Alveolar Buccal Bone Maintenance After Immediate Implantation with a Surgical Flap Approach: A Study in Dogs

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This study evaluated buccal bone maintenance after implantation with a surgical flap approach immediately following tooth extraction in a dog model. Mandibular premolars of six dogs were extracted, and threaded implants of 4-mm diameter and 8-mm length with as-machined and dual acid-etched surfaces were placed through balanced procedures in the distal root extraction sockets with a full-thickness flap design. Submerged healing was allowed for 4 weeks, and following euthanization, bone-to-implant contact and buccal and lingual bone loss were evaluated. None of the parameters evaluated were indicative of an effect of implant surface in hindering bone loss around immediately placed implants. (Int J Periodontics Restorative Dent 2011;31:e80–e86.)

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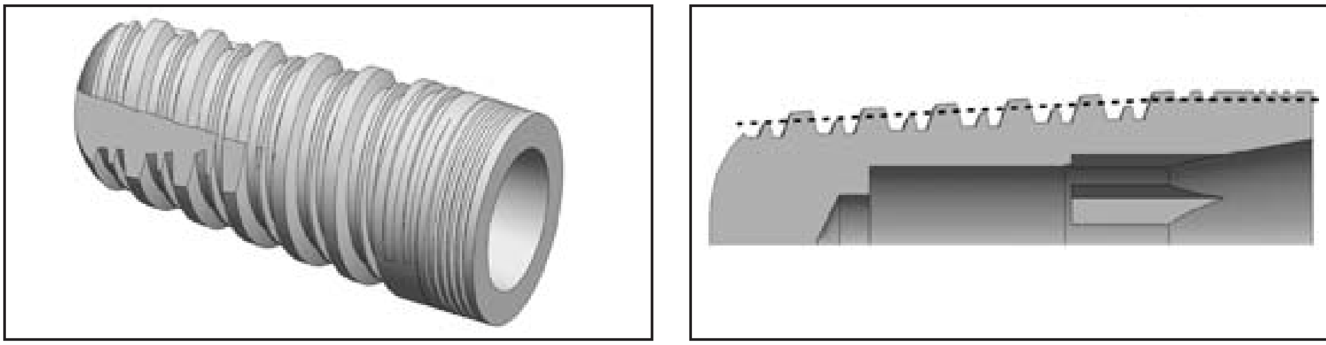
Implant dentistry has become one of the most successful dental treatment modalities, with success rates often exceeding 90% over several years.[1,2] However, despite the high success rates reported for classic implant placement and restorative protocols, where implants are placed and allowed to heal for several months prior to restoration,[3–5] implant design has dynamically changed over the past decades.[6] Design change rationales include attempts to decrease the healing period between implant placement and prosthetic restoration and to allow for an increased treatment outcome predictability in challenging scenarios.[6]

Numerous studies have shown that early osseointegration is positively affected by surface modifications.[6–8] From the early days of implant dentistry, surfaces have evolved from as-machined to moderately rough surface textures to moderately rough surfaces with slight chemistry alterations.[6–8] From an early healing standpoint, histomorphometric and biomechanical studies have shown higher



Figs 1a and 1b (left) *Computer-aided design representation of the implant macrogeometry showing microthreads in the crest module region and two thread patterns along its remaining length.* (right) *The dashed line depicts the outer diameter of the final bur with respect to the implant shape.*

osteoconductivity of textured surfaces over as-machined surfaces.[7,8] However, while surface modifications have shown promising results, controlled evaluation of their effects on clinically challenging scenarios, such as grafted regions and immediate placement following extraction, has received limited attention.

Since tooth extraction is followed by temporal progressive alveolar bone loss, potentially compromising the placement of implants of larger dimensions and thereby the implant–restoration system biomechanics, implant placement immediately following extraction has been attempted to maintain or reduce alveolar bone morphology alteration after extraction.[9–12] It is of general consensus that nontraumatic extraction followed by implant stabilization in the extraction socket (typically achieved over the last 5 mm of the apical region of the implant) should be carefully observed during treatment.[9–12] Such an approach would result in an environment where the extraction socket walls surround implants healing in a defect-like scenario.[9–12]

