: subcrestally with ID of 2 mm (2 SCL) and 3 mm (3 SCL) and crestally with ID of 2 mm (2 CL) and 3 mm (3 CL). Metallic crowns were immediately installed with a distance of 3 mm between the contact point and the bone crest. Eight weeks later, clinical measurements were performed to evaluate papilla formation, and radiographic images were taken to analyze the crestal bone remodeling. The subcrestal groups achieved better levels of papillae formation when compared with the crestal groups, with a significant difference between the 3 SCL and 3 CL groups ($P = .026$). Radiographically, the crestal bone preservation was also better in the subcrestal groups, with statistically significant differences between the 2SCL and 2CL groups ($P = .002$) and between the 3SCL and 3CL groups ($P = .008$). With the present conditions, it could be concluded that subcrestal implant placement had a positive impact on papilla formation and crestal bone preservation, which could favor the esthetic of anterior regions. However, the IDs of 2 and 3 mm did not show significantly different results.

Key Words: dental implants, interimplant distance, crestal bone levels, gingival papilla, bone resorption, contact point

INTRODUCTION

The presence of papilla is essential for esthetic rehabilitation with dental implants, especially in the anterior region. Various factors can contribute to papilla formation and preservation, but all are related to crestal bone remodeling.

One theory of crestal bone resorption holds that peri-implant bone loss can routinely be expected to occur within the first year of functional loading as a physiological response to the formation of the biologic width around implants.$^{1,2}$ Cochran et al.$^3$ for example, evaluated healing around nonsubmerged implants in dogs and observed a mean biologic width
of 3.08 mm, which consisted of average-depth values for sulcus (0.16 mm), junctional epithelium (1.88 mm), and connective tissue attachment (1.05 mm) after 12 months of functional loading. The establishment of a biological seal around implants is considered an important natural phenomenon, but it has also been theoretically linked to bone remodeling.\textsuperscript{1,3,4}

Recent studies in dogs\textsuperscript{5–7} suggested that the distance between the contact point and crestal bone tip should be about 3 mm, to compensate for the crestal bone resorption that occurs around adjacent implants. However, other factors can contribute to the crestal bone resorption, such as the anatomy of the cervical region and surface treatment of the implants, the type of connection between implant and prosthesis, the implant positioning in relation to the crestal bone, and the distance between contiguous implants, to name a few.\textsuperscript{8–10}

Implants with Morse cone connections feature internal, tapered, and conical abutments to eliminate the microgap often found in 2-stage implant systems. The implant/abutment connection of these systems and the microgap may allow repetitive micromovements between the parts during clinical function,\textsuperscript{11} as well as accumulation of food debris and bacteria, both of which can lead to localized inflammation and crestal bone loss.\textsuperscript{12–14} This system uses the platform-shifting protocol for restoration, in which the abutment is 1 mm narrower than the implant platform at the time of surgery. A reduced peri-implant crestal bone resorption has been demonstrated with this protocol,\textsuperscript{15} and an explanation for this finding could be the displacement of stresses during function away from the dense cortical bone and toward the resilient trabecular bone.\textsuperscript{11}

More recently, clinical studies were conducted to evaluate whether the subcrestal positioning of the implants could alter the crestal bone resorption. However, no consensus was achieved. While one study indicated that the level of placement did not jeopardize the height of the peri-implant ridge,\textsuperscript{16} another stated that implants placed below the crestal bone level had the least amount of bone loss compared with those crestally placed,\textsuperscript{17} and yet another study found that the crestal bone resorption around more deeply placed implants was higher and increased over time.\textsuperscript{18}

Further to be considered is the interimplant distance once it could influence the lateral bone loss around the implants, the vertical bone loss, and finally the papillae formation. Scarano et al\textsuperscript{19} evaluated bone remodeling around interimplant distances of 2, 3, 4, and 5 mm in a canine histological study and found that vertical crestal bone loss decreased from 1.98 mm (group I, 2-mm interimplant distance) to 0.23 mm (group IV, 5-mm interimplant distance).

The aim of this study was to evaluate clinically and radiographically the influence of the horizontal spacing and vertical placement of contiguous Morse cone connection implants restored with the platform-shifting approach on the papillae formation and crest bone response in the canine model.

