Interimplant Distance and Crestal Bone Resorption: A Histologic Study in the Canine Mandible

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ABSTRACT

Background: Crestal bone loss has been shown to occur around dental implants. This crestal bone resorption may determine a more apical position of the gingival margin. A clear trend of increased bone loss with increased interimplant distance has been reported.

Purpose: The aim of the present study was to evaluate, in the canine mandible, the crestal bone behavior around dental implants inserted with different interimplant distances.

Materials and Methods: Sandblasted and acid-etched implants (Bone System, Milano, Italy) were placed in the mandibles of six beagle dogs. Each dog received 10 implants in the mandible (five in the right side and five in the left side). A total of 60 implants was used in this study. The implants were divided in four groups: group I, with a 2 mm interimplant distance; group II, with a 3 mm interimplant distance; group III, with a 4 mm interimplant distance; and group IV, with a 5 mm interimplant distance. The dogs were killed after 12 months.

Results: No statistically significant differences were found in regard to vertical bone loss whereas on the contrary, statistically significant differences were found in regard to lateral bone loss ($p = .0001$). Statistically significant differences also were found in regard to vertical crestal bone loss ($p = .0001$). In fact vertical crestal bone loss decreased, from 1.98 mm in group I to 0.23 mm in group IV.

Conclusions: The clinical significance of these data lies in the fact that the increased crestal bone loss results in an increase in the distance between the base of the contact points of the neighboring implants and the crest of bone, and this fact could determine whether the papilla is present or absent between two implants.

KEY WORDS: biologic width, bone loss, bone resorption, interimplant distance, microgap, titanium implants

Long-term implant success is related to the development of periimplant hard tissue and soft tissue margins with the coronal portion of the implants.[1] Crestal bone loss has been shown to occur around dental implants,[2,3] and its precise mechanisms are not yet completely understood.[4] If crestal bone resorption occurs in a periimplant location, this may determine a more apical position of the gingival margin.[1] Bone loss may result from implant design, bone density, surgical trauma at implant insertion or at second-stage surgery, occlusal overload, apical migration of crevicular epithelium in an attempt to isolate bacteria-induced infection or to establish a biologic width, blood supply interruption, or development of a pathogenic bacterial biofilm.[2–10] It has been hypothesized that a certain width of the periimplant mucosa is required to enable a proper epithelial- and connective-tissue attachment and that if this soft tissue dimension is not satisfied, bone resorption will occur to ensure the establishment of attachment with an appropriate biologic width.[11,12] After an implant-abutment inter-

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face is established, the bone resorbs about 1.5 to 2.0 mm apically.[5] This vertical bone loss has been well researched. The biologic width around implants is as physiologically formed and stable in dimension as that found around the teeth.[13–16] The development and the location of the biologic width relative to the implant and the alveolar crest become more important when minimal bone is available due to anatomic conditions or when the implant is located in the aesthetic regions of the jaws.[1] Subsequent crestal bone loss may produce an unfavorable crown/implant ratio or expose the metal collars and increase subgingival bacterial colonization, which could result in further alveolar bone loss.[1] Hermann and colleagues reported that periimplant bone loss resulted from the creation of a microgap.[5] Thus the presence and location of the microgap change the dimensions of the periimplant tissues in relation to any crestal bone resorption.[1] The changes that occur at the level of periimplant bone influence the location of gingival margins.[1] The bone will resorb and create a distance from the bacteria eventually present in the microgap.

