Influence of Interimplant Distance on Gingival Papilla Formation and Bone Resorption: Clinical-Radiographic Study in Dogs

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Purpose: *The purpose of this study was to evaluate in dogs the area between implants after prosthetic restoration within 5 mm distance between the contact point (CP) between crowns and the bone crest (BC).* ***Materials and Methods:*** *The mandibular premolars of 6 dogs were extracted bilaterally. After 12 weeks of healing, each dog received 8 implants. On each side, 2 implants were separated by 2 mm (group 1) and 2 by 3 mm (group 2). After a healing period (3 months), the implants were restored with temporary acrylic resin prostheses and after 4 more weeks, with definitive metallic prostheses. After 8 weeks, the distance between the CP and the papilla (P) was measured. The distance between a line extending from the CP and the gingival height at the distal extension of the prosthesis (DE) was also measured. Digital radiographic images were obtained for evaluation of the CP-BC and BC-P distances and the analysis of bone resorption adjacent to the implant surfaces.* ***Results:*** *The median CP-P distances were 1.75 mm and 1.98 mm for groups 1 and 2, respectively; the median CP-DE distances were 2.60 and 2.69, respectively. The mean CP-BC distances were 5.64 mm and 6.45 mm, for groups 1 and 2, respectively; mean BC-P distances were 3.07 mm and 3.55 mm, respectively.* ***Discussion and Conclusions:*** *The differences in distances of 2 and 3 mm between implants did not present significant differences in the formation of papillae or in crestal resorption. The CP-BC distances for prostheses should be different from those of natural teeth because in natural teeth, the biologic width is already present, and in the case of implant-supported prostheses, it will develop following second-stage surgery.* Int J Oral Maxillofac Implants 2006;21:45–51

Key words: *bone crest, bone resorption, contact point, gingival papilla, interimplant distance*

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Dental implants are considered predictable treatment for the replacement of lost teeth.[1] Currently, osseointegrated implants offer excellent function and good esthetics and phonetics, especially when placed in anterior regions. The esthetic objective of dental implants is similar to that of conventional prostheses. However, frequently it may not be possible to place implants in ideal regions because of limitations in bone quantity and quality.[2]

The biologic width surrounding the tooth has been evaluated in studies that reported the dimensions of the physiologic attachment apparatus.[3,4] Implants are also surrounded by a biologic width.[5] Berglundh and associates[6] compared the composition of gingiva and mucosa around implants and found clinically healthy soft tissues surrounding both teeth and implants. These tissues also presented common microscopic characteristics; both tissues were covered by a kera-

tinized epithelium continuous to the junctional epithelium, which around both teeth and implant had 2 mm in extension. The epithelium was separated from the alveolar bone by a connective tissue area larger than 1 mm. Characteristics similar to the implant/mucosa union, ie, junctional epithelium and connective tissue, have been reported in studies that used 1- and 2-stage implants.[7,8]

After the exposure of 2-stage implants and abutment placement, an implant-abutment interface is established, and bone resorption of 1.5 to 2.0 mm may occur toward the apical portion of the implant.[9] The biologic reason for this phenomenon is that if a chronic irritant, such as bacteria, reaches the implant-abutment interface, or if the abutment is removed after initial healing, bone resorption can occur, creating a distance from the irritated area. Tarnow and associates[10] previously reported a similar bone response to subgingival prosthetic crown preparations that violate the attachment apparatus on natural teeth.

The presence or absence of papilla in the interproximal area is a major concern for periodontists, restorative dentists, and patients. Its loss can lead to esthetic deformities, phonetic problems, and lateral food impaction.

The vertical distance between the base of the contact point and the crestal bone seems to be a determining factor for the presence of an interproximal papilla. When evaluating interdental sites,[11] Tarnow and colleagues observed that when the distance was 5 mm or less, the interproximal papilla was present in 98% of the cases. When the distance was 6 mm, the presence of papilla decreased to 56%; when the distance was 7 mm or more, the papilla was present in a maximum of 27% of the cases. Other variables, such as the degree of inflammation, probing depth, fibrous or edematous tissue, position of teeth (anterior or posterior), surgical history, and proximal restorations, can also contribute to the presence or absence of papilla.

