Crestal Bone Changes Around Titanium Implants. A Histometric Evaluation of Unloaded Non-Submerged and Submerged Implants in the Canine Mandible

Joachim S. Hermann,*† Daniel Buser,‡ Robert K. Schenk,‡§ and David L. Cochran*

Background: Today, implants are placed using both non-submerged and submerged approaches, and in 1- and 2-piece configurations. Previous work has demonstrated that peri-implant crestal bone reactions differ radiographically under such conditions and are dependent on a rough/smooth implant border in 1-piece implants and on the location of the interface (microgap) between the implant and abutment/restoration in 2-piece configurations. The purpose of this investigation was to examine histometrically crestal bone changes around unloaded non-submerged and submerged 1- and 2-piece titanium implants in a side-by-side comparison.

Methods: A total of 59 titanium implants were randomly placed in edentulous mandibular areas of 5 foxhounds, forming 6 different implant subgroups (types A-F). In general, all implants had a relatively smooth, machined coronal portion as well as a rough, sandblasted and acid-etched (SLA) apical portion. Implant types A-C were placed in a non-submerged approach, while types D-F were inserted in a submerged fashion. Type A and B implants were 1-piece implants with the rough/smooth border (r/s) at the alveolar crest (type A) or 1.0 mm below (type B). Type C implants had an abutment placed at the time of surgery with the interface located at the bone crest level. In the submerged group, types D-F, the interface was located either at the bone crest level (type D), 1 mm above (type E), or 1 mm below (type F). Three months after implant placement, abutment connection was performed in the submerged implant groups. At 6 months, all animals were sacrificed. Non-decalcified histology was analyzed by evaluating peri-implant crestal bone levels.

Results: For types A and B, mean crestal bone levels were located adjacent (within 0.20 mm) to the rough/smooth border (r/s). For type C implants, the mean distance (± standard deviation) between the interface and the crestal bone level was 1.68 mm (± 0.19 mm) with an r/s border to first bone-to-implant contact (fBIC) of 0.39 mm (± 0.23 mm); for type D, 1.57 mm (± 0.22 mm) with an r/s border to fBIC of 0.28 mm (± 0.21 mm); for type E, 2.64 mm (± 0.24 mm) with an r/s border to fBIC of 0.06 mm (± 0.27 mm); and for type F, 1.25 mm (± 0.40 mm) with an r/s border to fBIC of 0.89 mm (± 0.41 mm).

Conclusions: The location of a rough/smooth border on the surface of non-submerged 1-piece implants placed at the bone crest level or 1 mm below, respectively, determines the level of the fBIC. In all 2-piece implants, however, the location of the interface (microgap), when located at or below the alveolar crest, determines the amount of crestal bone resorption. If the same interface is located 1 mm coronal to the alveolar crest, the fBIC is located at the r/s border. These findings, as evaluated by non-decalcified histology under unloaded conditions, demonstrate that crestal bone changes occur during the early phase of healing after implant placement. Furthermore, these changes are dependent on the surface characteristics of the implant and the presence/absence as well as the location of an interface (microgap). Crestal bone changes were not dependent on the surgical technique (submerged or non-submerged).

KEY WORDS
Alveolar bone/anatomy and histology; dental implants; bone resorption/etiology; titanium.

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The placement of endosseous dental implants has evolved using 2 surgical approaches. One of these approaches uses a submerged technique where the implant is placed into the bone and the top of the implant is placed at or below the alveolar crest. The soft tissues are closed over the bone and implant thereby submerging the implant. The other surgical approach involves an implant that extends coronally beyond the alveolar crest where the soft tissue flap is placed around the coronal portion of the implant body. The placement of additional restorative components with the submerged implant creates an interface or gap (often termed a “microgap”) at or below the alveolar crest. In the non-submerged approach, when restorative components are placed, the interface is located 2 to 3 mm coronal to the alveolar crest, which is even with or slightly below the gingival level. Additionally, such 1-piece implants generally exhibit an “apical” or endosseous portion with a roughened implant surface and a “coronal” or transgingival portion with a relatively smooth surface.