**MATERIALS AND METHODS**

The study protocol was approved by the Ethical Committee of the School of Dentistry of Ribeirão Preto, University of São Paulo, SP, Brazil (Process 07.1.122.53.8) and involved 2 surgical interventions that were performed in 6 young adult male mongrel dogs, weighing approximately 20 kg. The animals presented intact maxillae, no general occlusal trauma, and no oral viral or fungal lesions. They were in good general health, with no systemic involvement as determined during clinical examination by a veterinarian.

Two weeks before the surgery, the dogs received antiparasitic treatment, multivitamins, and vaccines. Ultrasound prophylaxis was administered to remove supragingival calculus, and a solution of chlorhexidine gluconate 0.12% was applied on the teeth with gauze.

The animals began fasting the night before surgery. Anesthesia consisted of an intramuscular injection of a preanesthetic (acepromazine 0.02% - 0.05 mg/kg) followed by intravenous administration of thiopental (1 mL/kg; 20 mg/kg thiopental diluted in 50 mL saline). The animals were then moved to the operating room and maintained on gas anesthesia (1%–2% isoflurane/O\textsubscript{2} to effect).

In the first phase of the study, full-thickness flaps were elevated bilaterally, and the 4 mandibular premolars of both hemiarchs of each animal were extracted. The teeth were sectioned in the buccolingual direction at the bifurcation, and the roots were individually extracted using a periosteum in order to not damage the bony walls. The flaps were repositioned and sutured with nonabsorbable 4–0 sutures (Shalon, S.L.M. Belos, GO, Brazil). The animals received analgesic and anti-inflammatory injections and multivitamins.

After a healing period of 8 weeks, the dogs received 20 000 IU penicillin and streptomycin (1.0 g/10 kg) the night before the second surgery. This dose provided antibiotic coverage for 4 days, and another dose was given 4 days later to provide coverage for a total of 8 days.
After repeating the same sedation and anesthesia protocol described previously, horizontal crestal incisions were bilaterally made from the distal region of the canine to the mesial region of the first molar (Figure 1). Four implants (Neodent, Curitiba, Brazil), 4.5 × 9.0 mm with internal Morse cone connections and sandblasted and acid-etched surfaces (Figure 2), were randomly placed 1.5 mm subcrestally (Figure 4) on one side of the mandible, and the other 4 implants were placed crestally (Figure 5) on the contralateral side. A total of 48 implants were placed in the study. Distances between 2 adjacent implants were alternatively 2 or 3 mm on both sides of the mandible (Figure 3). Thus, 4 groups were treated: group 1, implants subcrestally with 2 mm of interimplant distance (2 SCL); group 2, implants subcrestally with 3 mm of interimplant distance (3 SCL); group 3, implants crestally with 2 mm of interimplant distance (2 CL); and group 4, implants crestally with 3 mm of interimplant distance (3 CL). The distances between the implants as well as the positions of implant placement were arbitrarily determined by a coin toss.

After implant placement, metallic crowns were immediately installed with 3 mm of distance between the contact point and the bone crest. The soft tissues were sutured around the crowns for nonsubmerged healing (Figure 6). The animals were maintained on a soft diet for 14 days until the sutures were removed. Healing was evaluated weekly, and plaque control was maintained by flushing the oral cavity with chlorhexidine gluconate. The remaining teeth were cleaned monthly with ultrasonic points.

Eight weeks after restoration, the animals were anesthetized and clinical analyzes were conducted. Then they were killed with an overdose of thiopental, as required for a study that was conducted with the same animals, and digital radiographic analysis was performed (Trophy-Radiologie, Vincennes, France).

**Clinical analysis**

The presence of papillae between the restorations placed on the implants was evaluated. The distance between the contact point (CP) and the tip of the interimplant papilla (P) was measured with a compass (MOD 9002, Trident, Brasil) (CP-P). An imaginary reference line transversal to the long axis of the crowns was made crossing the CP to evaluate the distance between the top of the soft tissue presented in the edentulous regions (ED) and the supposed CP (CP-ED) (Figure 7).

**Radiographic analysis**

Immediately after the animals were killed, the hemimandibles were dissected and removed. Then, digital radiographic images were obtained (Figures 8 and 9). This procedure was carried out to standardize the distance between the X-ray source and the specimen.

The digital images were analyzed and assessed using measuring software (Image J1.32j, Wayne Rasband, National Institutes of Health, Bethesda, Md). A line drawn parallel to the top of the implant shoulders and crossing the contact point was used as a fixed reference. Then the final distance between the CP and the top of the bone crest (BC) (CP-BC) was measured (Figure 10). In addition, the distance between the shoulder of the implant (l) and the first bone-to-implant contact was measured individually at the interimplant regions (IR) (l-IR, mean of A and B), and this procedure was repeated at the edentulous regions (ER) (l-ER, mean of C and D), where the CP did not exist (Figure 11).
**Statistical analysis**

Mean values and SDs were calculated. The data were grouped using the dogs as units for analysis. The mean differences between the groups were analyzed using the Mann-Whitney nonparametric test with a significance level of $P \leq .05$.