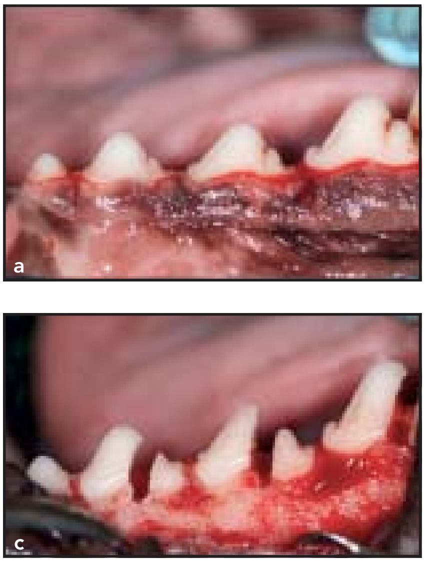
It has been demonstrated previously that from an anatomical perspective, extraction sockets present thinner buccal plates compared to lingual plates.[13–18] Conversely, studies have demonstrated pronounced buccal plate loss following implant placement immediately after extraction compared to lingual plate loss.[12,16] Considering different surgical techniques for immediate implant placement, a recent study showed that if a flapless approach was used rather than a flap approach (mucoperiosteal flap design), reduced buccal bone loss was observed.[12]

Although surgical and anatomical considerations have been investigated previously regarding the dynamics of bone remodeling for implant placement immediately after extraction,[12,16] a substantially smaller literature body concerning the effects of implant design (ie, macrogeometry or surface) on the topic is available. The objective of this study was to evaluate buccal bone maintenance of two surfaces after the placement of implants with a surgical flap approach immediately following tooth extraction in a dog model.

Method and materials

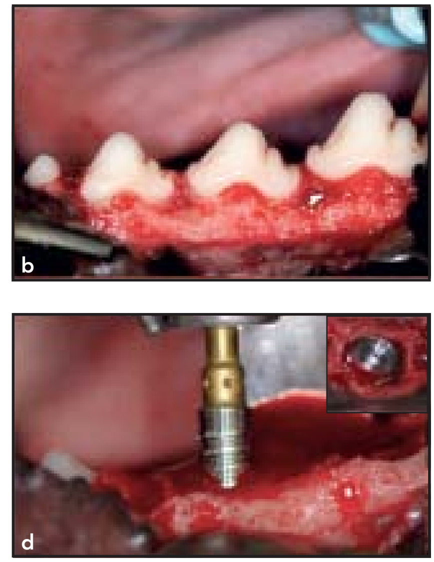
This study used screw root form grade 5 titanium alloy endosseous implants of 4-mm diameter and 10-mm length presenting microthreads in the cervical third and two distinct thread patterns through the remaining length (Unitite, SIN-Sistema de Implante) (Fig 1). The implant groups included as-machined (M) and dual acid-etched (DAA) surfaces (n = 6 for each surface).

Following approval of the Bioethics Committee for Animal Experimentation at the Universidade Federal de Santa Catarina, Brazil, six mongrel dogs in good health were acquired for the study and underwent a 2-week in-house period prior to surgery. All surgical procedures were performed under general anesthesia. The preanesthetic procedure comprised intramuscular administration of aceprozamine maleate (0.2 mg/kg), diazepam (0.5 mg/kg), and fentanyl



Figs 2a to 2c (a) *An initial sulcular incision was performed and a* (b) *full-thickness mucoperiosteal flap was created prior to* (c) *buccoligual sectioning separation of the tooth's mesial and distal roots. Extractions were performed by means of root elevators or forceps.*

Fig 2d *The implant was placed at the crestal bone level, allowing a minimum gap of approximately 1 mm between the implant and buccal plate.* (inset) *Healing cover screws were then adapted to the implant's internal connection prior to flap repositioning and sutures.*



(4 mg/kg). Anesthetic induction was then achieved using ketamine (3 mg/kg), and general anesthesia was then obtained and maintained using 1% to 2% halotane.

Bilateral extractions of one premolar (either the second, third, or fourth premolar) were performed (Fig 2a). The procedure involved a full-thickness mucoperiosteal flap (Fig 2b) and tooth sectioning in the buccolingual direction (Fig 2c) so that individual roots could be extracted by means of root elevators and forceps without damage to the bone wall. One implant surface was placed per side of the mandible (n = 6 per surface, one of each surface per animal). Thus, the two surfaces were evaluated in the same premolar distal socket, one on each side. Implant placement distribution compared the same number of surfaces per animal and per tooth distal socket symmetrically per mandible side (right or left).

