

Influence of a Machined Collar on Crestal Bone Changes Around Titanium Implants: A Histometric Study in the Canine Mandible

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Background: It has been shown that peri-implant crestal bone reactions are influenced by both a rough–smooth implant border in one-piece, non-submerged, as well as an interface (microgap [MG] between implant/abutment) in two-piece butt-joint, submerged and non-submerged implants being placed at different levels in relation to the crest of the bone. According to standard surgical procedures, the rough–smooth implant border for implants with a smooth collar should be aligned with the crest of the bone exhibiting a smooth collar adjacent to peri-implant soft tissues. No data, however, are available for implants exhibiting a sandblasted, large-grit and acid-etched (SLA) surface all the way to the top of a non-submerged implant. Thus, the purpose of this study is to histometrically examine crestal bone changes around machined versus SLA-surfaced implant collars in a side-by-side comparison.

Methods: A total of 60 titanium implants (30 machined collars and 30 SLA collars) were randomly placed in edentulous mandibular areas of five foxhounds forming six different subgroups (implant subgroups A to F). The implants in subgroups A to C had a machined collar (control), whereas the implants in subgroups D to F were SLA-treated all the way to the top (MG level; test). Furthermore, the MGs of the implants were placed at different levels in relation to the crest of the bone: the implants in subgroups A and E were 2 mm above the crest, in subgroups C and D 1 mm above, in subgroup B 3 mm above, and in subgroup F at the bone crest level. For all implants, abutment healing screws were connected the day of surgery. These caps were loosened and immediately retightened monthly. At 6 months, animals were sacrificed and non-decalcified histology was analyzed by evaluating peri-implant crestal bone levels.

Results: For implants in subgroup A, the estimated mean crestal bone loss (\pm SD) was -0.52 ± 0.40 mm; in subgroup B, $+0.16 \pm 0.40$ mm (bone gain); in subgroup C, -1.28 ± 0.21 mm; in subgroup D, -0.43 ± 0.43 mm; in subgroup E, -0.03 ± 0.48 mm; and in subgroup F, -1.11 ± 0.27 mm. Mean bone loss for subgroup A was significantly greater than for subgroup E ($P = 0.034$) and bone loss for subgroup C was significantly greater than for subgroup D ($P < 0.001$).

Conclusions: Choosing a completely SLA-surfaced non-submerged implant can reduce the amount of peri-implant crestal bone loss and reduce the distance from the MG to the first bone–implant contact around unloaded implants compared to implants with a machined collar. Furthermore, a slightly exposed SLA surface during implant placement does not seem to compromise the overall hard and soft tissue integration and, in some cases, results in coronal bone formation in this canine model. *J Periodontol* 2011;82:1329-1338.

KEY WORDS

Bone resorption; comparative study; dental implants; implants, experimental; surface properties.

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Over the past 35 years, two major design and surgical approaches have evolved in implant dentistry. In 1969, Brånemark et al.¹ first described a submerged, two-piece implant placement protocol, where the top of the implant is aligned with the bone crest level according to standard surgical procedures,² using a completely machined titanium surface. After a healing period of ≈ 6 to 9 months, machined titanium abutments are connected with a butt-joint and within 4 weeks impressions are taken followed by the delivery of the prosthetic component. In 1976, Schroeder et al.³⁻⁵ suggested a non-submerged (transgingival), implant placement approach, using an implant with a titanium-plasma sprayed (TPS), roughened endosseous portion in combination with a machined portion being located within soft tissues. In accordance with standard surgical procedures,⁶⁻⁸ the rough/smooth (r/s) implant border between the coronal portion (machined) and the apical part (TPS) should be aligned with the bone crest level resulting in the top of the implant located at or slightly below the gingival margin. After a healing period of 3 to 4 months, impressions were taken, and the prosthetic restoration placed within another 2 to 3 weeks.

Based on multiple experimental and clinical studies, it could be shown that rough endosseous implant surfaces provide a significantly better hard tissue integration (osseointegration¹ or functional ankylosis⁵) as opposed to machined titanium surfaces.⁹⁻¹⁴ Furthermore, healing periods could significantly be reduced (1.5 months for type I to III bone, or 3 months for type IV bone, respectively)¹⁵ when using a sandblasted, large-grit and HCl/H₂SO₄ dual acid-etched (SLA) surface,¹⁶ thus shortening significantly patient treatment protocols.