Another factor could be important in relation to periimplant bone loss. Tarnow and colleagues, in a clinical and radiologic human study on the influence of different interimplant distances on bone crest, showed that a clear trend of increased bone loss existed as the interimplant distances decreased.[17] In the study described above there was a lateral component to the bone loss around implants once the biologic width had formed. This fact has an important clinical significance because the increase in crestal bone loss produces an increase in the distance between the base of the contact points of the adjacent crowns and the bone crest. This fact could determine whether the papilla will or not be present between two adjacent implants. In a precedent study on teeth, Tarnow and colleagues found that when the distance from the base of the contact point to the crest of bone was 3, 4, or 5 mm, the papilla was present almost 100% of the time whereas when the distance was 7, 8, 9, or 10 mm, the papilla was missing most of the time.[18]

The aim of the present study was to perform a histologic evaluation, in the canine mandible, of crestal bone behavior around dental implants inserted with different interimplant distances to determine if interimplant distance influenced lateral bone loss and crestal bone resorption.

MATERIALS AND METHODS

Implantation

Sandblasted and acid-etched implants (Bone System, Milan, Italy) were placed in the mandibles of six beagle dogs (three males and three females) at least 18 months of age. The protocol was approved by the ethics committee of the University of Madrid (Madrid, Spain). The two premolars and the first molars had been extracted 3 months previously. Each dog received 10 implants in the mandible (five on the right side and five on the left side). A total of 60 implants were used in this study. The distance between the implants was set, with a surgical dam, at 2, 3, 4, and 5 mm (Figure 1), and the groups were randomized for anatomic position. All surgical procedures were performed with the dog under general anesthesia (premedication with acepromazine, 0.5 mg/kg subcutaneously; anesthesia with pentobarbitol, 15 mg/kg intravenously) and with antibiotic prophylaxis. The implant sites were prepared with drills under generously chilled saline irrigation. The implants were then inserted with a tapping instrument. All implants were placed in a submerged approach, and the tops of the implants (microgaps) were located clinically at the alveolar crest. The mucosal tissues were sutured with 3-0 silk sutures. In the first 2 weeks following surgery, the oral cavities were rinsed daily with chlorhexidine digluconate 0.12% (Peridex®, Zila, Inc., Phoenix, AZ, USA). In addition the dogs were fed a soft diet. The sutures were removed after 1 week. An oral hygiene regimen was instituted consisting of plaque removal 3 times a week with a soft toothbrush and 0.2% chlorhexidine (Peridex). Three months after implantation second-stage surgery was performed for abutment connection. After a midcrestal incision, the periimplant soft tissues were evaluated with exposure of the periimplant bone

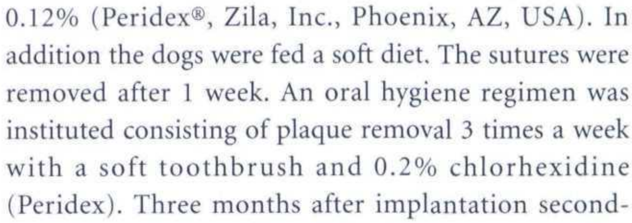

Figure 1 Diagram showing distances between implants. *Dark blue arrows* represent the lateral bone loss from the implant to the bone crest, *yellow arrows* represent the vertical crestal bone loss, and *black arrows* represent interimplant distances. The *green line* represents the level of the implant-abutment interface.

crest, and abutments were inserted in all implants. No postoperative complications or deaths occurred. The dogs were killed after 12 months, and a total of 60 implants were retrieved. The block sections were assessed by radiographic examination. The radiographs were evaluated for the presence or absence of bone loss in the mesial and distal parts of each implant. No other measurements were carried out. The implants were divided into four groups: group I, implants with a 2 mm interimplant distance; group II, implants with a 3 mm interimplant distance; group III, implants with a 4 mm interimplant distance; and group IV, implants with a 5 mm interimplant distance.