Longitudinal descriptions of the use of both submerged and non-submerged techniques in humans have demonstrated that the implants can be clinically successful in a large percentage of cases over extended periods of time. In the clinical descriptions of endosseous implant use in humans, one criterion of success has typically included radiographic alveolar crestal bone changes. This criterion is a mean crestal bone loss of less than 1.5 mm in the first year after abutment connection and less than 0.2 mm in subsequent years. This criterion was established using the submerged approach and a machined screw implant where an interface was created at or below the alveolar crest at the uncovering (second-stage) surgery. For 1-piece implants placed in a non-submerged approach, several long-term studies indicate that the level of crestal bone remodels to approximately the border between the rough and smooth implant surfaces. A detailed radiographic evaluation of approximately 100 such implants revealed that more implants gained bone over an 8-year period compared to the number of implants that lost crestal bone. The authors concluded that mean bone level changes are not as informative as is a distribution analysis of bone changes.

One inherent advantage of a non-submerged approach is the fact that only one surgical procedure has to be performed. Therefore, some investigators have begun to attach secondary components on submerged implants at the time of implant placement. This represents a non-submerged approach; however, an interface (microgap) remains at or below the alveolar crest, similar to the traditional submerged approach. In this situation, the interface is created earlier in the procedure at implant placement rather than after a submerged healing period for the implant. Radiographic analyses of such 2-piece non-submerged implants, however, reveal crestal bone loss changes similar to the traditional submerged approach, except that the changes are observed earlier.

The purpose of the present investigation was to evaluate crestal bone changes by histological analyses around submerged and non-submerged implants placed in a side-by-side comparison. Additionally, 1- and 2-piece implant/abutment systems were studied to determine the influence of the location of the interface (microgap) in 2-piece systems or the rough/smooth border on 1-piece implant systems in relation to the first bone-to-implant contact.

MATERIALS AND METHODS

Implant Surfaces
A full-body screw design was chosen for all 6 different cylindrical titanium implants (A-F) which were made from cold-worked, grade IV commercially pure titanium (Fig. 1). The total length was 9 mm, and the
for type B implants, the rough part (SLA) measured 5.0 mm, with the rough/smooth border placed 1.0 mm below the alveolar crest. For all other implants (types C-F), the rough implant surface (SLA) was 4.5 mm in vertical dimension, with the rough/smooth implant border located 1.5 mm below the crest. Types A and B were 1-piece implants, meaning there was no interface (microgap) present; implant types C-F consisted of 2 pieces, with an interface or microgap of about 50 µm in size between the implant and the secondary component, the abutment. The location of the interface was defined to be at the bone crest level for types C and D; for types E and F, the interface was located 1 mm above and 1 mm below the crest, respectively. Implant types A-C were placed according to a non-submerged approach and types D-F were placed using a submerged technique.

Power Analysis

One of each of the 6 types of implants could be placed on each side of the dog mandible. To ensure that position in the arch did not influence the results, the sequence of placement was randomized for the left and right sides of the mandible in each dog. Because the goal of the study was to detect implant group differences of 1 mm or more, a sample size of 60 implants was confirmed by power analysis to be sufficient to identify significant implant group differences using analysis of variance at the 0.01 level with power of 80%. Five dogs, each with 12 implants placed, were used in the study. Ten different sequences of implant type placement were selected and randomly assigned to the left and right sides of the mandible of each dog.

Animals

The protocol was approved by the Institutional Animal Care and Use Committee of the University of Texas Health Science Center at San Antonio. Five lab-bred, male American foxhounds were used. The dogs were approximately 2 years of age at the beginning of the study and had a body weight of about 30 to 35 kg. No heartworms were found and all dogs were quarantined.

Surgeries

Extraction. Extractions were performed in an operating room under intravenous (iv) general anesthesia and sterile conditions utilizing 4% thiopental-Na solution (0.4 ml/kg bw) for premedication purposes (Fig. 4).* The animals were put on a heating pad, intubated and inhaled with 1.5 to 2% isoflurane,* and monitored with an electrocardiogram during the surgery. First, the surgical site was disinfected with 10% povidone-iodine solution/1% titratable iodine.** Subse-
quently, 2% lidocaine HCl with epinephrine 1:100,000 was given as local anesthetic,†† and all 4 premolars (P1–P4) and the first molar (M1) were extracted carefully. Before extraction, all teeth were scaled and cleaned, and P2–M1 were sectioned to help prevent tooth fracture. Finally, interrupted sutures were used allowing for an appropriate approximation of the wound margins.