In recent years, a series of studies have demonstrated that implant design characteristics (micrograph [MG] or interface [the space between implant components, such as the implant and abutment] and r/s implant border [the border between rough and smooth implant surfaces]) and the placement technique in relation to the crest of the bone have clinically significant influences on peri-implant crestal bone levels,¹⁷⁻²¹ soft tissue dimensions (biologic width),²²⁻²⁴ and the degree of peri-implant inflammation if these interfaces are formed with a butt-joint connection.^{25,26} These findings indicated that for esthetic sites, the most biocompatible approach with the least amount of peri-implant crestal bone loss, amount of inflammation, and soft tissue dimensions could be achieved when non-submerged implants were placed with their r/s border slightly below the bone crest level exhibiting ≈ 2 mm of the machined collar within peri-implant soft tissues at the time of implant placement (tissue-directed implant placement).²⁷ Furthermore, in one particular

configuration (subgroup type F implants)^{18,19} the influence and location of the butt-joint MG was greater than the position of the r/s implant border when related to crestal bone resorption patterns.

For the past 12 years, commercially available implants have been used exhibiting an SLA- or TPS-surfaced endosseous portion and either a 2.8- or a 1.8-mm machined portion within soft tissues with the r/s implant border being aligned at the bone crest level.^{14,21,28,29} No comparative histometric data from a side-by-side comparison exist, however, when placing such implants with their r/s implant border at, below, or above the bone crest level. Because both the effect of the MG as well as the influence of an r/s border have significant implications on peri-implant crestal bone levels, the purpose of this study was to examine a modified implant design with an SLA surface covering the entire implant and comparing it to an implant with a machined collar. Furthermore, the implants were placed with their MG and r/s border at varying levels above, at, or below the alveolar crest.

MATERIALS AND METHODS

Animals

Five laboratory-bred, male American foxhounds (≈ 2 years old and weighing 30 to 35 kg) were used for this study. All procedures were approved by the Institution Animal Care and Use Committee of the University of Texas Health Science Center at San Antonio, San Antonio, Texas. Experiments (February 2002 to January 2003) were carried out in the Department of Laboratory Animal Resources at the University of Texas Health Science Center at San Antonio. At the beginning of the study, the dentition was cleaned. Furthermore, an oral hygiene program was carried out throughout the study.¹⁷⁻²¹

Extractions

Tooth extractions were carried out in an operating room under general anesthesia and sterile conditions using 4% thiopental-Na solution intravenously (0.4 mL/kg body weight) for premedication purposes. The dogs were placed on a heating pad, intubated and inhaled with 1.5% to 2% isoflurane, and additionally monitored with an electrocardiogram during the surgery. The surgical site was first disinfected with 10% povidone-iodine solution/1% titratable iodine; 2% lidocaine HCl with epinephrine 1:100,000 was given as local anesthetic; and all four mandibular premolars (P1 to P4), and the first molar (M1) were extracted bilaterally. Before extraction P2 to M1 was sectioned to help prevent tooth fracture.

On the day of surgery, the animals were given 20 mg of the analgesic nalbuphine subcutaneously twice a day (10 mg/mL). In addition, the hounds received 3 mL of the antibiotic benzathine penicillin (150,000 IU)

combined with procaine penicillin G (150,000 IU) subcutaneously once a day every 48 hours for 7 to 10 days. After a period of 7 to 10 days, the animals were briefly anesthetized with a combination (1.1 mL/15 kg body weight) of xylazine (7.1 mg/mL), acepromazine (2.1 mg/mL), atropine (0.1 mg/mL), and ketamine (50 mg/mL) intravenously. After anesthesia, sutures were removed after disinfection of the wound site with a 0.12% chlorhexidine digluconate-soaked gauze.

Implant Designs and Surfaces

Two different designs (control implants with a machined collar and test implants without a machined collar) of cylindrical titanium implants with a full-body screw-shape design were used, made from cold-worked grade IV commercially pure titanium (Fig. 1). For all implants, the inner diameter was 3.5 mm and the outer diameter was 4.1 mm. The total length measured 9 mm. The rough part of each implant consisted of an SLA surface.¹¹ The upper 1.8 mm of the commercially available control implants** had a relatively smooth, machined titanium surface, with the lower 7.2 mm having an SLA surface (Fig. 1A). For test implants,†† the SLA surface covered the entire 9 mm vertical height, revealing no machined collar (Fig. 1B). When the abutments were placed on the implants, an interface (MG) was created between the implant and abutment with a butt-joint connection.

Implant Placement

Implant placement was performed similarly to previously described procedures.¹⁸ Briefly, implants were placed under the same surgical conditions as tooth extractions (sterility, operating room, and anesthesia) after a healing period of 5 months. A crestal incision was made to maximize keratinized tissue on each side of the incision. Mucoperiosteal flaps were reflected on the lingual and buccal aspects. The edentulous osseous ridge was flattened with an acrylic resin bur with copious irrigation and chilled sterile physiologic saline. Measurements were made using a Boley gauge to help distribute six implants (three control and three test) on each side of the mandible according to a randomized selection to ensure that no implant subgroup had a biased position in the arch. Implant osteotomy was performed with torque reduction rotary instruments at 500 rpm and also chilled saline. Implants were placed with an insertion device and a hand ratchet, and healing screws of different lengths were connected according to a non-submerged, two-piece approach (Fig. 2).