Processing of Specimens

The specimens (Figures 2 and 3) were retrieved, stored immediately in 10% buffered formalin, and processed with the Precise 1 Automated System™ (Assing, Rome, Italy) to obtain thin ground sections.[19] The specimens were dehydrated in an ascending series of alcohol rinses and embedded in a glycol methacrylate resin (Technovit® 7200 VLC, Heraeus Kulzer GmbH & Co., Wehrheim, Germany). After polymerization the specimens were sectioned longitudinally along the major axis of the implant and in a mesiodistal direction with a high-precision diamond disk at about 150 μm and ground down to about 30 μm. Three slides were obtained for each implant. The slides were stained with basic fuchsin and toluidine blue. Double staining with von Kossa and basic fuchsin was done to evaluate the degree of bone mineralization, and one slide per implant, after polishing, was immersed in silver nitrate for 30 minutes and exposed to sunlight; the slides were then washed under tap water, dried, immersed in basic fuchsin for 5 minutes, and then washed and mounted.

Histomorphometry

Histomorphometry of vertical and lateral crestal bone loss (see Figure 1) was performed with a light microscope (Laborlux S, Ernst Leitz GmbH, Wetzlar, Germany) connected to a high-resolution video camera (3CCD, JVC KY-F55B) and interfaced to a monitor and a personal computer using an Intel® Pentium® III 1200 MMX microprocessor (Intel Corporation, Santa Clara, CA, USA). This optical system was associated with a digitizing pad (Matrix Vision GmbH, Oppenweiler, Germany) and a histometry software package with image-capturing capabilities (Image-Pro® Plus version 4.5, Media Cybernetics Inc., Immagini & Computer Snc, Milan, Italy).

Statistical Evaluation

The differences in the vertical and lateral crestal bone loss in the different groups were evaluated with analysis of variance. The significance of the differences observed was evaluated with the Bonferroni test for multiple comparisons. The percentages were expressed as a mean plus-or-minus standard deviation (SD) and standard error. Statistically significant differences were set at $p < .05$.

RESULTS

Macroscopically it was possible to observe that the periimplant soft tissues were located at a higher level between the implants, with a larger interimplant dis-

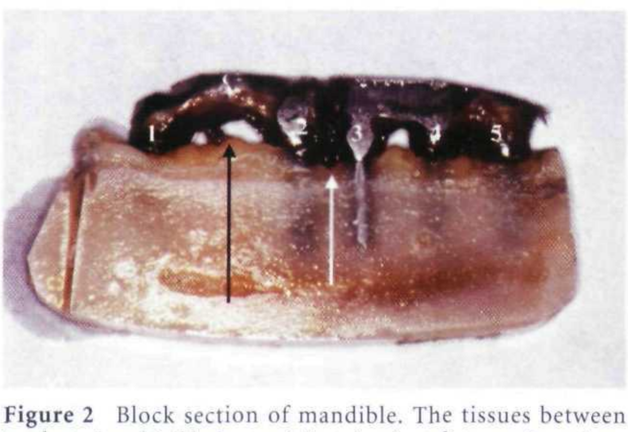

Figure 2 Block section of mandible. The tissues between implants 1 and 2 (*black arrow*) (interimplant distance, 5 mm) are located at a higher level than the tissues between implants 2 and 3 (*white arrow*) (interimplant distance, 2 mm).

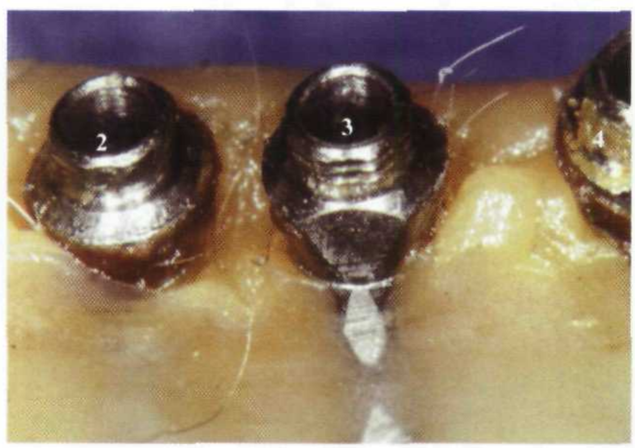

Figure 3 Closer view of same block section of mandible shown in Figure 2. The distance between implants 2 and 3 is 2 mm.

tance (see Figures 2 and 3). (Figure 1 shows the bone levels in the different situations.)