**Results**

**Clinical findings**

Postextraction healing was uneventful in all dogs. At implant surgery 8 weeks later, the extraction sites appeared clinically healed. After implant placement, healing was also uneventful. There were no complications throughout the experimental period.

**Radiographic analysis**

The digital radiographic analyzes provided the distances from the contact point to the top of bone crest (CP-BC) that are represented in Table 3. The intergroup analysis showed statistically significant differences when group 1 (2 SCL) was compared with group 3 (2 CL), with $P = .026$, and also when group 2 (3 SCL)
was compared with group 4 (3 CL), with $P = .015$. On the other hand, the intragroup analysis showed a statistically significant difference only between groups 3 (2 CL) and 4 (3 CL), with $P = .031$. The mean distance of CP-BC at the edentulous regions (CP-ER) is represented in Table 4. The results were not statistically significant ($P > .05$).

According to the analysis of the bone level in the areas between implants (A/B) (Figure 11), represented in Table 5, very statistically significant differences between groups 1 (2 SCL) and 3 (2 CL), with $P = .0022$, and between groups 2 (3 SCL) and 4 (3 CL), with $P = .0087$, were obtained.

In addition, the bone level in the edentulous regions (C/D) (Figure 11) is represented in Table 6, and the results were not statistically significant ($P > .05$).

**DISCUSSION**

Functional and esthetic successes of adjacent implants are strongly correlated to crestal bone resorption and papilla formation at the interimplant region. The present study investigated both of these parameters, taking into consideration 2 different distances between the implants and also 2 different depths of implant placement. A Morse cone connection implant system was used with an initial distance between the contact point and the tip of the bone crest of 3 mm.

The effect of implant placement depth (crestal or subcrestal) on the interimplant bone remodeling has recently been investigated, with inconclusive results. In the present study, the subcrestal groups showed better results in all of the parameters evaluated when compared with the crestal groups. In contrast, Hermann et al and Piattelli et al reported that when the implant-abutment junction was positioned deeper within the bone, a more pronounced loss of vertical crestal bone height was observed. The authors attributed this finding to the implant/abutment connection used. Other researchers have reported that the microgap found in the 2-stage implant systems may potentially facilitate the accumulation of debris and bacteria. Same implant systems may also permit micromovements at the abutment-implant connection during clinical function that finally leads to localized inflammation and crestal bone loss. Conversely, the subcrestal positioning of implants in the present study resulted in bone located above the implant shoulder, as demonstrated by the radiographic results of the distance from the top of the implant to the first bone-to-implant contact at the interimplant region (I-IR). The reason for this finding could not be deduced from the present data, but it has been speculated that the Morse cone connection that allows abutments to emerge from a more central area of the implant (platform-shifting protocol) may help to protect the peri-implant soft and mineralized tissues.
FIGURES 7–11. FIGURE 7. Clinical measurements showing the distance between the contact point and the tip of interimplant papilla (CP-P) and the distance from the contact point and the tip of the papilla in the adjacent edentulous area (CP-ED). FIGURE 8. Immediately after sacrifice, digital radiographic images were taken from the experimental subcrestal side. Note the bone level around the implants. FIGURE 9. Radiographic images were also taken from the experimental crestal side. Note the bone level around the implants. FIGURE 10. Radiographic measurements of the bone resorption in the areas between implants (A/B) and in the edentulous regions around the implants (C/D). FIGURE 11. Radiographic measurements of the final distance between contact point and bone crest (CP-BC) and the final distance between contact point and bone crest in the edentulous regions (CP-ER).
and reduce the rate of bone resorption\textsuperscript{13,25} by positioning the implant-abutment junction away from the external, outer edge of the implant and neighboring bone, and thereby decreasing potential abutment inflammatory cell infiltrate on the surrounding tissues.\textsuperscript{13,24,26} Randomized prospective comparative clinical research is needed to evaluate the validity of this theory.

It is also important to note that crestal bone loss in the present study was reduced but not absent for all of the groups evaluated, especially considering the radiographic analysis of the distance from the top of the implant to the first bone-to-implant contact at the interimplant region (I-IR). Other possible etiologic factors associated with the observed bone response include the surgical trauma and the formation of the biologic distances.