Six combinations of implants and placement positions were studied (Fig. 2) and labeled subgroups A through F. For subgroups A, B, and C, commercially available control implants were used (Fig. 1A). Subgroup A implants were control implants with the r/s border placed flush to the bone crest in accordance

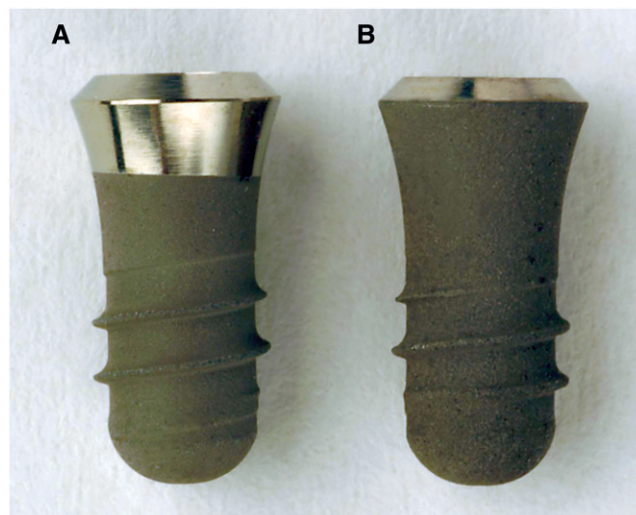


Figure 1.

A) Commercially available control implant with an overall length of 9 mm. The machined collar of the control implant measures 1.8 mm, whereas the roughened implant portion consists of an SLA surface. **B)** Test implant with an overall length of 9 mm exhibiting a completely roughened SLA surface.

to standard surgical procedures.⁶⁻⁸ For subgroup B, the r/s border was aligned 1 mm above the crest, and for subgroup C 1 mm below the crest (Fig. 2A). For subgroups D, E, and F, test implants without a machined collar were used (Fig. 1B). For subgroup D, the top (MG [interface]) of the implant was placed 1 mm above the bone crest, for subgroup E 2 mm above the crest, and for subgroup F implants the MG (interface) was placed flush with the bone crest level (Fig. 2B). Subsequently, healing screws of appropriate lengths were inserted with all emerging through peri-implant soft tissues up to the same level for all six implant subgroups.

If necessary, periosteal relieving and contouring incisions were made on the buccal and lingual aspects to achieve tension-free wound closure. Horizontal mattress and interrupted sutures were placed. The dogs received the same medication given after the tooth extractions. However, to reduce swelling, the dogs were also administered 2 mL of the anti-inflammatory dexamethasone intramuscularly once a day on days 1 and 4 (2 mg/mL). The sutures were removed after 7 to 10 days.

Follow-Up Period

Beginning 2 weeks after implant placement, oral hygiene procedures were carried out twice a week using 0.2% chlorhexidine gel in combination with a soft toothbrush. The healing abutments of all implants were disconnected and immediately tightened

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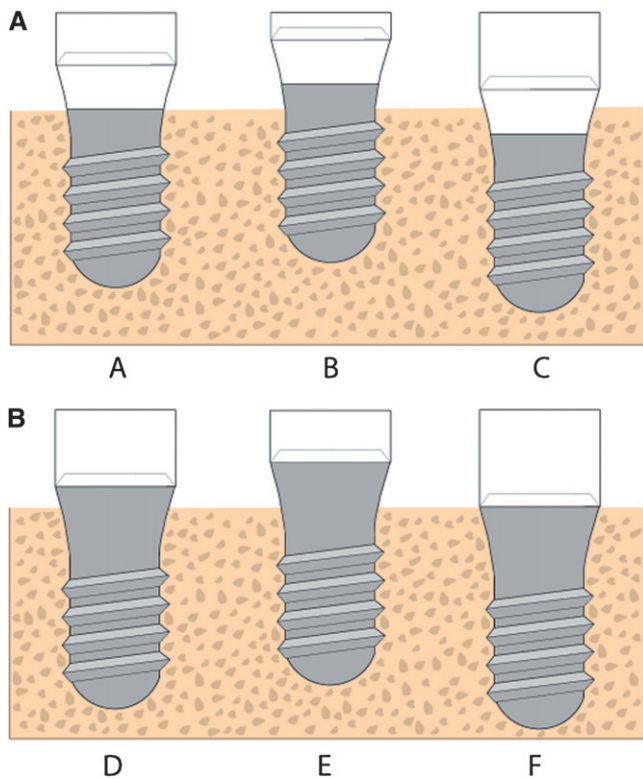


Figure 2. Schematic (true to scale) of implant subgroups at time of implant placement in relation to the crest of the bone. **A)** subgroups A to C, **B)** subgroups D to F.