Group I (2 mm Interimplant Distance)

Radiography showed a lateral bone loss (Figure 4). No intrabony defects were present. Microscopically there was lateral bone loss in the cortical bone in the coronal area (Figure 5). The bone in contact with the implant surface was mature, with small marrow spaces. The crestal bone was covered by osteoclasts actively resorbing bone (Figure 6) while no osteoblasts were present. The crestal bone was covered by a 70 to 120 μm bone layer without haversian systems. A cement line divided this bone from underlying bone.

The numbers of osteoclasts near the implants and in the central portion between two implants were similar. Vertical crestal bone loss was 1.98 mm (SD, 0.22), and lateral bone loss was 1.97 mm (SD, 0.19).

Group II (3 mm Interimplant Distance)

Radiographically there was a vertical and lateral bone loss (see Figure 4); microscopically in the central portion between the implants, a small crestal bone was present (Figure 7), and it was possible to observe two intrabony defects. No clinical signs of inflammation were present in the soft tissues.

At low magnification it was possible to observe that bone was in close contact with the implant surface, and no gaps were present at the bone-implant interface (Figure 8). There were osteoclasts in the coronal portion of the crestal bone between the implants. This bone did not contain osteons and was intensely stained with acid fuchsin (see Figure 8). The underlying bone showed a different architecture, the lamellar bone being arranged concentrically around the haversian canals.

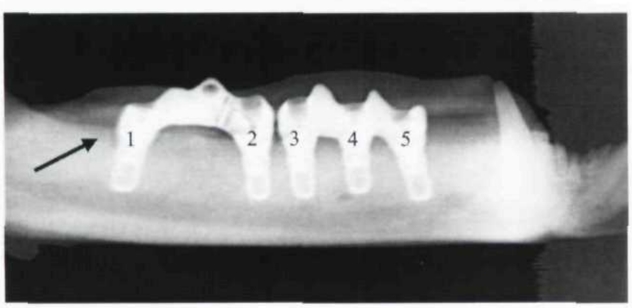

Figure 4 Radiograph of group I implants shows vertical bone loss around implant 1 (*arrow*) while vertical and lateral bone loss is present between implants 2 and 3, between implants 3 and 4, and between implants 4 and 5.

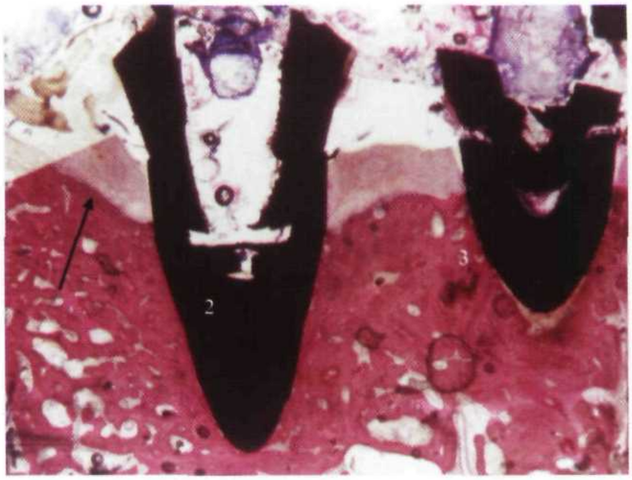

Figure 5 Photomicrograph of group I implants. An intrabony defect is present around implant 2 (*arrow*); there is lateral and vertical bone loss between implants 2 and 3 (×12 original magnification; stained with toluidine blue and basic fuchsin).

Vertical crestal bone loss was 1.78 mm (SD, 0.19), and lateral bone loss was 3.00 mm (SD, 0.1).