On the day of surgery, the animals were given 20 mg of the analgesic nalbuphine subcutaneously (sc) bid (10 mg/ml).‡‡ In addition, after a period of 7 to 10 days, the dogs received 3 ml of the antibiotic benzathine penicillin (150,000 I.U.) combined with procaine penicillin G (150,000 I.U.) sc sid every 48 hours.§§ The animals were then briefly anesthetized with a combination (1.1 ml/15 kg bw) of xylazine (7.1 mg/ml), acepromazine (2.1 mg/ml), atropine (0.1 mg/ml), and ketamine (50.0 mg/ml) iv.## After anesthesia, sutures were removed following disinfection of the wound site with a 0.12% chlorhexidine digluconate-soaked gauze.***

**Implant placement.** After a healing period of 6 months (Fig. 4), non-submerged and submerged implants were placed under the same surgical conditions as when tooth extraction had been performed (operating room, anesthesia, sterility). A crestal incision was performed to maximize keratinized gingiva on each side of the incision. Consequently, mucoperiosteal flaps were reflected on the lingual and buccal aspect. Foramina mentalia were dissected and exposed. Using an acrylic bur, the edentulous osseous ridge was carefully flattened and combined with copious irrigation with chilled sterile physiologic saline. A Boley gauge was used to help distribute 6 test implants on each side of the mandible. Implant site preparations were carried out with torque reduction rotary instruments at 500 rpm using chilled saline. Implant types A–C were inserted according to a non-submerged approach; i.e., for type C, implants and abutments were screwed together at the time of first-stage surgery. Implant types D–F were placed according to a submerged technique. Finally, one of each kind of test implant was inserted per side in a randomized fashion. Thus, no implant type had a biased position in the arch.

If indicated, periosteal relieving and contouring incisions were carried out on the buccal and lingual aspects of each implant to obtain tension-free adaptation of the wound margins for close adaptation of the gingiva to the transgingival portion of the nonsubmerged implants (types A and B) and the abutment of type C. Wound closure over the submerged implant types D–F was achieved using horizontal mattress and interrupted sutures. The animals received 20 mg of the analgesic nalbuphine sc bid (10 mg/ml) on the day of surgery. Three ml of the antibiotic benzathine penicillin (150,000 I.U.) with procaine penicillin G (150,000 I.U.) was given sc sid every 48 hours for 14 days. On day 1, 100 mg of the antibiotic gentamicin was given sc bid, and the same amount sid from day 2 through 10 (50 mg/ml).††† The animals received 2 ml of the anti-inflammatory dexamethasone intra-muscularly (im) sid day 1 and day 4 (2 mg/ml).‡‡‡ Suture removal was performed after 7 to 10 days as described above. To minimize loading, the dogs were fed a softened diet. Three times per week, mechanical and chemical plaque control were carried out utilizing a soft toothbrush and a soft sponge in combination with a 0.2% chlorhexidine gel.§§§

**Abutment connection.** Three months after implant placement, second-stage surgery was carried out and abutments were connected for submerged implant types D–F. Surgical conditions were the same as described above. First, the surgical sites were disinfected and local anesthesia administered. Over the top of these implants, a midcrestal incision was performed, combined with a small vertical relieving incision at the buccal and lingual aspect. Implants were uncovered after the elevation of a full-thickness flap. In the case