without removing the abutment at monthly intervals after implant placement surgery, to imitate clinically relevant steps that have been shown to be a crucial procedure in experimental implant studies.¹⁷ To ascertain the bone response to implant placement, standardized radiographs were obtained at the time of implant placement and at 1-month intervals until sacrifice.²⁰ The radiographic results have been published in another article.³⁰

Sacrifice

Six months after implant placement, all animals were sacrificed. Euthanasia was carried out with an overdose of pentobarbital sodium intravenously (0.2 mL = 65 mg/kg body weight). The block-resection of the mandibles was performed using an oscillating autopsy saw. The recovered segments with the implants were immersed in a solution of 4% formaldehyde combined with 1% CaCl₂ for histologic preparation and analysis.³¹

Non-Decalcified Histologic Analysis: Preparation

Each implant with surrounding tissues was prepared for non-decalcified histology. Specimens were carefully dehydrated and embedded in methyl methacrylate. Per implant, first one well-centered mesio-distal

section was cut with a diamond saw. The two remaining blocks were then glued together with an interposed plastic spacer (cyanoacrylate), and subsequently sectioned in an orofacial direction. All sections were ground to a final thickness of $\approx 80 \mu\text{m}$ and superficially stained with toluidine blue and basic fuchsin (Fig. 3).

Non-Decalcified Histologic Analysis: Histometry

Histometric quantification was carried out using a light microscope at different magnifications ($\times 40$ to 200) to best locate anatomic reference points. The microscope was connected to a high-resolution video camera and interfaced to a monitor and a personal computer. This optical system was associated with a digitizing pad and a bone histometry software package with image-capturing capabilities. Consequently, the distance between MG (interface) and the first bone-to-implant contact (fBIC) was measured at each implant site (Fig. 3).

Power Analysis and Statistical Methods

A power analysis was conducted to determine the number of dogs that were necessary to detect population mean differences of ≥ 1 mm among the six implant study design subgroups using a mixed-model analysis of variance (ANOVA) with $P < 0.05$ considered statistically significant and a power of 80%. Because there was sufficient space to place six implants on each side of a dog's mandible, it was possible to place 12 implants (specifically two implants from each of the six subgroups) within each dog. Using statistical software,^{††} a sample of five dogs was determined to have sufficient power. Ten sets of implant study design subgroup arrangements were selected so that no site, ordered one to six with six representing the most distal position of the mandibular arch, had > 2 of a specific subgroup. The 10 sets of implant subgroup arrangements were then randomly assigned to the 10 mandible sides in the five dogs.

From the sets of histologic sections obtained for each implant, the measurements of the distance from MG to fBIC were compared using a mixed-model ANOVA to determine if significant mean differences were observed among mesial, distal, buccal, and lingual views. A single representative mean distance value for each implant was obtained by averaging the distances recorded for each histologic view of the implant. Based on the results of previous histologic studies,^{17,19,20,32} the buccal view has tended to have significantly longer distances than the other three views. If this result was true for this data set, then individual implant mean distances based on the average of all non-buccal views would be calculated (non-buccal distance means). For implants with a machined collar (control implants, subgroups A to C),

