

INFLUENCE OF INTERIMPLANT DISTANCE ON PAPILLA FORMATION AND BONE RESORPTION: A CLINICAL-RADIOGRAPHIC STUDY IN DOGS

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Implant esthetics has been the focus of attention for the past decade, and one vital issue is the effect of interimplant distance on interimplant papilla formation and crestal bone loss. The aim of this study was to evaluate the effect of 1, 2, and 3 mm of interimplant distance on papilla formation and crestal resorption in submerged and non-submerged Ankylos implants after prosthetic restoration. Bilateral mandibular premolars of 7 dogs were extracted, and after 12 weeks each dog received 8 implants. Implants were placed so that 3 interimplant distances were created at 1 mm (group 1), 2 mm (group 2), and 3 mm (group 3). The sides and the position of the groups were randomly selected. Twelve weeks after placement, the implants received metallic prostheses that allowed 5 mm of space between the prosthetic contact point (CP) and the crestal bone (CB). After 8 weeks, the distance between the CP and the papilla (CP-P) and the gingival height at the distal proximal aspect of the prosthesis (CP-DE) was clinically measured. Radiographic images were obtained to measure the distance of the CP to the CB within the interimplant surfaces (CP-IP) and adjacent to the edentulous surfaces (CP-ED). The clinical measurement of CP-P for submerged and nonsubmerged implants was 3.57 ± 1.17 mm and 3.10 ± 0.82 mm for group 1, 3.57 ± 0.78 mm and 3.16 ± 0.87 mm for group 2, and 3.35 ± 0.55 mm and 3.07 ± 0.93 mm for group 3. The CP-DE was 3.25 ± 0.77 mm for submerged and 2.78 ± 0.64 mm for nonsubmerged implants. The CP-IP for the submerged and nonsubmerged implants was 6.91 ± 0.95 mm and 7.68 ± 2.73 mm for group 1, 7.46 ± 1.43 mm and 5.87 ± 1.71 mm for group 2, and 7.72 ± 0.81 mm and 7.59 ± 1.33 mm for group 3. The CP-ED was 6.77 ± 1.33 mm for submerged implants and 6.03 ± 1.58 mm for nonsubmerged implants. There were no statistical significant differences for any of the measured parameters. We conclude that when the distance from the CP to the CB was 5 mm, interimplant distances of 1 to 3 mm did not affect papilla formation or crestal resorption of submerged or nonsubmerged implants in the dog model.

INTRODUCTION

Gingival esthetics around natural teeth is influenced by a vertical dimension of healthy periodontal tissues comprising the biologic width. When placing osseointegrated implants, several factors, including the interimplant distance, influence peri-implant soft and hard tissue behavior.¹ The presence of a biologic width surrounding a tooth has been evaluated in numerous studies that have described the dimensions of this physiologic attachment apparatus.^{2,3}

Around natural teeth, the biologic width consists of 3 components: the gingival sulcus, the epithelial attachment, and the connective tissue attachment. The dimensions of these components were described in human skulls by Gargiulo et al,² who reported the average depth values of 0.69 mm for the gingival sulcus, 0.97 mm for the epithelial attachments, and 1.07 mm for the connective tissue attachments for a total of 2.73 mm on average.

Likewise, around dental implants, junctional epithelium and connective tissue exist, comprising the biologic seal around dental implants and acting as a barrier against bacterial invasion and ingress of debris around the implant-tissue interface.⁴ The epithelial attachment around both implant and natural tooth is composed of hemidesmosomes and a basal lamina. However, collagen fiber orientation of the connective tissue is parallel to implant surfaces and perpendicular to the natural tooth.⁵⁻⁷ The significance of this difference is not clearly understood at this time.

Berglundh et al⁸ compared the constitution of clinically healthy

supra-alveolar soft tissue around teeth and implants. These tissues also presented common microscopic characteristics. Tissues surrounding both teeth and implants were covered by a keratinized epithelium continuous to the junctional epithelium, which extended approximately 2 mm around both teeth and implant. The epithelium was separated from the alveolar bone by a connective tissue area slightly larger than 1 mm. Similar findings were reported in subsequent studies using both 1- and 2-stage implants.^{9,10}