Regarding the importance of the contact point between teeth, Garber and associates[12] reported that when an implant is positioned, the surrounding tissues must be maintained so that the soft tissue that extends coronally from the free gingival margin to the crestal bone apically at a distance of 3 mm is completely supported by a prosthetic restoration. In order to evaluate the effect of the distance between adjacent implants on the height of the crest of the bone, Tarnow and coworkers[13] measured the lateral bone loss in radiographs from 36 patients. It was observed when the distance between the implants was 3 mm or less, the crestal bone loss was greater than when the implants were spaced more than 3 mm apart. This study demonstrates that there is a lateral component to the bone loss around implants in addition to the more commonly discussed vertical component. The clinical significance of this phenomenon is that the increased crestal bone loss would result in an increase in the distance between the base of the contact point of the adjacent crowns and the crest of bone. This could determine whether the papilla is present or absent between 2 implants, as has previously been reported between 2 teeth.[11] Selective utilization of implants with a smaller diameter at the implant-abutment interface may be beneficial when multiple implants are to be placed in the esthetic zone so that a minimum of 3 mm of bone can be retained between them at the implant-abutment level.

Based on the results discussed here, it is conceivable that there is a critical distance between implants around 2 and 3 mm. Therefore, the purpose of this study was to determine clinically and radiographically the effect of these distances between contiguous implants on crestal bone resorption and presence of papillae after prosthetic restoration with a distance of 5 mm between the interproximal contact and the crestal bone.

MATERIALS AND METHODS

Six young adult male mongrel dogs (10 kg) were used. They had intact maxillae and mandibles, were in good general health, and had no viral or fungal oral lesions.

The night before surgery, the animals were taken off their food. They received an intramuscular injection of preanesthetic (2% Rompun, 20 mg/kg, 0.5 mL/10 kg) and were then anesthetized intravenously with thiopental (1 mL/kg; 20 mg/kg diluted in 50 mL saline). A flap was raised in the region of the 4 mandibular premolars, and the teeth were sectioned in the buccolingual direction and extracted with forceps. The flaps were repositioned and sutured with resorbable 4-0 suture.

A healing period of 3 months was allowed before second-stage surgery. The animals received 20,000 IU penicillin and 1.0 g/10 kg streptomycin the night before surgery. This dose provided antibiotic coverage for 4 days. Another dose was given 4 days later; thus, coverage was provided for a total of 8 days. This broad-spectrum antibiotic is commonly used to treat infections in small animals.[14] After repeating the same sedation and anesthesia as in phase 1, a horizontal crestal incision was made from the distal region of the canine to the mesial region of the first molar, and implants were placed according to manu-

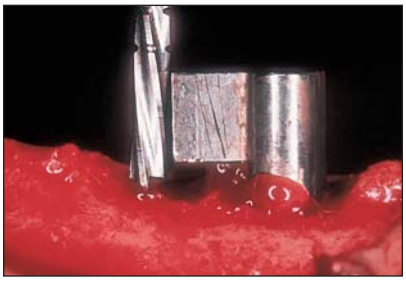

Fig 1a The device made to standardize both the angle and distance between implants.

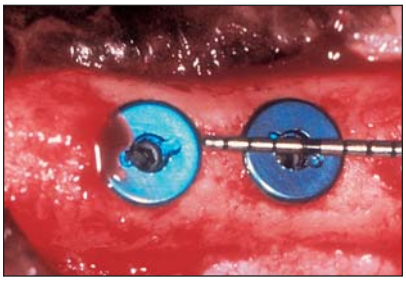

Fig 1b Interimplant distance of 2 mm.

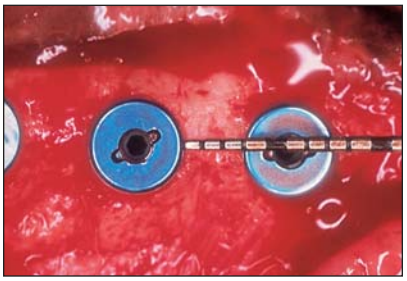

Fig 1c Interimplant distance of 3 mm.