Group III (4 mm Interimplant Distance)

The vertical and lateral crestal bone loss was visible in the radiograph; two intrabony defects were present in the mesial and distal implants (see Figure 4). The implant surfaces were in close contact with mature bone with small marrow spaces. The cortical bone was intensely stained with acid fuchsin without haversian systems and had a thickness of 70 to 120 μm. Multinucleated osteoclasts were observed in a periimplant location, actively resorbing bone

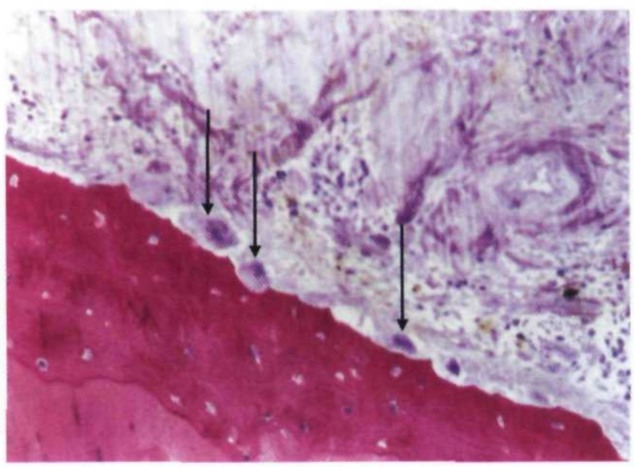

Figure 6 Photomicrograph of group I implants (2 mm interimplant distance). Osteoclasts (*arrows*), in the process of actively resorbing bone, are present in the central portion of crestal bone (×400 original magnification; stained with toluidine blue and basic fuchsin).

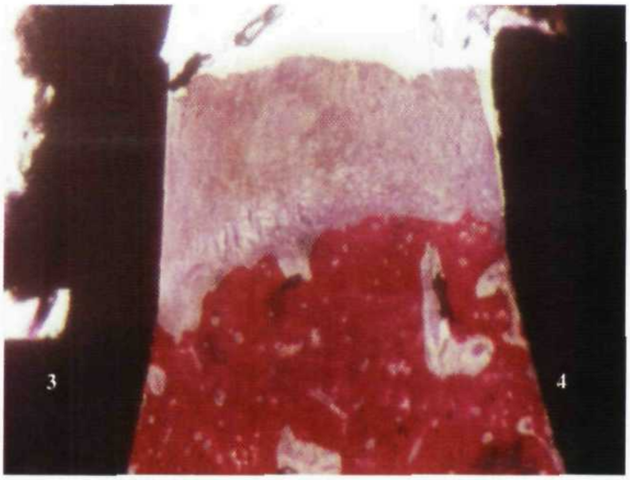

Figure 7 Photomicrograph of group II implants (3 mm interimplant distance), showing lateral and vertical bone loss between implants 3 and 4 (×14 original magnification; stained with toluidine blue and basic fuchsin).

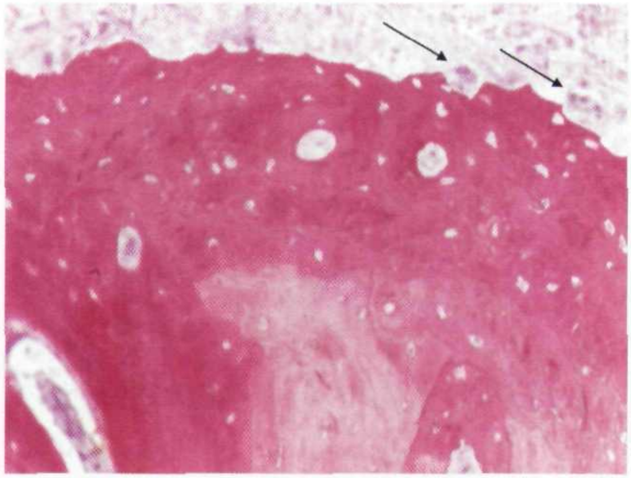

Figure 9 Photomicrograph of a group III periimplant location (4 mm interimplant distance). In the most coronal area it is possible to observe vertical and lateral bone loss and the presence of a few osteoclasts actively resorbing bone (*arrows*) (×100 original magnification; stained with toluidine blue and basic fuchsin).