Cochran et al¹¹ histomorphometrically evaluated loaded and unloaded nonsubmerged titanium implants and found that the dimensions of the implant-gingival junction remained constant over time up to 12 months after loading. The dimensions were comparable with dentogingival tissues.² After 12 months of loading, the values were 0.16 mm for the sulcus depth, 1.88 mm for the junctional epithelium, and 1.05 mm for the connective tissue, totaling 3.08 mm. Later, Hermann et al¹² histometrically evaluated the dimensional change of the biologic width around nonsubmerged implants. They observed that the dimension of the sulcus depth, junctional epithelium, and connective tissue changed over time but within the range of previously reported biologic width dimension. The dimensions of the biologic width around submerged implants are similar and have also been reported.^{8,9,13}

Berglundh and Lindhe¹³ studied the dimensions of the peri-implant mucosa by using a 2-stage implant system in a beagle dog model. Before abutment connection, the mucosa on the test side was surgically thinned from inside the flap to 2 mm or less, whereas the abutment connection

on the contralateral side (control) was performed per routine manufacturer protocol. After 6 months of plaque control, the dogs were sacrificed and biopsies were taken for microscopic observations. The results illustrated that wound healing in the test sites consistently included bone resorption in order to establish a biologic width dimension of approximately 3 mm. This suggests that a minimum width of peri-implant mucosa may be required to form a stable soft tissue attachment. Furthermore, Hämmerle et al¹⁴ studied the effect of subcrestal placement of polished surfaces of nonsubmerged implants on marginal soft and hard tissues in 11 patients. In test sites, the apical border of the polished surface was placed about 1 mm below the alveolar crest, whereas the junction between rough and polished surfaces was located at the crest in control sites. After 1 year of function, the average crestal bone loss was 2.26 mm in the test group and 1.02 mm in the control group. The study suggested that during the first year of function the biologic seal was established 1 mm apical to the polished-rough implant junction at the expense of the crestal bone.

There are 2 basic approaches to place endosseous dental implants, including submerged (2 stage) and nonsubmerged (1 stage) techniques. In most 2-stage implant systems, after abutment connection, a microgap exists between the implant and abutment at or below the alveolar crest. In 1-stage implant designs, the implant itself extends above the alveolar crest level; therefore, a microgap does not exist at the level of the bone.

After implant exposure and abutment placement in 2-stage systems, an implant-abutment interface is established and bone

resorption of 1.5 to 2.0 mm commonly occurs toward the apical portion.¹⁵ The biologic theory for this phenomenon is that if chronic irritants, such as bacteria, reach the implant-abutment interface, or if the abutment is removed after initial healing, bone resorption may occur, creating a space between the irritated area and the bone. Tarnow et al¹⁶ reported a similar bone response to subgingival prosthetic crown preparations that violate the attachment apparatus on natural teeth.

The presence or absence of papilla is a major concern for periodontists, implant surgeons, restorative dentists, and patients. Its loss can lead to esthetic deformities, phonetic problems, and food impaction. The vertical distance between the base of the prosthetic contact point (CP) and crestal bone seems to be a determining factor for predicting the presence of an interproximal papilla. When evaluating interdental sites, Tarnow et al¹⁷ observed that if this distance was 5 mm or less, the interproximal papilla filled the entire embrasure space in 98% of the cases. When the distance was 6 mm, the presence of a complete papilla decreased to 56% of the cases, and when the distance was 7 mm or more, the papilla was completely present in only 27% or fewer of the cases. Other variables such as the degree of inflammation, probing depth, fibrous or edematous tissue, position of teeth (anterior or posterior), surgical or nonsurgical history, and proximal restorations can also contribute to the presence or absence of papilla.

Similar in importance of the CP is lateral bone loss, which Tarnow et al¹⁸ measured in a retrospective study by using radiographs from 36 patients. The authors observed that when the distance between adjacent implants was 3 mm or less, crestal bone loss was greater than when the implants were spaced more than 3 mm from each other. Their study demonstrates that there may be a lateral component to the bone loss around implants in addition to the more commonly discussed vertical component.

Therefore, the purpose of this study was to determine clinically and radiographically the effect of various distances of 1, 2, or 3 mm between adjacent implants on crestal bone resorption and presence of papillae after prosthetic restoration with a 5-mm distance between the interproximal CP and the crestal bone.