According to the radiographic analysis of the distance from the contact point to the bone crest (CP-BC), the mean values of the 2SCL and 3SCL groups of 2.94 and 2.99 mm, respectively, were not representative as crestal bone loss when one considers that this initial distance was 3 mm. This result is in disagreement with the findings of Tarnow et al,\textsuperscript{27} who observed a crestal bone loss of 1.04 mm when the adjacent implants had an interimplant distance of <3.00 mm, and also with Scarano et al,\textsuperscript{19} who found a vertical crestal bone loss of 1.98 mm with the interimplant distance of 2 mm and of 1.78 mm with the interimplant distance of 3 mm using 2-piece implants. In addition, the comparisons between the 2SCL and 2CL groups and also between the 3SCL and 3CL groups were statistically significant for the radiographic analysis of the distance from the contact point to the crestal bone, suggesting that the subcrestal positioning may have some positive influence in the maintenance or formation of a crestal bone peak at the interimplant area.

The interdental papilla formation that is always described in close relation to the crestal bone level at this area also showed numerically better results for the subcrestal groups when compared with the crestal groups, but this difference was statistically significant only when the 3-mm interimplant distances for the subcrestal group were compared with the crestal group.

Interimplant distances of 2 and 3 mm did not present significant intragroup differences in terms of crestal resorption and interimplant papillae formation. This is in contrast to other studies\textsuperscript{19} that showed decreased vertical crestal bone loss and lateral bone

\begin{table}
\centering
\caption{Clinical analysis: distance from the contact point to the tip of the papilla (CP-P)}
\begin{tabular}{lllll}
\hline
Dog & 2 mm & 3 mm & 2 mm & 3 mm \\
\hline
1 & 3.04 & 3.28 & 0.85 & 1.85 \\
2 & 1.24 & 4.35 & 1.32 & 0.41 \\
3 & 0.91 & 1.67 & 0.63 & 1.13 \\
4 & 1.38 & 1.40 & 0.64 & 0.86 \\
5 & 1.37 & 1.36 & 0.80 & 0.97 \\
6 & 0.57 & 1.39 & 0.91 & 0.85 \\
\hline
\end{tabular}
\end{table}

\begin{table}
\centering
\caption{Clinical analysis: distance from the contact point to the tip of the papilla in edentulous regions (CP-ED)}
\begin{tabular}{llll}
\hline
Dog & Equicrestally & Subcrestally \\
\hline
1 & 3.53 & 2.83 \\
2 & 3.31 & 2.47 \\
3 & 1.98 & 1.78 \\
4 & 3.15 & 2.75 \\
5 & 2.75 & 2.30 \\
6 & 1.00 & 1.00 \\
\hline
\end{tabular}
\end{table}

\begin{table}
\centering
\caption{Radiographic analysis: distance from the contact point to the bone crest (CP-BC)}
\begin{tabular}{llllll}
\hline
Dog & 2 mm & 3 mm & 2 mm & 3 mm \\
\hline
1 & 3.76 & 4.52 & 3.26 & 3.38 \\
2 & 3.33 & 3.52 & 2.79 & 2.87 \\
3 & 3.59 & 3.78 & 2.73 & 3.17 \\
4 & 3.21 & 3.63 & 2.98 & 3.04 \\
5 & 3.06 & 3.12 & 2.77 & 2.51 \\
6 & 3.18 & 3.20 & 3.10 & 2.95 \\
\hline
\end{tabular}
\end{table}

\*Significance level of $P < .05$.
loss with the interimplant distance of 3 mm when compared with the interimplant distance of 2 mm, but those implants were not loaded immediately and the distance between the contact point and the bone crest tip was not evaluated, and these 2 factors could actually influence bone resorption. Tarnow et al also found differences when the interimplant distances of 3 mm or less were compared with those greater than 3 mm, and this could possibly be because their study was based on radiographs from the anterior maxilla, where the alveolar ridge is often narrower than the dog posterior mandibles. On the other hand, the present results are in accordance with the work of Novaes et al and Oliveira et al, who found that interimplant distances of 1 to 3 mm did not affect papilla formation or crestal resorption in dog models. In both studies, the initial distance between the contact point and the bone crest was 5 mm; especially in the Oliveira et al study, which used a similar implant system and restorative approach, the values of CP-P distances varied from 3.07 to 3.16 for nonsubmerged implants. Based on these results, the authors concluded and suggested that the use of a distance smaller than 5 mm could compensate the crestal bone alterations that occur during the establishment of the biologic width around implants and could favor papilla formation between contiguous implants. Thus, in the present study, the distance between the contact point and bone crest of 3 mm was used, and all of the groups showed excellent fill of the embrasures with soft tissue, exhibiting mean CP-P values from 0.86 to 1.01 mm for the subcrestal groups, despite the short period of evaluation. Degidi et al analyzed the soft-tissue levels between contiguous implants over 24 months and observed that longer periods of time are related to more papillae formation. Thus, if the observation period of the present study was longer, a complete fill of the embrasures might be expected.