(Figure 9). No osteoclasts were present in the central portion between the two implants. Vertical crestal bone loss was 1.01 mm (SD, 0.11), and lateral bone loss was 4.00 mm (SD, 0.39).

Group IV (5 mm Interimplant Distance)

Intrabony defects at the level of the periimplant region were visible in the radiographs (see Figure 4). At low magnification it was possible to observe that bone was in close contact with the implant surface, and no gaps were present at the bone-implant interface. There was vertical bone loss, and osteoclasts were present in this pocket, actively resorbing bone (see Figure 9). The cortical bone was compact, with a few haversian systems and with small osteocyte lacunae (Figure 10). A 70 to 120 μm layer of immature bone was present. Vertical crestal bone loss was 0.23 mm (SD, 0.11), and lateral bone loss was 1.91 mm (SD, 0.35).

Statistical Evaluation

Statistically significant differences were found in the lateral bone losses between the different groups (Tables 1 and 2). Statistically significant differences were found also among the vertical crestal bone losses of the different groups (Table 3; see also Table 1).

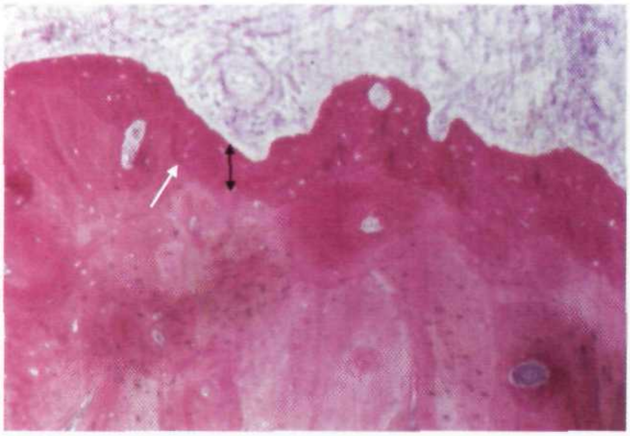

Figure 8 Photomicrograph of a group II implant (3 mm interimplant distance), showing the crestal bone covered by a 70 to 120 μm layer of bone (*black arrow*) without haversian systems. A cement line (*white arrow*) separates this bone from the underlying bone (×100 original magnification; stained with toluidine blue and basic fuchsin).

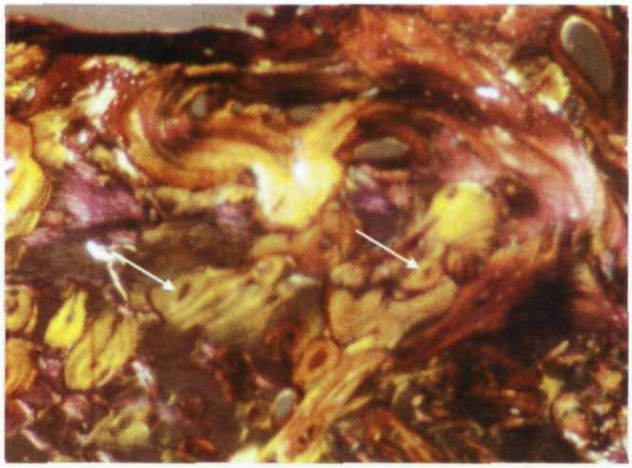

Figure 10 Photomicrograph of a group IV periimplant region (5 mm interimplant distance), showing bone between implants in polarized light. Most of the lamellar bone is arranged concentrically around the haversian canals (*arrows*) (×100 original magnification).