MATERIAL AND METHODS

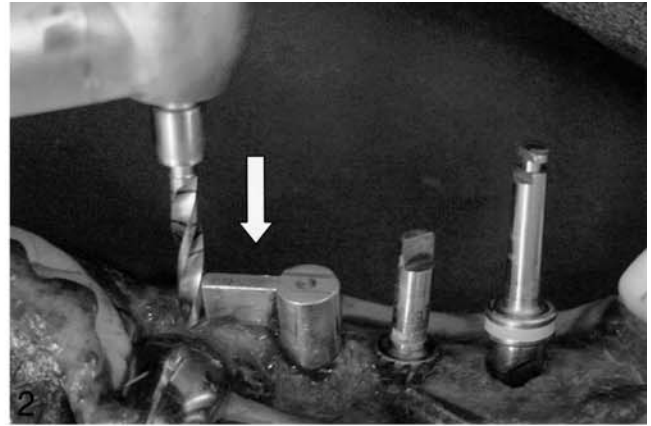
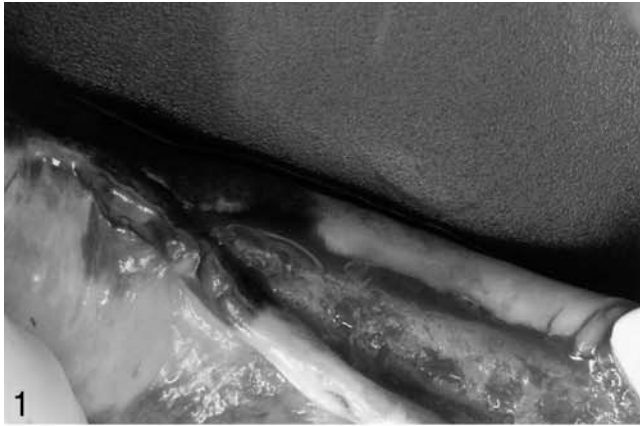
The Animal Research Committee of the School of Dentistry of Ribeirão Preto, University of São Paulo, approved the experimental protocol. Seven young adult male mongrel dogs (15 kg) were used. They had intact maxillae and mandibles, were in good general health, and had no viral or fungal oral lesions. The dogs were kept fasting starting the night before the surgery. They were sedated and then anesthetized intravenously with thiopental (1 mL/kg; 20 mg/kg thiopental diluted in 50 mL saline). A full-thickness flap was raised in the region of the mandibular premolars, and the teeth were sectioned

in the buccolingual direction and extracted with forceps. The flaps were then repositioned and sutured with absorbable 4-0 sutures.

After a healing period of 3 months, the dogs received 20 000 IU penicillin and streptomycin (1.0 g/10 kg) the night before surgery. This dose provides antibiotic coverage for 4 days, and another dose was given 4 days later to provide coverage for a total of 8 days. This broad-spectrum antibiotic is commonly used in small animals.¹⁹ After repeating the same sedation and anesthesia as described earlier, a horizontal crestal incision was made from the distal region of the canine to the mesial region of the first molar (Figure 1), and implants were placed according to the manufacturer's instructions. Four Ankylos 4.5- × 9.5-mm implants (sandblasted/acid-etched surfaces, Dentsply-Friudent, Mannheim, Germany) were placed 1.5 mm subcrestally on either side of the mandible on each dog, totaling 56 implants in the study. The implants were placed so that 2 adjacent implants were 1 mm (group 1), 2 mm (group 2), or 3 mm (group 3) distant from each other. To achieve this, a stainless-steel calibration device was made to standardize both the angle and the distance between implants (Figure 2). The distances between implants as well as the side that received the 2-stage protocol (submerged therapy) (Figure 3) or 1-stage protocol (nonsubmerged therapy) (Figure 4) were randomly assigned by a coin toss.

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FIGURES 1–7. FIGURE 1. Clinical aspect before the second surgery. Full-thickness flap and clinical aspect of the alveolar crest. FIGURE 2. The surgical guide made to standardize both the angle and the distance between implants (arrow). FIGURE 3. Implants in position 1.5 mm subcrestally, submerged therapy. FIGURE 4. Implants in position, also 1.5 mm subcrestally, with the gingiva formers in place, nonsubmerged therapy. FIGURE 5. Clinical aspect when the prosthetic phase began, nonsubmerged side. FIGURE 6. Clinical aspect when the implants of the submerged side were exposed. FIGURE 7. Metallic crowns were fabricated for both sides with a distance of 5 mm between the contact point and the crestal bone.