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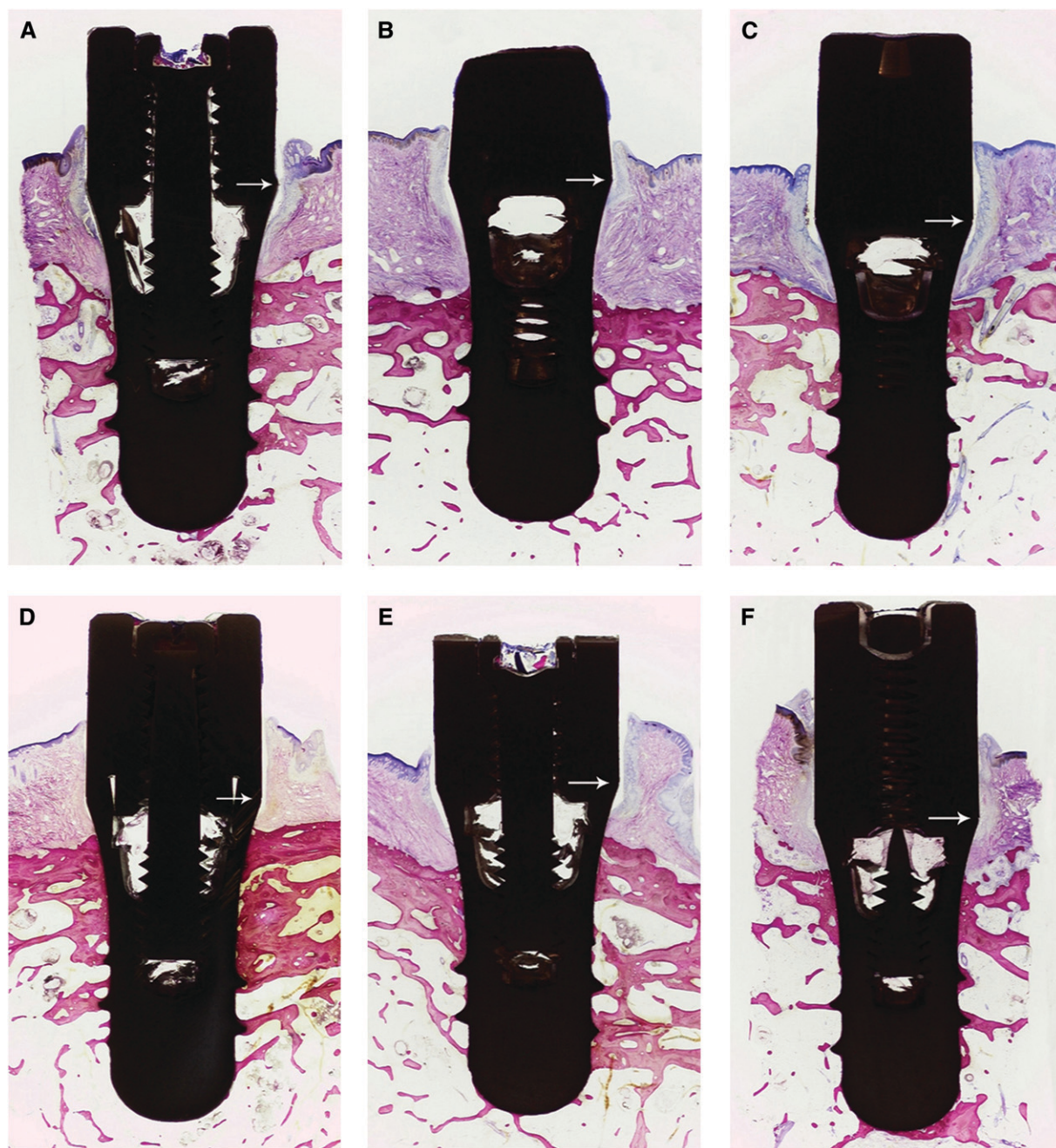


Figure 3.

Mesio-distal sections of implants in subgroups A (A), B (B), C (C), D (D), E (E), and F (F). The white arrows show the location of MG (interface). Non-decalcified histologic sections (toluidine blue and basic fuchsin, original magnification $\times 2.5$). Note that for implants in subgroup B, a crestal bone gain occurred adjacent to the SLA-surfaced implant portion (dark red-stained bone areas).

the distance from the MG to the r/s border was also obtained from every single histologic section and averaged in the same fashion for each implant with this design. This mean distance was expected to be ≈ 1.8 mm for each control implant, with any variation attributable to histologic distortion. To obtain estimates of bone loss for each control implant, the MG to r/s border mean distance was subtracted from the MG

to fBIC mean distance, resulting in an r/s border to fBIC mean distance. This adjustment was not necessary for the test implants (subgroups D to F) because the r/s border was located at the MG level for this design per definition. Because the protocol for implant placement level relative to the bone crest centered on the position of the r/s border for all implants, the protocol placement distance from the r/s border to

Table 1.**Estimated Bone Loss for Control Subgroups A to C Versus Test Subgroups D to F at Time of Sacrifice***

Type	A (n)	B (n)	C (n)
BC: fBIC	-0.52 ± 0.40 (10)	+0.16 ± 0.40 (10)	-1.28 ± 0.21 (10)
Type	D (n)	E (n)	F (n)
BC: fBIC	-0.43 ± 0.43 (10)	-0.03 ± 0.48 (10)	-1.11 ± 0.27 (7)

n = number of measured implant sites; BC = bone crest.

A > B ($P < 0.001$); A > E ($P = 0.034$); C > A, B, D, and E ($P < 0.001$); D > B ($P = 0.005$); F > A ($P = 0.013$); F > B and E ($P < 0.001$); F > D ($P = 0.003$).

* Mean values ± SD (mm). Negative numbers indicate bone loss and positive numbers represent bone gain. Note that implant subgroups A and E or subgroups C and D had the same distances from the MG to the BC level at time of implant placement, whereas implant subgroups B and F were placed 3 mm above and at the BC level, respectively.