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†† Henry Schein Inc., Port Washington, NY.  
‡‡ Nuibain, Astra Pharmaceutical Products Inc., Westborough, MA.  
§§ Pen-B, Pfizer Inc., Lee's Summit, MO.  
¶¶ Miles Inc., Shawnee Mission, KS.  
## Burns Veterinary Supply, Oakland, CA.  
††† Fort Dodge Laboratories Inc., Fort Dodge, IA.  
*** Peridex, Procter & Gamble Co., Cincinnati, OH.  
†††† Gentocin, Schering-Plough Animal Health Corp., Kenilworth, NJ.  
†††† Dazaject, Burns Veterinary Supply.  
§§§ PlakOut Gel, Hawe-Neos AG, Bioggio/TI, Switzerland.
of implants partially covered with bone, mostly in type F implants, a minor osteotomy was performed using hand instruments (chisel, mallet). Consequently, flat-head cover screws could be removed in the submerged implant group. Abutments of individual lengths were connected specifically for each implant type, meaning that all implants emerged to the same level after abutment placement.Interrupted sutures combined with small V-shaped gingivectomies were used for wound closure around the abutments. Postoperative care and suture removal were performed the same way as after tooth extractions. Abutments (types C-F) were disconnected and immediately tightened afterwards at 4, 8, and 10 weeks after second-stage surgery to imitate the placement of another healing abutment, impression taking, as well as the placement of the final prosthetic component.

Three months after abutment connection, all dogs were sacrificed. Euthanasia was carried out with an overdose of pentobarbital sodium iv (0.2 ml = 65 mg/kg bw). 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% CaCl$_2$ for histologic preparation and analysis.

**Non-Decalcified Histologic Analysis**

**Preparation.** Each implant with surrounding tissues was prepared for non-decalcified histology. Specimens were embedded in methyl methacrylate and stained with basic fuchsin. One to 3 mesio-distal and up to 5 orofacial sections at a thickness of approximately 80 µm were obtained to maximize the available data per implant.

**Histometry.** Histometric quantification was carried out using a light microscope at different magnifications to best locate anatomical reference points. The microscope was connected to a high-resolution video camera and interfaced to a monitor as well as a personal computer. This optical system was associated with a digitizing pad and a bone histometry software package with image capturing capabilities. All implants had a rough/smooth border (r/s) at a particular level in relation to the crest of the bone. Due to the manufacturing process, however, there was a very small zone where only acid attack occurred just apical to the machined surface. About 0.1 mm more apical, the sandblasted surface combined with the acid-etched surface could be detected. This level, where both sandblasting and acid attack occurred, was defined as the rough/smooth border for the histologic evaluation. Finally, the following measurements were performed at each implant site (Fig. 5):

1. Distance between the top of the implant (top) and the first bone-to-implant contact (fBIC) for implant types A and B.
2. Distance between the interface (microgap) of the implant (IF) and the first bone-to-implant contact (fBIC) for implant types C through F.
3. Distance between the top of the implant (top) and the rough/smooth border (r/s) for implant types A and B.
4. Distance between the interface (microgap) of the implant (IF) and the rough/smooth border (r/s) for implant types C through F.

**Statistical Analysis**

Of particular interest in this study was the determination of the position of the first bone-to-implant contact (fBIC) relative to the location of the rough/smooth (r/s) border. This was done by initially obtaining histometric measurements of the distance from the top of the implant (types A and B), or the interface (types C-F), respectively, to the fBIC (Tables 1 and 2). Subsequently, histometric measurements from the top or interface to the r/s border were made on each implant site individually. Each implant had 4 or 5 sections with 2 sites for which histometric data were collected. In order to verify that the IF:fBIC values obtained from the histometric evaluation were not influenced by exam-
Histometric Data for Non-Submerged Implants

Table 1.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Type A n = 9 (42)</th>
<th>Type B n = 10 (47)</th>
<th>Type C n = 10 (50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IF: FBIC</td>
<td>2.98 ± 0.27 *</td>
<td>3.88 ± 0.42 †</td>
<td>1.68 ± 0.19 ‡</td>
</tr>
<tr>
<td>IF: r/s</td>
<td>2.79 ± 0.12</td>
<td>3.87 ± 0.22</td>
<td>1.29 ± 0.06</td>
</tr>
</tbody>
</table>

Mean values ± standard deviation (mm); n = number of implants analyzed; ( ) = number of measured implant sites; note that for groups A and B, the reference point (IF) is the top of the implant.

* P <0.02.
† P >0.9 (not significant).
‡ P <0.001.