The flaps were repositioned and sutured with nonresorbable sutures. Sutures were removed after 10 days.

During the 12-week healing period, the dogs received monthly ultrasonic prophylaxis. After 12 weeks, prosthetic restoration began (Figure 5). The same method of sedation and anesthesia was used, the implants of the submerged sides were exposed (Figure 6), and metallic crowns were fabricated so that the implants were placed in function for a period of 8 weeks (Figure 7). The metallic crowns were made so that an interproximal space of 5 mm¹⁷ between the CP and the crestal bone (CB) existed. The same prosthetic protocol was performed on the nonsubmerged implants. After prosthetic attachment, ultrasonic prophylaxis was performed weekly until sacrifice.

Eight weeks after placing the restorations, clinical and radiographic analyses were carried out.

Clinical analysis

The presence of papillae between the restorations placed on the implants that were inserted at 1, 2, and 3 mm apart were evaluated with a compass measuring the distance between the CP and the tip of the interimplant papilla (CP-P). A reference line was made from the CP to the edentulous area in order to measure the papilla presence in the adjacent edentulous area in the absence of a CP (CP-ED) (Figure 8).

Radiographic analysis

Hemi-mandibles were radiographed immediately after sacrifice after they were dissected and removed. This procedure was carried out to standardize the distance between the X-ray source and the specimen. Expo-

sure parameters and processing of radiographs were conducted according to the manufacturer's recommendations and by routine clinical protocols.

The radiographs were digitized with a resolution of 1200 dpi (Figures 9 and 10), and an investigator unfamiliar with the project blindly analyzed them with the Image J software (National Institutes of Health, Bethesda, Md). Measurements were made to evaluate the final distance of the CP to the CB (CP-CB) (Figure 11). Additionally, the final distance between the CP and the first bone-to-implant contact was measured at the interimplant regions (CP-IP, mean of A and B) and at the proximal regions (CP-ED, mean of C and D), where a CP did not exist (Figure 12).

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 through the analysis of variance nonparametric test with a significance level of $P \leq .05$. All calculations were performed by using SPSS for Windows (SPSS Inc, Chicago, Ill).

RESULTS

Clinical findings

Postextraction healing was uneventful in all dogs. At implant surgery 12 weeks later, the extraction sites appeared clinically healed (Figure 1). After implant placement, healing was also uneventful without complications throughout the experimental period.