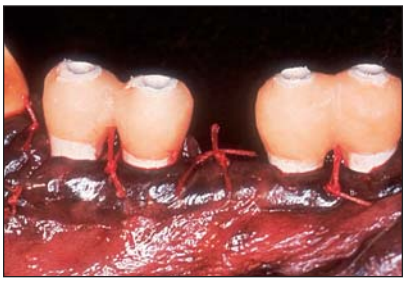

Fig 2a *(Left)* Temporary restorations, fabricated so that the distance between the point where the 2 restorations came into contact (the contact point [CP]) and the bone crest (the CP-BC distance) was 5 mm.

Fig 2b *(Above)* Temporary restorations cemented on the implants. They were separated from each other by 2 or 3 mm.

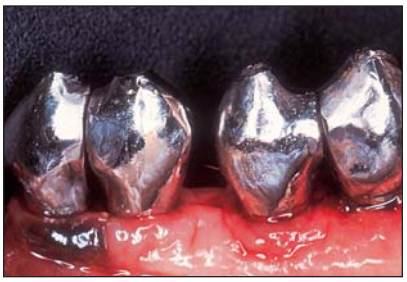

Fig 3 Metallic crowns. A distance of 5 mm between the contact point and the bone crest was maintained.

facturers' instructions. Four Frialit implants (sand-blasted/acid-etched surfaces; Dentsply Friadent, Mannheim, Germany) 4.5 × 10 mm were placed on each side of the mandible of each animal, for a total of 48 implants. The implants were placed so that 2 adjacent implants were 2 mm apart (group 1), while 2 were 3 mm apart (group 2). To achieve this, a stainless steel device was made to standardize both the angle and the distance between implants (Figs 1a to 1c). Contralaterally, the distances between implants were repeated; however, the positions of the implants were varied, respecting the random cross-location method. The flaps were repositioned and sutured with nonresorbable sutures so that the implants were totally submerged. The sutures were removed after 10 days.

During the 12-week healing period, the animals received monthly ultrasound prophylaxis. After 12 weeks, prosthetic restoration was begun. The same method of sedation and anesthesia was followed as before. The implants were exposed, and temporary acrylic resin prostheses were fabricated so that the implants were placed in function for a period of 4 weeks. These temporary restorations were fabricated so that the distance between the contact point and the crestal bone was 5 mm (Figs 2a and 2b). Definitive metallic crowns were also made to maintain this distance of 5 mm[11] (Fig 3). During the time that the prostheses remained in place, ultrasound prophylaxis was done weekly until sacrifice.

Eight weeks after placing the restorations, clinical and radiographic examinations were carried out. Digital radiographic images were obtained with the Trophy system (Trophy-Radiologie, Vincennes, France), and the sensitivity of the apparatus was regulated not only to observe mineralized structures and but also to provide a profile of the gingival soft tissues.

Clinical Analysis

The formation of papillae between the restorations placed on the implants was evaluated using a compass measuring the distance between the point where the 2 restorations came into contact (the contact point) and the tip of the interimplant papilla (CP-P). In order to determine whether the contact point influences papilla formation, the height of the papilla at the free surfaces of the implants (DE) was also measured. A line from the contact point was projected mesially and distally until it reached the

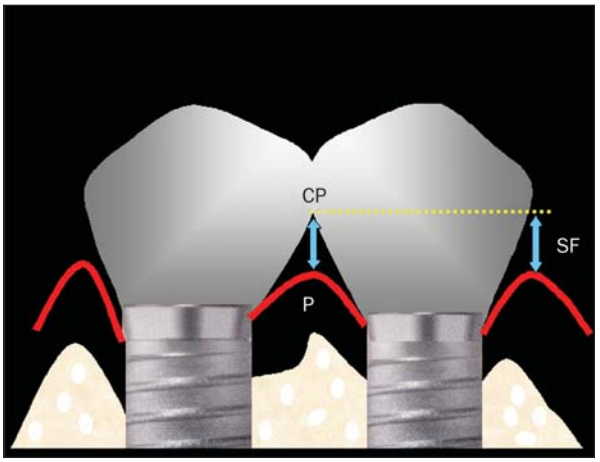

Fig 4 Diagram showing the clinical measurements made. The CP-P distance was measured, as was the distance between a line extending from the contact point and the tip of the papilla in the distal extension area of the restoration (the CP-DE distance).