For implant placement, a 2-mm-diameter pilot drill was used at 1,200 rpm under abundant saline irrigation for initial socket preparation. Then, sequential preparation with a 3.0-mm cylindric bur was performed at 800 rpm, followed by use of a final bur with dimensions according to the schematic representation shown in Fig 1b. Implants were then inserted in the osteotomy site at the socket bone level at 45 Ncm per the manufacturer's recommendation. A jump gap of approximately 1 mm was left between the implant and buccal plate (Fig 2d), and the drilling direction avoided invasion of the lingual plate during osteotomy or after implant placement. Healing cover screws were adapted to the implant's internal connection (no increase in total height was noted because of the healing caps) (Fig 2d), and the flap was repositioned and sutured with resorbable material (Ethicon). Postsurgical medication included intramuscular administration of antibiotics (kefazolin, 30 mg/kg every 12 hours for 3 days) and anti-inflammatory medication (ketoprofen, 0.2 mg/kg per day for 3 days). Euthanasia was performed by anesthesia (halotane) overdose.

At necropsy, the mandibles were retrieved by sharp dissection, the soft tissue was removed using surgical blades, and initial clinical evaluation was performed to determine implant stability. The implants in bone were then separated from the mandible, allowing for blocks with a minimum of 5 mm from the implant mesial and distal regions. The bone blocks were kept in 10% buffered formalin solution for

Fig 3 *Buccal* (B) *and lingual* (L) *bone loss were measured from the implant shoulder (most cervical region of the implant) using computer software (toluidine blue, original magnification ×10).*

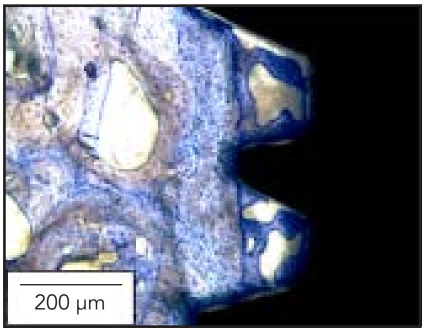
24 hours and gradually dehydrated in a series of alcohol solutions ranging from 70% to 100% ethanol. Following dehydration, samples were embedded in a methacrylate-based resin (Technovit 9100, Kulzer) according to the manufacturer's instructions. The sections were then reduced to a final thickness of approximately 30 µm by means of a series of silicone carbide abrasive papers (400-, 600-, 800-, 1,200-, and 2,400-grit) in a grinding/polishing machine (Metaserv 3000, Buehler) under water irrigation.[19] The sections were then stained using toluidine blue and referred for optical microscopy evaluation.

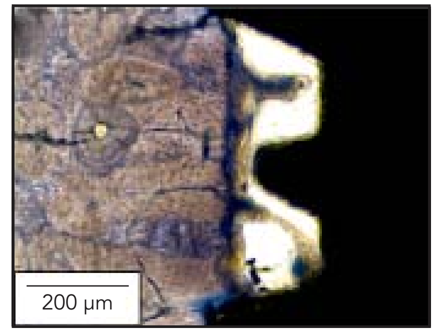
The bone-to-implant contact (BIC) was determined through the entire perimeter of the implant at 50× to 200× magnification by means of computer software. The regions of mineralized bone–to-implant contact along the implant perimeter were subtracted from the total implant perimeter, and calculations were performed to determine the BIC. Linear buccal and lingual bone distances from the implant shoulder (most cervical region, Fig 3) were acquired through computer software for each specimen. Buccal/lingual bone loss ratios were also calculated for each specimen. Following normality and variance checks, statistical analyses were performed using one-way analysis of variance considering BIC, buccal bone loss, lingual bone loss, and buccal/lingual bone loss ratio as dependent variables. The Tukey post hoc test was used for multiple comparisons. Statistical significance was indicated by *P* levels less than 5%.

Results

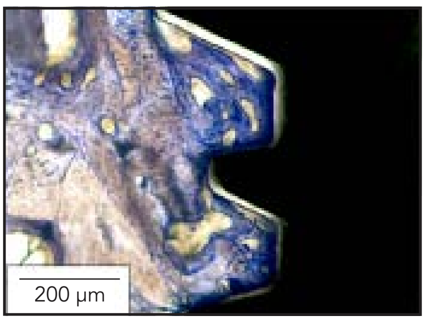
Surgical procedures and follow-up demonstrated no complications regarding procedural conditions, postoperative infection, or other clinical concerns. All implants were integrated with bone after the 4-week healing period.