Clinical analysis

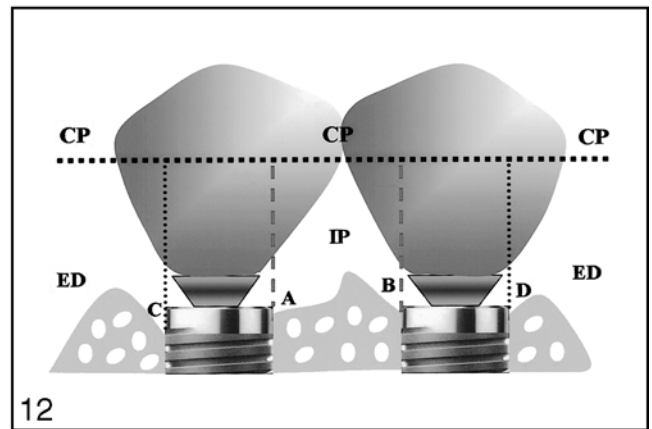
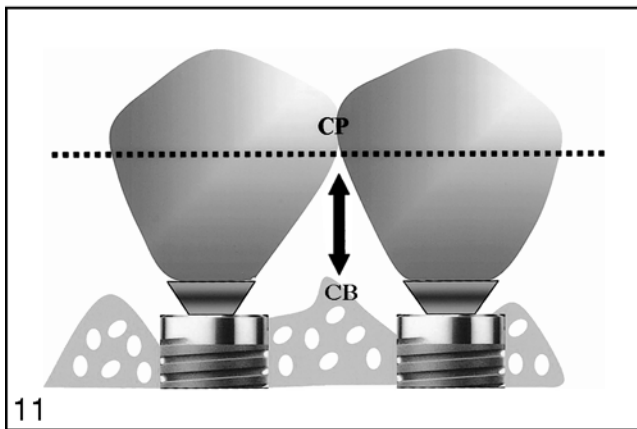
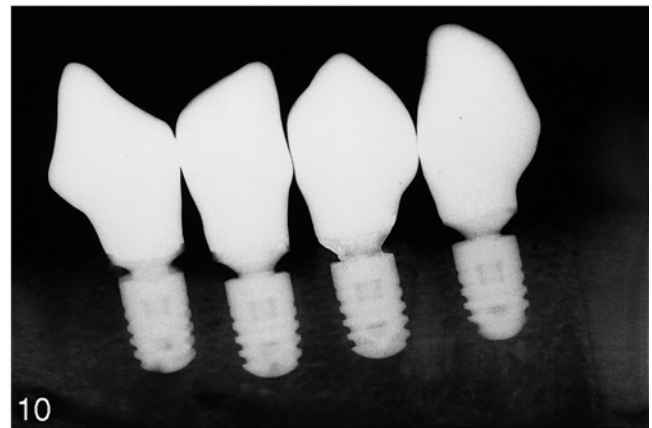
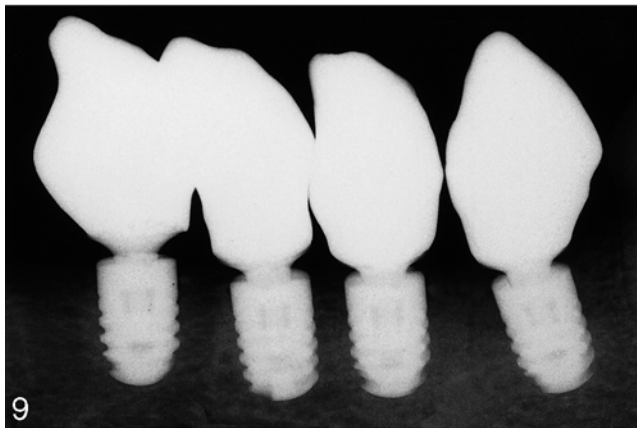
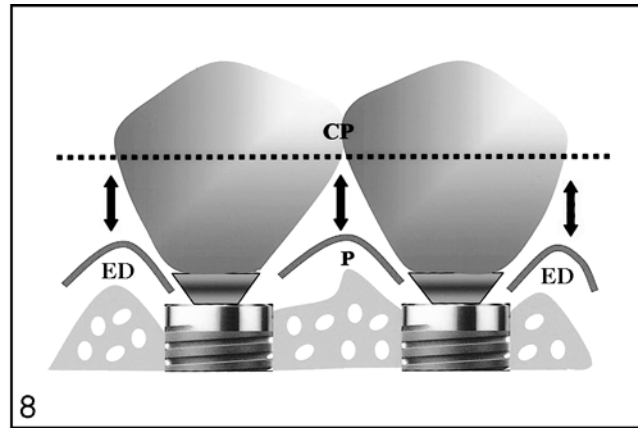
The mean distances of the prosthetic CP to the point of the

papilla (CP-P) for group 1 were 3.10 ± 0.82 mm (range 2.00–4.00 mm) for nonsubmerged implants and 3.57 ± 1.17 mm (range 2.50–6.00 mm) for submerged implants. For group 2, the mean distances were 3.16 ± 0.87 mm (range 2.00–4.50 mm) for nonsubmerged implants and 3.57 ± 0.78 mm (range 2.50–4.50 mm) for submerged implants. For group 3, the mean distances were 3.07 ± 0.93 mm (range 2.00–5.00 mm) for nonsubmerged implants and 3.35 ± 0.55 mm (range 3.00–4.50 mm) for submerged implants (Table 1). There were no statistically significant differences among the groups ($P > .05$).

The mean distance of gingival height at the proximal regions (CP-DE) was 2.78 ± 0.64 mm (range 2.00–4.50 mm) for the nonsubmerged group and 3.25 ± 0.77 mm (range 2.50–4.50 mm) for the submerged group (Table 2). The results were not statistically significant ($P > .05$).