Histometric Data for Submerged Implants

Table 2.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Type D n = 10 (47)</th>
<th>Type E n = 9 (48)</th>
<th>Type F n = 10 (49)</th>
</tr>
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<tr>
<td>IF: FBIC</td>
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Mean values ± standard deviation (mm); n = number of implants analyzed; ( ) = number of measured implant sites.

* P <0.01.
† P >0.4 (not significant).
‡ P <0.001.

RESULTS

Clinical Data

Fifty-nine out of the possible 60 implants could be placed. One implant could not be placed since the bone at this site was too soft and, therefore, primary stability could not be achieved. All the implants placed in this study achieved clinical stability and no complications occurred during healing or during the follow-up period. A previous publication of the same data set based on monthly radiographic evaluations demonstrated that no peri-implant radiolucencies were found around any of the implants and that only crestal bone loss was noted around specific implant types. Thus, these implants achieved excellent hard tissue integration by clinical and radiographic analyses. Although both meticulous mechanical and chemical plaque control were carried out 3 times per week, different degrees of peri-implant inflammation could be detected. Type A and B implants (1-piece, non-submerged) presented with only minimal clinical signs of peri-implant inflammation. However, type C implants (2-piece, non-submerged) as well as type D-F implants (2-piece, submerged) also large in a histometric sense, as the buccal sites had distances that exceeded mesial sites by an average of 0.28 mm per implant and both lingual and distal sites by an average of 0.38 mm per implant. Furthermore, these differences were definitely related to the position of the bone for buccal sites, as evidenced by the fact that the measured distances from the top or interface of the implant to the r/s border were not significantly different for the 4 types of sites (P >0.5), so that distortion among sections and sites was quite small. These results indicate that only the lingual, mesial, and distal sites should be used to calculate mean values for each implant from the top or interface to the fBIC in this study. For the purposes of consistency, buccal sites were also excluded in the calculation of mean values for each implant from the top or interface to the r/s border. In addition, the difference between these 2 measures was also calculated for each site (buccal sites excluded), and the mean difference for each implant was determined. If either measure was unreadable for a site, then that site was excluded from the analysis. The mean implant measures were then analyzed using F-tests to verify that the effects of dog and position in the arch for the implant were not significant (P >0.05). One-sample Student t tests were performed for each implant type to determine if the implant type mean (obtained from the mean implant measures) of the distance from the r/s border to the fBIC was significantly different from 0 mm. F-tests were then performed to check for significant (P <0.05) differences across implant types. For dimensions in which the F-test was significant, Bonferroni-adjusted unpaired Student t tests were carried out to identify group differences.

Histometric Data

Table 1.

Histometric Data for Non-Submerged Implants

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Mean values ± standard deviation (mm); n = number of implants analyzed; ( ) = number of measured implant sites; note that for groups A and B, the reference point (IF) is the top of the implant.

* P <0.02.
† P >0.9 (not significant).
‡ P <0.001.

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Histometric Data for Submerged Implants

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Mean values ± standard deviation (mm); n = number of implants analyzed; ( ) = number of measured implant sites.

* P <0.01.
† P >0.4 (not significant).
‡ P <0.001.

After excluding sites that were unreadable, a mean histometric dimensional value was calculated for each implant. However, the fBIC for buccal sites tended to be lower than that for the lingual, mesial, or distal sites. In fact, the mean distance between the top or interface of the implant and the fBIC was significantly greater for buccal sites compared to any of the other three sites for all implants combined (P <0.001 for Bonferroni-adjusted paired Student t test). These differences were
merged) showed moderate to severe clinical signs of peri-implantitis. These particular results will be described in a subsequent publication.