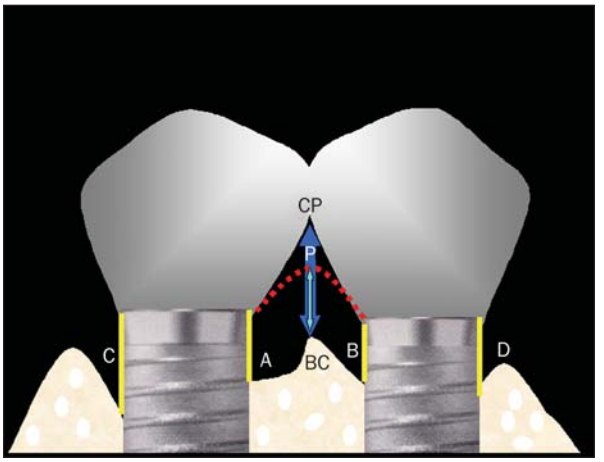

Fig 5 Diagram showing the radiographic measurements made. Bone resorption was measured in the areas between the implants (A/B) and in the distal extension around the implants (C/D). The distances between the contact point and bone crest (CP-BC) and between the bone crest and the papilla (BC-P) were also reported.

Table 1 Clinical Analysis of the CP-P Distance

Dog	Group 1	Group 2
1	2.21	2.78
2	1.70	—
3	2.65	4.08
4	1.75	1.47
5	1.76	1.98
6	1.30	1.62
Median ± SD	1.75 ± 0.46	1.98 ± 1.07

edentulous areas. The height of the papilla was measured from the line to the tip of the papilla in the edentulous areas (CP-DE, Fig 4).

Radiographic Analysis

Digital radiographs were used to evaluate the BC-CP distance and the distance between the bone crest and the tip of the papilla (BC-P). Additionally, vertical bone resorption was measured at the interimplant regions (A and B) and at the distal extension regions (C and D), where the contact point did not interfere (Fig 5).

Statistical Analysis

The normality of the data was analyzed with the Kolmogorov-Smirnov test. Since the data had a normal distribution, the Student *t* test was used instead of Wilcoxon's nonparametric test to compare differences between paired groups. However, in evaluating the results of these tests, the standard error of the difference, which was affected by the sample size, must be considered. $P < .05$ was considered significant.

RESULTS

During the healing period, 1 implant in group 1 and 3 implants in group 2 were lost. All other implants were stable until the end of the investigation.

Clinical Analysis

The median CP-P distance was 1.75 ± 0.46 mm (range, 1.30 to 2.65 mm) for group 1 and 1.98 ± 1.07 mm (range, 1.47 to 4.08 mm) for group 2 (Table 1). There were no statistically significant differences between groups ($P > .05$).

The median CP-P distance (1.75 ± 0.46 mm) was also compared to the median gingival height at the distal extension region (2.60 ± 0.73 mm; range, 1.71 to 3.92 mm) for group 1 (Table 2); the difference was statistically significant ($P < .05$). On the other hand, when the median CP-P distance for group 2 (1.98 ± 1.07 mm) was compared to the median gingival height at the distal extension region (2.69 ± 0.70 mm; 1.80 to 3.52 mm) (Table 3), the results were not statistically significant ($P > .05$).

The median was used for clinical analyses because the distribution was asymmetric and the median was not influenced by the extremes.

Radiographic Analysis

Radiographs showed that the mean distance CP-BC distance was 5.64 ± 0.50 mm (range, 5.10 to 6.36 mm) for group 1 and 6.45 ± 1.01 mm (range, 5.33 to 8.08 mm) for group 2 (Table 4). There were no statistically significant differences between the 2 groups ($P > .05$). Analyzing the mean CP-P distance, group 1 presented a mean of 3.07 ± 0.23 mm (range, 2.78 to 3.41

Table 2 Comparison Between the CP-P Distance and CP-DE Distance for Group 1*

Dog	CP-P	CP-DE
1	2.21	3.07
2	1.70	3.92
3	2.65	2.70
4	1.75	2.50
5	1.76	2.46
6	1.30	1.71
Median ± SD	1.75 ± 0.46†	2.60 ± 0.73†

*Significance level of 5%.
†Difference was statistically significant ($P < .05$).