the bone crest was then subtracted from the r/s border to fBIC mean distance to obtain the bone loss estimates for each implant. The MG to fBIC distance and estimated bone loss data were analyzed using mixed-model ANOVA to compare implant subgroups A to F controlling for any dog effect. If any of the *F* tests were significant ($P < 0.01$), then relevant pairwise comparisons, using Bonferroni-adjusted unpaired Student *t* tests excluding any dog effect, were performed to identify differences of interest among the implant subgroups. Comparisons of interest for the MG to fBIC distance data included possible mean differences among control implant subgroups (A to C) and among test implant subgroups (D to F) to determine if the placement level protocol effect was observable after healing. These same comparisons of interest were also made for the estimated bone loss data, and two additional comparisons were made between implant subgroups with the same MG placement level protocol, which were A versus E (MG 2 mm above the bone crest level) and C versus D (MG 1 mm above the bone crest level). For the Bonferroni-adjusted unpaired Student *t* tests, $P < 0.05$ was considered significant. Statistical analyses were performed using appropriate software.^{§§}

RESULTS**Clinical Findings**

After implant placement, healing was uneventful in all dogs. One month after implant placement, two subgroup F implants showed periapical radiolucent defects with marked mobility. These implants were removed. One implant was in the anterior aspect of the mandible; the other implant was in the posterior aspect of the mandible in another dog. The other 58 implants showed successful tissue integration exhibiting ankylotic stability without clinical signs

of peri-implant infection. Although oral hygiene was performed twice weekly, there was a variation of tissue response around the different implants. This response ranged from minimal inflammation to very inflamed tissue that was hyperplastic in nature.

Histologic Findings

Light microscopic evaluation of the BIC of the 58 implants indicated that hard tissue integration of all implants was achieved (Fig. 3). In all implant subgroups, intimate contact of bone was found directly adjacent to the SLA surface. As expected,¹¹ dense cortical bone had large areas of BIC compared to cancellous bone areas where more marrow space was found.

There were 58 implants for which histologic sections were taken at the time of sacrifice. Each implant had exactly one mesio-distal section (Fig. 3) and two to four orofacial sections for a total of 218 sections. Among the 58 mesio-distal sections, the fBIC could be identified both mesially and distally for 45, only for the mesial view for four, only for the distal view for four, and was unidentifiable for five. Among the 160 orofacial sections, the fBIC could be identified both buccally and lingually for 79, only for the buccal view for 12, only for the lingual view for 57, and was unidentifiable for 12. Fifty-two implants had identifiable fBIC in both mesio-distal and orofacial sections; one subgroup E implant had identifiable fBIC in the mesio-distal section only; and one subgroup A, one subgroup E, and two subgroup F implants had identifiable fBIC in two to three orofacial sections only. One subgroup F implant did not have an identifiable fBIC for any of the four histologic sections obtained, so fBIC distance data were available for seven subgroup F implants and 10 implants for each of the other subgroups (Tables 1 and 2).

Statistical Findings

The mixed-model ANOVAs comparing mesial, distal, buccal, and lingual views for the MG to fBIC distance data were significant ($F = 35.28$; $P < 0.001$), and Bonferroni-adjusted Student *t* tests revealed that the buccal view had significantly ($P < 0.001$) longer distances than the other three views, and the mesial, distal, and lingual views were not significantly ($P = 1.00$) different from each other. The 95% confidence intervals for the mean differences between the buccal views and the other views ranged from 0.46 to 0.88 mm, which was a clinically significant difference. As a result, means of non-buccal views were calculated for each

§§ IBM, Chicago, IL.

Table 2.
Distances From MG to fBIC for Control Subgroups A to C Versus Test Subgroups D to F at Time of Sacrifice*

Type	A (n)	B (n)	C (n)
MG: fBIC	2.36 ± 0.36 (10)	2.67 ± 0.42 (10)	2.10 ± 0.22 (10)
Type	D (n)	E (n)	F (n)
MG: fBIC	1.43 ± 0.43 (10)	2.03 ± 0.48 (10)	1.11 ± 0.27 (7)

n = number of measured implant sites.

A > D and F ($P < 0.001$); B > C ($P = 0.008$); B > E ($P = 0.002$); B > D and F ($P < 0.001$); C > D ($P = 0.001$); C > F ($P < 0.001$); E > D ($P = 0.005$); E > F ($P < 0.001$).

* Mean values ± SD (mm). Note that implant subgroups A and E or subgroups C and D had the same distances from the MG to the bone crest level at time of implant placement, whereas implant subgroups B and F were placed 3 mm above and at the bone crest level, respectively.