TABLE 1 Statistical Evaluation of Crestal Bone Loss

Group	Bone Loss (mm)	SD	SE	*p* Value
Vertical crestal bone loss				.0001*
I (2 mm interimplant distance)	1.98	0.18	0.007	
II (3 mm interimplant distance)	1.78	0.19	0.077	
III (4 mm interimplant distance)	1.01	0.24	0.097	
IV (5 mm interimplant distance)	0.23	0.11	0.044	
Lateral bone loss				.0001*
I (2 mm interimplant distance)	2.00	0.10	0.04	
II (3 mm interimplant distance)	3.00	0.10	0.04	
III (4 mm interimplant distance)	4.00	0.39	0.02	
IV (5 mm interimplant distance)	1.91	0.35	0.14	

SD = standard deviation; SE = standard error.
*Significant at 95% (according to analysis of variance).

DISCUSSION

The exact mechanism responsible for the crestal bone remodeling in two-piece implants is unknown.[5] Surgical trauma, occlusal overload, periimplantitis, the presence of a microgap, the establishment of a biologic width, and crestal module considerations have been implicated.[9] While the etiology of such bone loss is the subject of academic debate, the clinical ramifications of crestal bone resorption are clear. Such localized bone resorption can lead to a compromise in the patient's oral health owing to deep soft tissue pockets, which cannot be properly cleaned. Periimplantitis often develops, which causes more crestal bone loss because of the immune response of the host. An insidious cycle of bone loss can progress to complete implant failure. More recent investigations, however, have sought to extend the understanding of crestal bone resorption surrounding endosteal dental implants with additional study variables such as the location of placement, the length of the polished collar, and implant surface conditions.[2,5,7] Moreover the presence or absence of the interproximal papilla is of great concern to periodontists, restorative dentists, and patients.[18] The loss of papilla can lead to cosmetic deformities, phonetic problems, and lateral food impaction.[18] In the study of Tarnow and colleagues, the crestal bone loss was 1.04 mm when the adjacent implants had a distance of ≤ 3.00 mm between them whereas it was 0.45 mm when the interimplant distance was > 3.00 mm.[18] Our histologic data are in accord with these findings, and in fact we found that the vertical crestal bone loss decreased from 1.98 mm in group I (interimplant distance, 2 mm), to 1.78 mm in group II (interimplant distance, 3 mm), to 1.01 mm in group III (interimplant distance, 4 mm), and to 0.23 mm in group IV (interimplant distance, 5 mm). These differences were statistically significant between all groups, with the exception of groups I and II (see Table 3). Tarnow and colleagues reported that there is then a lateral component to the bone loss after the abutment connection and that this lateral component can determine a greater interimplant bone loss when two neighboring implants are not distanced apart by more than 3 mm.[17]

TABLE 2 Significance of Differences in Vertical Crestal Bone Loss between Implant Groups*

Comparison	Significance
I vs II	No
I vs IV	Yes
I vs III	Yes
III vs II	Yes
III vs IV	Yes
IV vs II	Yes

*$p < .5$.

CONCLUSIONS

Interimplant distance influences lateral bone loss because the lateral bone loss from adjacent implants

TABLE 3 Significance of Differences in Lateral Bone Loss between Implant Groups*

Comparison	Significance
I vs II	Yes
I vs IV	No
I vs III	Yes
III vs II	Yes
III vs IV	Yes
IV vs II	Yes

*Bonferroni test for multiple comparisons ($p < .5$).

overlaps, with a resultant increase in crestal bone loss, whereas there is no influence on the vertical bone loss; in fact our results showed no differences in vertical bone loss between the different groups. Tarnow and colleagues' results[17] and our data demonstrate that in the anterior aesthetic zone it can be necessary to use implants with a smaller diameter to decrease interimplant bone loss. The clinical significance of this phenomenon is that the increased crestal bone loss results 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 two implants.[17,18]

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