**Histometric Analysis**

Light microscopic evaluation of the bone-to-implant contact indicates that hard tissue integration of the implants was achieved as well (Figs. 6 through 11). In all implant types, intimate contact of bone was found directly adjacent to the sandblasted and acid-etched (SLA) surface. As expected, dense cortical bone had large areas of bone-to-implant contact compared to cancellous bone areas where more marrow space was found. It can be noted, however, that in more cancellous bone, osseous tissue was found along the SLA surface demonstrating and confirming the excellent osteoconductive nature of this surface.24-37

Nine 1-piece, non-submerged implants (type A) were analyzed in 34 histological sections allowing 42 implant site measurements (Fig. 1A). The mean distance from the top of the implant to the fBIC was 2.98 mm (Table 1, Fig. 12A). The mean distance between the rough/smooth border (r/s) to the fBIC was 0.19 mm, which was marginally statistically different ($P < 0.02$). This indicated that the fBIC was found approximately 0.2 mm below the r/s border which had been placed clinically as close to the alveolar crest as possible.

For the 1-piece, non-submerged type B implants with the r/s border located approximately 1 mm below the crest (Fig. 1A), the mean distance between the top of the implant and the fBIC was 3.88 mm, while the distance of the r/s border to the fBIC was 0.01
mm (Table 1, Fig. 12A). The fBIC was not significantly different from the location of the r/s border, indicating that in the case of type B implants, the bone was located at the r/s border. In this group, 10 implants with 36 sections (47 readable sites) could be analyzed.

The third type of implant (type C) placed in a non-submerged approach had the r/s border located clinically approximately 1.5 mm apical to the crest of bone and differed from type B by having an interface (microgap) located clinically at the alveolar crest (Fig. 1A). The mean distance based on 50 measurements from the interface between the implant and abutment to the fBIC was 1.68 mm (Table 1, Fig. 12A). This was based on analyzing 10 implants with 41 sections. The r/s border to fBIC was 0.39 mm, which was statistically significantly different ($P < 0.001$).

Type D implants were exactly like type C implants (2-piece, level of r/s border, interface placed clinically at the alveolar crest); however, they were placed in a submerged approach (Fig. 1B). Thus, the implant was placed such that the top of the implant was located at the alveolar crest, and the soft tissue flap covered the implant. After 3 months of healing, the implant was uncovered and an abutment was placed such that implant types C and D were now identical, with the exception being the time of exposure to the oral cavity (nonsubmerged versus submerged approach). At the time of sacrifice for type D implants, the mean distance from the interface to the fBIC was 1.57 mm. The mean distance of the r/s border to the fBIC was 0.28 mm, which indicated that the location of the fBIC was significantly different ($P < 0.01$) from the r/s border (Table 2, Fig. 12B). These measurements were based on 10 implants with 42 sections and 52 measurable sites.
Type E implants were 2-piece implants placed in a submerged technique, but had an extension of the endosseous portion projecting clinically, approximately 1.0 mm above the alveolar crest. This placed the interface (microgap) above the bone crest level. The r/s border, however, was similar to types B, C, D, and F in that it was located apical to the alveolar crest (Figs. 1A and 1B). For one of the type E implants, the fBIC could not be observed on any of the 5 sections taken. The remaining 9 implants with 39 sections and 48 measurable sites were analyzed. The mean distance from the interface to the fBIC was 2.64 mm with an r/s border to fBIC distance of 0.06 mm (Table 2, Fig. 12B). The r/s border and fBIC measurements were not significantly different ($P>0.5$) indicating that, similar to type B implants, the bone was located at the r/s border (Table 2).

Type F implants were placed with a submerged technique also, but the top of the implant was placed clinically approximately 1.0 mm below the alveolar crest and the r/s border about 0.5 mm apical to the interface/microgap (Fig. 1B). Ten implants with 40 sections and 52 measurable sites were analyzed. The mean distance from the interface to the fBIC was 1.25 mm, with a distance of 0.89 mm between the r/s border and the fBIC (Table 2, Fig. 12B). This latter distance was significantly ($P<0.001$) apical to the location of the r/s border, indicating that crestal bone loss occurred past the interface clinically located 1.0 mm below the alveolar crest and approximately 1.0 mm apical to the r/s border (located apical to the interface/microgap).

A comparison of the amount of crestal bone loss among the 6 implant types revealed that the greatest bone loss (2.25 mm) was observed around type F implants (Tables 1 and 2, Figs. 12A and 12B), which
the change occurs. An important aspect of this study is that all 6 implant types were experimental implants with no differences in shape and that the implants were randomized in a side-by-side comparison. CRESTAL bone changes that occurred correlated with each specific implant type irrespective of its position within the arch, left or right side, or the individual dog. The crestal bone loss that occurred around implant type C compared to type B was due only to the difference in the implants, the existence of an interface (microgap).