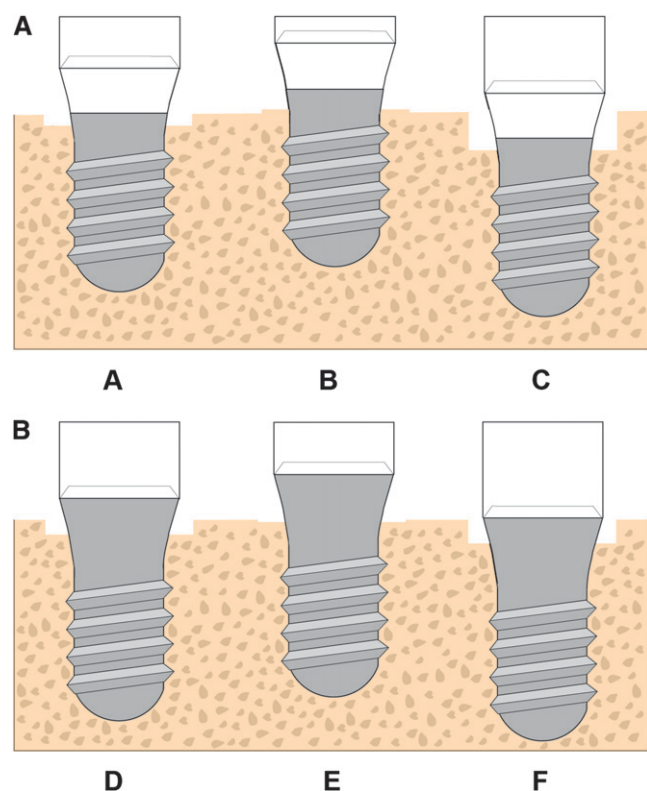


Figure 4.

Schematic (true to scale) of (A) implant subgroups A to C (control) and (B) implant subgroups D to F (test) at time of sacrifice in relation to the crest of the bone indicating the amount of bone loss or gain 6 months after implant placement.

implant for use in the final analyses comparing implant subgroups. However, among the four sections for one of the remaining seven subgroup F implants, the fBIC was identifiable for only three buccal views. Rather than exclude this implant from the analysis, the overall average buccal distance increase of 0.66 mm was subtracted from the observed buccal mean

for this implant to give an estimate of the mean of non-buccal views for this implant.

The mixed-model ANOVA comparing implant subgroup means of estimated bone loss for implants (based on non-buccal histologic views) were significant ($F = 26.42$; $P < 0.001$). For the comparisons of interest, Bonferroni-adjusted Student *t* tests revealed that A was significantly greater than B ($P < 0.001$) and E ($P = 0.034$); C was significantly greater than A, B, D, and E ($P < 0.001$); D was significantly greater than B ($P = 0.005$); and F was significantly greater than D ($P = 0.003$) and B and E ($P < 0.001$). When comparing control to test

implants with the same MG placement levels, the estimated bone loss for A was significantly greater than for E ($P = 0.034$) and bone loss for C was significantly greater than for D ($P < 0.001$). (Fig. 4, Table 1). The mixed-model ANOVA comparing implant subgroup means of non-buccal MG to fBIC distances for implants were significant ($F = 24.61$; $P < 0.001$). For the comparisons of interest, Bonferroni-adjusted Student *t* tests revealed that A was significantly greater than D and F ($P < 0.001$); B was significantly greater than C ($P = 0.008$), E ($P = 0.002$), and D and F ($P < 0.001$); C was greater than D ($P = 0.001$) and F ($P < 0.001$); and E was significantly greater than D ($P = 0.005$) and F ($P < 0.001$). (Fig. 4, Table 2).

DISCUSSION

The results of this experimental side-by-side comparison with matched (butt-joint) implant and abutment designs indicate that the effect of implant placement level is significant after healing, because subgroups C and F were placed 1 or 2 mm deeper than other implants having the same design, and machined-collar implants had greater mean bone loss than non-machined-collar implants having comparable MG placement levels (Fig. 5). Furthermore, these histometric analyses revealed that crestal bone loss can significantly be reduced when placing a completely roughened implant 1 mm above the bone crest level compared to an implant exhibiting a machined collar at the same level in relation to the crest of the bone. In addition, when comparing a machined-collar implant to an SLA-surfaced implant collar with MG (interface) initially located 2 mm above the crest, significantly increased amounts of crestal bone loss occurred for machined-collar implants, whereas no crestal bone loss could be identified for SLA-surfaced implant collars. Moreover, coronal bone migration occurred if an SLA surface was located within soft tissues or above the bone crest level at the time of implant