Radiographic analysis

Radiographs showed that the mean distances from the CP to the CB (CP-CB) between the restorations for group 1 were 6.46 ± 1.92 mm (range 4.53–10.15 mm) for nonsubmerged implants and 6.67 ± 1.17 mm (range 4.80–8.09 mm) for submerged implants. For group 2, the mean distances were 5.62 ± 1.24 mm (range 3.07–6.77 mm) for nonsubmerged implants and 6.68 ± 1.53 mm (range 4.29–9.00 mm) for submerged implants. For group 3, the mean distances were 6.92 ± 0.98 mm (range 5.31–8.09 mm) for nonsubmerged implants and 7.07 ± 0.88 mm (range 5.82–8.26 mm) for submerged implants (Table 3). There were no statistically significant differences among the groups ($P > .05$). In the proximal regions, the mean dis-



FIGURES 8–12. FIGURE 8. Clinical measurements showing the distance between the contact point and the tip of the 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 9. Digitized radiograph from the submerged side. FIGURE 10. Digitized radiograph from the nonsubmerged side. FIGURE 11. Radiographic measurements of the final distance between contact point and crestal bone (CP-CB). FIGURE 12. Radiographic measurements of the bone resorption in the areas between the implants (A/B) and in the proximal regions around the implants (C/D).

tances were 6.03 ± 1.58 mm (range 3.55–9.44 mm) for non-submerged implants and 6.77 ± 1.33 mm (range 3.87–8.97 mm) for submerged implants (Table 4). There were no statistically signif-

icant differences among the groups ($P > .05$). In the analysis of the final distance from the CP to the first bone-to-implant contact (CP-IP), group 1 presented mean distan-

ces in region A/B of 7.68 ± 2.73 mm (range 5.12–12.01 mm) for nonsubmerged implants and 6.91 ± 0.95 mm (range 5.32–7.95 mm) for submerged implants. Group 2 presented mean distan-

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ces in region A/B of 5.87 ± 1.71 mm (range 3.43–7.99 mm) for nonsubmerged implants and 7.46 ± 1.43 mm (range 4.75–9.00 mm) for submerged implants. Group 3 presented mean distances in region A/B of 7.59 ± 1.33 mm (range 5.83–9.85 mm) for nonsubmerged implants and 7.72 ± 0.81 mm (range 6.67–8.98 mm) for submerged implants. In region C/D, the mean distances were 7.16 ± 1.44 mm (range 4.65–9.07 mm) for nonsubmerged implants and 7.24 ± 1.40 mm (range 4.51–8.29 mm) for submerged implants (Table 5). No significant statistical differences were found among the groups or between regions A/B and C/D for the groups.

DISCUSSION

The presence of a biologic width around implants has been previously investigated and has been verified by multiple research groups.^{1,10-13} This occurs for implants of all shapes after uncovering (stage 2 surgery). For 1-piece nonsubmerged implants^{10,15,20} or 2-stage implants used in a single-stage nonsubmerged protocol, the biologic width will form at the time of implant placement. This phenomenon will occur whether the implant is unloaded or loaded.¹⁰ The biologic reason is that healthy bone exposed to the oral environment will always cover itself with periosteum and connective tissue, and healthy connective tissue will always cover itself with epithelium. If irritants such as bacteria reach the implant-abutment interface, the bone will resorb to create a distance from this exposed or irritated area. In most 2-stage implant systems, after the abutment is connected, a microgap exists between the implant and abutment at or below the crestal

TABLE 1
Clinical analysis of the distance of the contact point to the tip of the papilla (CP-P)*

Dog	Interimplant Distances (mm)					
	Nonsubmerged			Submerged		
	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3
1	4.00	4.50	5.00	3.50	4.00	3.00
2	2.00	2.00	2.50	6.00	4.00	4.50
3	3.50	3.50	3.00	3.00	2.50	3.50
4	3.50	3.00	3.00	3.00	3.50	3.00
5	2.00	3.00	3.00	3.00	4.00	3.00
6	4.00	2.50	2.00	4.00	4.50	3.50
7	2.50	3.50	3.00	2.50	2.50	3.00
Mean	3.10	3.16	3.07	3.57	3.57	3.35
SD	0.82	0.87	0.93	1.17	0.78	0.55
P = .38	NS†	NS	NS	NS	NS	NS

*Significance level of $P \leq .05$.
†NS indicates not significant.

bone. This microgap ranges from 50 to 100 μm ^{21,22} and may allow the accumulation of debris and bacteria, which can cause localized inflammation and subsequent crestal bone loss. This microgap issue does not apply to the Ankylos and the Straumann implant system, because both systems have an internal conical abutment-implant (Morse taper) connection that prevents the accumulation of food debris and bacterial growth that has been reported for 2-stage implant systems.²⁰ The conical abutment-implant connection may eliminate this issue.