Many studies have demonstrated that bone tissue favors rough implant surfaces compared to relatively smooth titanium surfaces. The advantage of the rough surface reported in these studies has recently been summarized. Based on prior studies, it was expected that the first bone-to-implant contact would occur at the rough/smooth border on the type A as well as type B implants. However, for type A implants, a very small difference, statistically only marginally significant, existed between the r/s border and the fBIC. This may be due to the fact that type A implants had been placed with their r/s border even with the crest of the bone, meaning that the r/s border could just still be observed. The histometric results (at time of sacrifice) revealed that the crestal bone did not move coronally about two-tenths of a millimeter. These findings are further supported by the fact that the fBIC occurred exactly at the r/s border in type B implants. In addition, this small difference was about within the limits of the precision of the histometric method applied (intra/interexaminer evaluation).

Type B and type C implants were virtually identical in regards to both shape and location of the rough/smooth border. The main difference between these 2 implant types was the presence of an interface (microgap) which was located at the alveolar crest. Thus, the significant bone loss that occurred beyond the rough/smooth border around type C implants (while none was associated with type B implants beyond this border) was due to the presence of the interface (microgap). Both of these implants were placed in a non-submerged technique, indicating that the bone loss was related to the presence of the interface (microgap) and not due to a surgical technique (nonsubmerged versus submerged). This finding takes on clinical significance as investigators are reporting the use of 2-piece implant systems (typically submerged implants plus an abutment) placed in a non-submerged approach. These findings demonstrate that submerged implants placed with an abutment at the time of implant placement will also experience significant crestal bone resorption.

Type D implants were identical in all respects (shape, location of the r/s border, and location of the interface/microgap) to type C implants except that the type D implant was placed with a submerged surgical
Crestal Bone Around Non-Submerged and Submerged Implants

The largest amount of bone loss was associated with type F implants, which was significantly greater than that found around any of the other 5 implant types. This finding was expected, based on the premise that if bone loss was associated with an interface (microgap), then placement of that interface in a location apical to the alveolar crest would result in the greatest amount of bone loss. This finding further supports the fact that bone loss is associated with an interface (microgap) and has significant clinical implications, particularly in two indications. Some clinicians have advocated the placement of submerged (2-piece) implants well below (approximately 2 to 3 mm) the alveolar crest in the maxillary anterior sextant in order to have an esthetic implant-borne restoration.

The results of the present study demonstrate that significant crestal bone loss can occur around these types of restorations. Secondly, in the posterior sextants in the mouth, limited bone height may be available for implant placement due to the location of the mandibular canal/nerve and the maxillary sinus. Often times, in fact, bone grafting procedures are performed in these areas to increase the amount of bone available for implant placement. In these cases, placement of a 2-piece endosseous implant at or below the alveolar crest would result in a significant amount of crestal bone loss, and thus counteract the bone augmentation procedure and/or increase the crown-to-implant ratio in an area of the mouth where the greatest amount of occlusal force is found. Thus, in these clinical situations, based upon the 6 implant types used in this study, a one-piece implant designed with a rough/smooth border at the alveolar crest should be used to ensure the least amount of crestal bone loss.

In conclusion, this experimental study in the canine mandible compared 6 implant designs placed in 2 surgical approaches: submerged and non-submerged. Both 1-piece and 2-piece implants (with an interface/microgap) were included with variations in the location of the interface (microgap) and r/s border. The results demonstrate that significant amounts of crestal bone loss occur around 2-piece (typically submerged) implant designs depending on the location of the interface. Secondly, the location of a rough/smooth border on a 1-piece (typically non-submerged) implant has an influence on the first bone-to-implant contact. Lastly, the surgical technique of submerging or not submerging the implant has no influence on the amount of crestal bone loss that occurs. More significantly, the creation as well as the location of an interface (microgap) influences crestal bone loss and the first bone-to-implant contact.

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