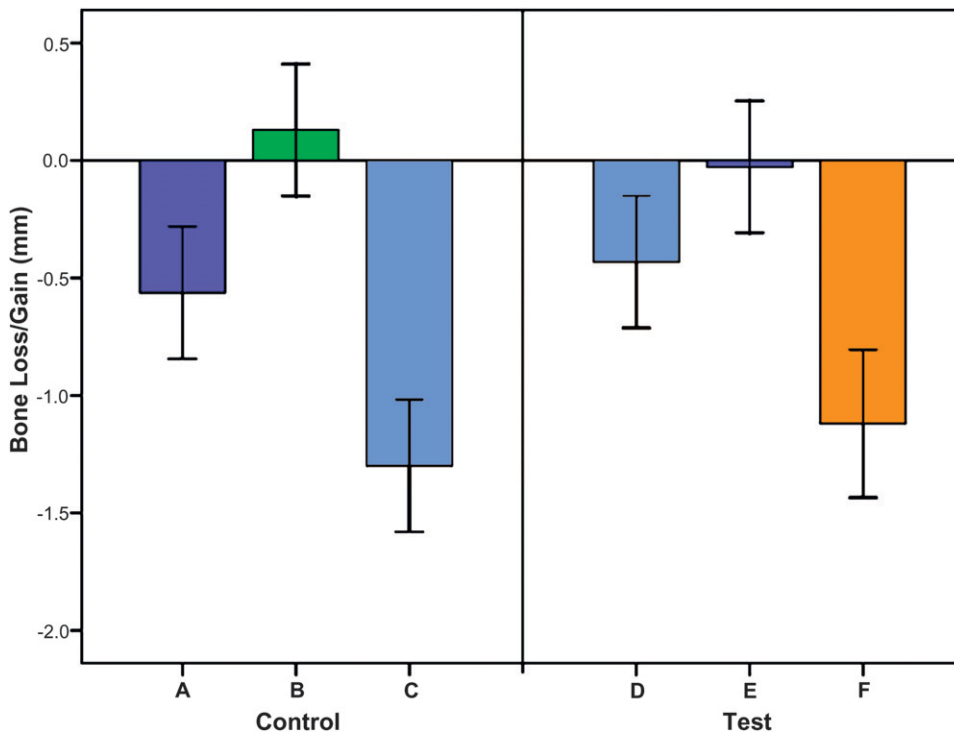


Figure 5.

Graph of estimated bone loss or gain for implant subgroups A to C (control) and D to F (test) at time of sacrifice in relation to the crest of the bone (black line). Negative numbers indicate bone loss, and positive numbers represent bone gain. Bars indicate 95% confidence intervals (A > B [P < 0.001]; A > E [P = 0.034]; C > A, B, D, and E [P < 0.001]; D > B [P = 0.005]; F > A [P = 0.013]; F > B and E [P < 0.001]; and F > D [P = 0.003]).

placement and the MG (interface) of such a machined implant 3 mm above the crest. Finally, placing a completely SLA-surfaced implant with its MG (interface) at the bone crest level does not prevent crestal bone loss.

For the past 20 years, a major focus in implant dentistry was surface technology to improve quality and quantity of hard tissue integration using roughened SLA-surfaced implants, which have shown significantly better results as opposed to machined and other roughened implant surfaces.^{9-12,16,33} As a consequence, shorter implants could be used long-term,³⁴ and earlier hard tissue integration and thus a reduced risk of early complications and failures could be observed.³⁵ Another focus during this period was the study of crestal bone loss patterns, dimensions of peri-implant soft tissues, and the degree of peri-implant inflammation to better understand peri-implant soft tissue conditions and a predictable and long-term esthetic and healthy result.^{14,17-26,32,36-39} Based on these clinical and experimental studies, it can be concluded that crestal bone loss can be prevented if a machined-collar implant with a butt-joint attached abutment is placed with its MG ≥ 2 mm above the bone crest level, whereas increasing amounts of

crestal bone loss and degrees of peri-implant inflammation occur if the MG is placed 1 mm above, at the bone crest level, or even 1 mm below the crest of the bone. In the present study, the exact same results were observed in regard to different implant placement levels, both for machined-collar implants and non-machined-collar implants.

Interestingly, the results of this experimental histologic side-by-side comparison show for the first time that crestal bone loss-up can significantly be reduced if implants are sprayed all the way to the top (non-machined-type implants) when comparing the exact same implant design in combination with the same distances of the MG:fBIC (subgroup implants A versus E and subgroup implants C versus D). This illustrates the fact that the SLA surface is able to promote better

crestal hard tissue integration as opposed to a machined titanium surface under such circumstances.

Another interesting finding is the fact that it can be documented for the first time that local, healed crestal bone (chronic defect sites) has the capacity to migrate in a coronal direction during healing on a particularly osteophylic SLA surface (subgroup B implants) initially being exposed to peri-implant soft tissues. A similar phenomenon could be observed in surgically created dehiscence-type defects in dogs for chemically modified SLA surfaced implants in acute-type buccal defect sites.⁴⁰ This might be a beneficial finding related to frequently discovered clinical scenarios with slightly exposed (buccal) SLA surfaces when placing implants in the interforaminal edentulous area and in slightly dehisced sites in an orofacial direction.

CONCLUSIONS

Completely SLA-surfaced one-piece, non-submerged implants can reduce the amount of peri-implant crestal bone loss and reduce the distance from MG to the fBIC around unloaded implants compared to implants with a machined collar. Furthermore, a slightly exposed SLA surface during implant

placement does not seem to compromise the overall hard and soft tissue integration and, in some cases, results in coronal bone formation in this canine model.

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