Again, in agreement with Oliveira et al, who found 2.78 ± 0.64 mm from the contact point to the papillae in the in the free regions of the bridges (CP-DE), the mean distance of CP-DE in the present study was 2.22 ± 0.67 mm for the subcrestal side and 2.59 ± 0.99 mm for the crestal side. However, this parameter could provide valuable information only when compared with the results obtained from the interimplant areas. In the present study, this comparison showed better results for the interimplant areas, confirming the importance of the prosthetic contact point for papilla formation. Jemt and Lekholm, for example, have already shown that the shape or the contour of the gingiva is highly variable and dependent on the location and area of the interproximal contact.

It should be noted from this dog model study that the presence or absence of papilla is influenced by many factors. Studies have been conducted in recent years with the aim of establishing the ideal treatment plan for implants placed in the esthetic zones, with special attention to the position of the contact point in relation to the bone crest and the interimplant distance. According to the results of the present study, when the contact point of restored contiguous implants is placed 3 mm above the bone crest, the interdental papilla formation achieved better indexes

<table>
<thead>
<tr>
<th>Dog</th>
<th>Crestally</th>
<th>Subcreastally</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.81</td>
<td>3.22</td>
</tr>
<tr>
<td>2</td>
<td>3.52</td>
<td>2.96</td>
</tr>
<tr>
<td>3</td>
<td>2.94</td>
<td>2.98</td>
</tr>
<tr>
<td>4</td>
<td>2.97</td>
<td>3.15</td>
</tr>
<tr>
<td>5</td>
<td>2.87</td>
<td>2.62</td>
</tr>
<tr>
<td>6</td>
<td>3.07</td>
<td>3.94</td>
</tr>
</tbody>
</table>

Mean ± SD 3.20 ± 0.45 3.15 ± 0.55

Table 4

Radiographic analysis: distance from the contact point to the crestal bone in edentulous regions (CP-ER)

<table>
<thead>
<tr>
<th>Dog</th>
<th>Crestally</th>
<th>Subcreastally</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.61</td>
<td>0.76</td>
</tr>
<tr>
<td>2</td>
<td>0.46</td>
<td>0.58</td>
</tr>
<tr>
<td>3</td>
<td>0.11</td>
<td>0.17</td>
</tr>
<tr>
<td>4</td>
<td>0.37</td>
<td>0.75</td>
</tr>
<tr>
<td>5</td>
<td>0.25</td>
<td>0.26</td>
</tr>
<tr>
<td>6</td>
<td>0.34</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Mean ± SD 0.41 ± 0.12* 0.53 ± 0.24** −0.09 ± 0.21* −0.04 ± 0.32**

Table 5

Radiographic analysis: distance from the top of the implant to the first bone-to-implant contact in interimplant region (I-IR)

*Significance level of P < 0.05 between groups.
when compared with previous studies using the same animal model; in reality, the embrasures were almost closed with soft tissue, and there is some possibility to get the total fill if longer healing periods had been used. Moreover, no significant differences between the interimplant distance of 2 and 3 mm were obtained in relation to papilla formation and crestal bone resorption with the nonsubmerged protocol with Morse cone connection implants with platform switching or shifting. Finally, in the subcrestal groups, bone was observed above the top of the implants. Clinically, this could have a great impact because the nonexposure of the implant into the soft tissues means that the implant metal will not compromise gingival translucency and final esthetic results.

CONCLUSIONS

On the present conditions of implant system and restoration method, the interimplant distances of 2 and 3 mm were not significantly different in terms of papilla formation and crestal bone resorption. Subcrestal implant placement had a positive impact on papilla formation and crestal bone remodeling around contiguous implants, and the presence of bone slightly above the top of the implants might play a beneficial outcome for esthetic regions.

REFERENCES