In recent years, attention has been given to the tissues that

surround implants providing a biologic seal.^{8,9,11,12,20} Berglundh et al,⁸ using a dog model, described a soft tissue barrier composed of an epithelial component continuous with a zone of connective tissue. The connective tissue in close contact with the surface of the implant is rich in collagen but poor in cells and vascular structures, resembling scar tissue. This was later confirmed by Buser et al,²⁰ who used undecalcified sections to examine 1-stage implants. Abrahamsson et al⁹ showed that the previously described tissue organization was similar for different implant systems not only for tissue composition but also for junc-

TABLE 2
Distance (mm) of the contact point to the proximal regions (CP-DE) for submerged and nonsubmerged groups*

Dog	Nonsubmerged	Submerged
1	3.75	3.25
2	2.25	3.80
3	2.75	4.00
4	3.00	3.00
5	2.50	3.00
6	2.50	3.50
7	2.75	2.25
Mean \pm SD	2.78 \pm 0.64	3.25 \pm 0.77
P = .31	NS†	NS

*Significance level of $P \leq .05$.
†NS indicates not significant.

TABLE 3
Radiographic analysis of the distance from the contact point to the crestal bone (CP-CB)*

Dog	Interimplant Distances (mm)					
	Nonsubmerged			Submerged		
	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3
1	4.90	6.77	7.50	5.76	5.88	6.72
2	6.87	6.72	7.61	7.41	5.98	8.05
3	5.25	3.07	7.04	8.09	6.37	6.44
4	6.20	5.62	5.31	7.77	9.00	6.72
5	7.34	6.03	7.00	6.36	7.77	7.47
6	10.15	5.77	8.09	6.51	7.45	8.26
7	4.53	5.37	5.88	4.80	4.29	5.82
Mean	6.46	5.62	6.92	6.67	6.68	7.07
SD	1.92	1.24	0.98	1.17	1.53	0.88
P = .45	NS†	NS	NS	NS	NS	NS

*Significance level of $P \leq .05$.
†NS indicates not significant.

tional epithelium and connective tissue dimensions. These reports showed that a junctional epithelium formed an attachment mechanism to the implant measuring about 2 mm in length apical to the abutment connection, or the neck of 1-stage implants. Between this epithelium and the crestal bone, a 1-mm wide band of connective tissue was established.

The consistency of these results led the authors to consider the possibility of the presence of minimum distances for the junctional epithelium and connective tissue. The dimensions, biologically determined, were similar to those described for the human dentition,² thereby suggesting

the presence of a biologic width around osseointegrated implants.

Cochran and colleagues¹⁰ evaluated the behavior of soft tissue around submerged and nonsubmerged implants and verified the presence of structures that comprise the biologic width—sulcus, junctional epithelium, and connective tissue—which measures approximately 3 mm. These structures are formed physiologically and have stable dimensions similar to those surrounding natural teeth.

In a histometric study, Weber et al²³ reported that the distance between the top of the implant to the crestal bone in contact with the implant is 2.92 mm at its most coronal portion. This study

TABLE 4
Radiographic analysis of the distance from the bone crest to the proximal regions*

Dog	Nonsubmerged	Submerged
1	6.50	6.97
2	6.83	6.35
3	5.27	6.43
4	5.74	8.29
5	6.50	7.24
6	6.76	7.60
7	4.65	4.50
Mean ± SD	6.03 ± 1.58	6.77 ± 1.33
P = .45	NS†	NS

*Significance level of $P \leq .05$.
†NS indicates not significant.

and others suggest that this bone loss occurs for the establishment of the biologic distances. Hermann et al¹⁵ observed radiographically in dogs that an initial bone loss of 1.5 mm occurred around implants and later stabilized. Their results indicated that biologic distances were established at the implant-gingival junction, confirming other studies.^{8,20,21} Bone loss has been reported to range from 0.5 mm to as high as 2 mm within the first year of implant placement.^{24,25} In 2002, Warren et al²⁶ reported that the crestal bone resorption of between 1.0 and 1.5 mm may occur almost immediately after second-stage surgery and implant loading. The radiographic evaluation in the present animal study showed a mean bone resorption of 1.19 mm around implants, which is slightly less than previously described animal studies.^{15,23} The decreased bone resorption may be explained by the fact the implant abutment connection in the Ankylos implant eliminates the microgap often found in 2-stage implant systems. This microgap may allow for the accumulation of debris and bacteria and also micromovement at the abutment-implant connection during clinical function, both of which can lead to a localized inflammation and crestal bone loss. The implant system used in this study does not have a microgap, and the crestal resorption seen is probably more related to the formation of the biologic seal^{27,28} regardless of the interimplant distances that were tested.