Table 3 Comparison Between the CP-P Distance and CP-DE Distance for Group 2

Dog	CP-P	CP-DE
1	2.78	2.91
2	–	–
3	4.08	2.69
4	1.47	3.52
5	1.98	1.97
6	1.62	1.80
Median ± SD	1.98 ± 1.07	2.69 ± 0.70

Table 4 Radiographic Analysis of the CP-BC Distance

Dog	Group 1	Group 2
1	6.36	6.44
2	5.10	–
3	5.50	8.08
4	5.71	5.33
5	6.05	6.04
6	5.12	6.34
Mean ± SD	5.64 ± 0.50	6.45 ± 1.01

Table 5 Radiographic Analysis of the BC-P Distance

Dog	Group 1	Group 2
1	3.26	5.96
2	2.90	–
3	3.41	3.69
4	3.06	2.86
5	2.78	2.51
6	2.98	2.75
Mean ± SD	3.07 ± 0.23	3.55 ± 1.42

Table 6 Radiographic Analysis of the Bone Resorption from the Abutment Connection to First Point of Bone-to-Implant Contact

	A/B		C/D	
Dog	Group 1	Group 2	Group 1	Group 2
1	2.97	1.51	2.56	1.88
2	2.15	–	2.21	–
3	1.95	2.07	1.65	2.19
4	2.89	2.50	1.78	1.95
5	2.48	2.35	2.33	2.04
6	2.10	2.13	2.03	2.11
Mean ± SD	2.42 ± 0.43	2.11 ± 0.38	2.10 ± 0.34	2.03 ± 0.12

mm) and group 2 presented a mean of 3.55 ± 1.42 mm (range, 2.51 to 5.96 mm) (Table 5). These differences were also not statistically significant ($P > .05$).

In the analysis of bone resorption, group 1 presented a mean of 2.42 ± 0.43 mm (range, 1.95 to 2.97 mm) in region A/B and 2.10 ± 0.34 mm (range, 1.78 to 2.56 mm) in region C/D. Group 2 presented a mean in region A/B of 2.11 ± 0.38 mm (range, 1.51 to 2.50 mm) and in region C/D of 2.03 ± 0.12 mm (range, 1.88 to 2.19 mm) (Table 6). No significant statistical differences were found between groups or regions A/B and C/D for the 2 groups.

DISCUSSION

The success of implants depends on the integration between soft and mineralized tissues. During initial healing and throughout the first year, there is a mean bone loss around implants of 1.5 mm, followed by a minimal bone loss of 0.2 mm in the following years.[15] Possible etiologic factors associated with this initial bone loss are surgical trauma, overload, peri-implantitis, the presence of a microgap, and the formation of biologic distances.[16]

In natural teeth, the dento-gingival junction consists of 3 components: the gingival sulcus, epithelial attachment, and the connective tissue attachment. Similarly, around the implant there are zones of marginal mucosa. Junctional epithelium and connective attachment cause the biologic sealing around the implant and act as a barrier against bacteria and food residues at the interface between the implant and soft tissue, thereby potentially affecting the success of implant integration.[17–19]

Cochran and coworkers[8] evaluated the behavior of soft tissue around submerged and nonsubmerged implants and verified the presence of structures that make up the biologic width: sulcus, junctional epithelium, and connective attachment, which comprise approximately 3 mm. These structures are formed physiologically and have stable dimensions similar to those surrounding natural teeth.

In a histometric study, Weber and associates[20] reported that the distance between the top of the implant and the point of contact between the alveolar bone and the implant was 2.92 mm at its most coronal portion. This study, among others, suggests that this bone loss occurs for the establishment of biologic distances.

Hermann and colleagues[9] observed radiographically in dogs that, although an initial bone loss of 1.5 mm occurred around implants, bone loss later stabilized. Their results, and the results of others, indicated that biologic distances were established at the implant-gingival junction, confirming other studies.[8,20,21] The radiographic evaluation of the present animal study showed a mean bone resorption of 2.1 mm around implants, which was similar to that previously found in other animal studies.[9,20,22,23] In another radiographic study, Tarnow and coworkers[13] evaluated the behavior of bone around contiguous implants that had already been restored. The implants were separated into 2 groups: in 1 group, the interimplant distance was greater than or equal to 3 mm; in the second, it was less than 3 mm. They concluded that when the distance between implants was greater than or equal to 3 mm, crestal bone was preserved; when the distance between implants was less than 3 mm, the crestal bone was reabsorbed because the loss of lateral bone that occurs around the implants influenced the preservation or formation of the interimplant papilla. This is important clinically because an increase in loss of crestal bone results in a greater CP-BC distance, thus determining whether a papilla will be present or absent between 2 implants. In fact, a clinical evaluation[11] of the CP-BC distance with natural teeth reported that even a small difference of 1 mm is clinically significant. When this distance remained around 5 mm, interproximal papillae were present in 98% of cases. On the other hand, when this distance increased to 6 mm, papillae were present in only 56% of cases. In the present study, a planned CP-BC distance of approximately 5 mm was used in the fabrication of the prostheses based on the results of Tarnow and associates. Although the formed papillae did not completely fill the interproximal space between the implants in either group, the results showed the influence of the contact point in papilla formation when these areas were compared to the distal extension areas.

Hermann and associates[24] studied changes in the crestal bone around implants and concluded that the occurrence and localization of an interface (microgap) influenced the resorption of alveolar crestal bone. In the present study, an increase was verified in the CP-BC distance that had been established at 5 mm; the actual distance varied from 5.64 and 6.45 for groups 1 and 2, respectively. This loss of alveolar crestal bone probably interfered with the formation of papilla between the prostheses supported by the implants in both groups 1 and 2. However, the mean height of the interproximal papillae between adjacent implants was 3.07 in group 1 and 3.55 in group 2. These heights in dogs, which were assessed radiographically, were in accordance with the results of Tarnow and colleagues[25] in a clinical retrospective study (mean = 3.4 mm in Tarnow and associates' study). In the present study, there were no statistically significant differences between the groups; however, the results were better for the 2-mm distance (group 1) than for the 3-mm distance (group 2) with respect to quantity of crestal bone resorption, and consequently, for the height of papilla formed.

The etiology of bone loss that occurs around implants during healing and during the first year of implant function has not yet been satisfactorily determined, although various studies[19,26,27] have confirmed the presence of bone resorption around implants. In view of the fact that initial marginal bone loss can vary from 0.9 to 1.6 mm[19] and that changes in the alveolar crestal bone can also occur, and taking into consideration the results of the present study and those of Tarnow and associates,[11] it can be suggested that when restoring 2 or more contiguous implants the distance from the contact point to the bone crest should be less than 5 mm, probably around 3 mm, to compensate for the crestal resorption that occurs around the implants. Implant-supported prostheses differ from natural teeth; in natural teeth the biologic width is already present so the 5-mm distance will not change unless there is disease. For implants, however, the biologic width will form after second-stage surgery, abutment

connection, or placement of the prosthesis. Therefore, the distance will not remain constant at 5 mm; rather, it will increase because of crestal bone resorption, and it is important for interimplant papilla formation that the final CP-BC distance be 5 mm.

CONCLUSIONS

In dog mandibles, distances of 2 and 3 mm between implants did not present significant differences in the formation of papilla or in crestal resorption when a prosthetic restoration with 5 mm between the contact point and the bone crest was fabricated. However, the results may have been influenced by sample size.

Considering the crestal bone resorption found in both groups when the CP-BC distance was initially 5 mm, it could be suggested that the use of a distance smaller than 5 mm, probably around 3 mm, to compensate for the crestal bone alterations that occur during the establishment of the biologic width around implants would be desirable if papilla formation between contiguous implants is the objective.

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