In a retrospective radiographic study, Tarnow et al¹⁸ evaluated the behavior of bone around contiguous implants that had already been restored. The implants were separated into 2 groups:

distance 3 mm or more and distance of less than 3 mm. The authors concluded that crestal bone was preserved when the distance between implants was 3 mm or more but was resorbed when the distance between implants was less than 3 mm because of the loss of lateral bone that occurs around the implants influencing the preservation or formation of the interimplant papilla. This is important clinically because an increase in loss of crestal bone may result in a greater distance between the base of the CP of adjacent crowns and the crestal bone, thus determining whether a papilla will be present or absent between 2 implants. In fact, a clinical evaluation¹⁷ of the distance of the base of the CP to the CB reported that even a small difference of 1 mm is clinically relevant. When this distance remained around 5 mm, interproximal papillae were present in 98% of the cases. On the other hand, when this distance increased to 6 mm, papillae were present in only 55% of the cases. In this study, complete fill of the embrasures by soft tissue did not occur in any of the groups (CP-P ranged from 3.07 to 3.57 mm). This supports the conclusion by Tarnow and coworkers²⁹ that the decision to place contiguous implants in the esthetic zone should be made with caution because an average of 3.04 mm of soft tissue height can be expected to form over the interimplant bone.

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. Various studies³⁰⁻³² have confirmed the presence of crestal resorption around implants. It has been shown that initial marginal bone loss can vary from 0.9 to 1.6 mm²⁹ and that changes

TABLE 5
Radiographic analysis of the final distance (mm) from the contact point to the first bone-to-implant contact (CP-IP) and contact point to the proximal regions of the prostheses (CP-ED)*

Dog	Nonsubmerged				Submerged			
	CP-IP (A/B)			C/D CP-ED	CP-IP (A/B)			C/D CP-ED
	Group 1	Group 2	Group 3		Group 1	Group 2	Group 3	
1	12.01	7.22	9.85	7.76	6.21	7.65	6.67	7.05
2	6.79	7.99	9.56	9.07	7.59	6.63	7.80	7.86
3	5.85	3.77	7.93	4.65	7.95	7.49	8.24	7.42
4	6.20	5.92	5.83	6.00	7.77	9.00	6.72	8.29
5	5.12	3.43	7.00	8.84	6.54	7.98	7.74	7.44
6	11.15	6.87	8.45	8.06	6.98	8.74	8.98	8.10
7	6.68	5.93	6.77	7.47	5.32	4.75	7.87	4.51
Mean	7.68	5.87	7.59	7.16	6.91	7.46	7.72	7.24
SD	2.73	1.71	1.33	1.44	0.95	1.43	0.81	1.40
P = .42	NS†	NS	NS	NS	NS	NS	NS	NS

*Significance level of P ≤ .05.
†NS indicates not significant.

in the alveolar crestal bone can also occur. When these measurements are correlated with those of Tarnow et al¹⁷ and with those of the present study, it can be suggested that when restoring 2 or more contiguous implants the distance from the CP to the CB should be less than 5 mm. To compensate for the crestal resorption that occurs around the implants, this distance should probably be around 3 mm. Implant-supported prostheses differ from the restoration of natural teeth, for with natural teeth the biologic width is already present and the 5 mm will not change unless there is disease. For implants, however, the biologic seal will form after the second-stage surgery or placement of the prosthesis, as in this case. Therefore, the distance of 5 mm will not remain but will increase because of crestal bone resorption. It is important for interimplant papilla formation that the final distance from the CP to the CB be 5 mm. The animal model may be questioned, but previous studies have shown that interproximal papilla in dogs can be reestablished following the re-

storative alveolar interface procedure³³ and that the newly formed papilla is maintained after prosthetic restoration of the embrasure.³⁴

CONCLUSIONS

In dog mandibles, distances of 1, 2, and 3 mm between implants did not reveal significant differences in the formation of a papilla or crestal bone resorption when the prosthetic CP was 5 mm from the CB.

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