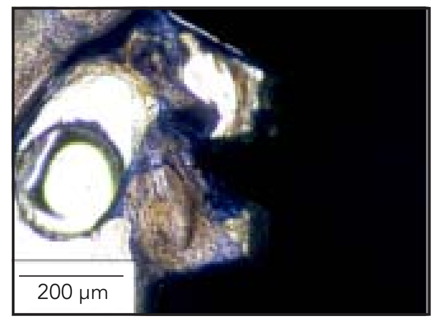
Qualitative evaluation of the toluidine blue–stained thin sections showed intimate contact between cortical (Fig 4) and trabecular (Fig 5) bone for both implant surfaces, including regions that were in close proximity or away from the osteotomy walls (Figs 3 to 5). The interplay between implant geometry and final drilling dimensions allowed intimate contact between the implant and bone at the microthread and outer portion of the large threads. In tandem, healing chambers between large and smaller implant





Figs 4a and 4b *Healing chambers between large and smaller implant threaded regions and the sharply defined osteotomy walls were formed at cortical regions.* (left) *DAA surfaces presented a more uniform spatial distribution of the healing chamber, whereas* (right) *bone filling within the M surface often presented new bone formation in proximity to the osteotomy wall and healing chamber central regions, with qualitatively less bone in close proximity with the implant surface compared to the DAA group (toluidine blue, original magnification ×100).*





Figs 5a and 5b *Healing chambers filled with woven bone were also observed at trabecular bone regions.* (left) *DAA group and* (right) *M group. The gap observed between the bone and implant surface in the DAA group specimen* (left) *is because of a sample processing artifact (toluidine blue, original magnification ×100).*

threaded regions and the sharply defined osteotomy walls were formed (Figs 4 and 5). All implants presented new bone formation through the classic appositional healing pathway at regions where intimate contact existed between implant surface and bone immediately after placement. These regions comprised the microthreaded region and the outer aspects of the outer threads. In contrast, the initial healing pattern observed at the healing chambers formed as a result of the combination of implant design and surgical drilling followed an intramembranous-type healing mode, with the chamber partially filled with newly formed woven bone (Figs 4 and 5).

No substantial morphologic differences were observed for the different implant surfaces. Specific to the healing chamber regions at cortical and trabecular bone regions, woven bone formation occurred primarily at the central region of the healing chamber for the M surface group, whereas woven bone formation occurred at both central regions and at regions in close proximity to the implant surface for the DAA group (Figs 4 and 5). No difference in BIC was observed between groups ($P > .13$), where M implants presented (mean ± 95% confidence interval) 41.36% ± 9.75% BIC and DAA implants presented 55.27% ± 9.72% BIC.

Considering buccal and lingual bone loss within groups, both M and DAA implants presented significantly higher buccal bone loss compared to lingual bone loss ($P < .02$ and $P < .04$, respectively) (Table 1). No differences in buccal bone loss, lingual bone loss, and buccal/lingual bone loss ratio were observed between groups ($P > .77$, $P > .99$, and $P > .71$, respectively) (Table 1).

Discussion

The "immediate implant" was regarded in a recent consensus report as an implant placed immediately after tooth extraction and as part of the same surgical procedure.[20] Such a treatment modality has been common practice in implant dentistry and, according to several clinical investigations, has presented high success rates.[20–23]

Previous studies in dogs,[12,13,16,17] in agreement with an evaluation in humans,[24] have shown that bone

Table 1 Mean (95% confidence interval) buccal bone loss, lingual bone loss, and buccal/lingual bone loss ratio for the dual acid-etched (DAA) and as-machined (M) surfaces

Group	Buccal bone loss (mm)	Lingual bone loss (mm)	Buccal/lingual bone loss ratio
DAA	2.13 (0.92)	0.66 (0.31)	1.47 (0.73)
M	2.37 (0.93)	0.66 (0.29)	1.71 (0.73)
*P**	> .77	> .99	> .71

*No significant values were observed between groups.

resorption was not prevented by immediate implant placement. Thus, it is apparent that bone loss could not be prevented solely by implant placement in fresh extraction sockets, and whether surgical techniques and implant design parameters would help in minimizing such bone loss is under active investigation. A preliminary report concerning the effect of surgical technique (flap versus flapless) has shown that bone loss was significantly decreased by the use of a flapless surgical protocol over a period of 12 weeks.[12] On the other hand, while substantial data have been published considering a range of implant macrogeometries and surfaces, controlled evaluations of the effect of implant design parameters on immediate implants are lacking in the literature.

The general histologic findings observed followed the natural healing pathway for implants placed in extraction sockets[16–18] and healed alveolar ridges[25–27] irrespective of implant surface. The implant macrogeometry and surgical instrumentation used allowed for different bone healing patterns that were dependent on how the implant interacted with the final osteotomy.[25–27] At regions where intimate contact between the bone and implant surface occurred immediately after implant placement, classic appositional bone healing occurred. At contact-free regions, where healing chambers resulted because of the combination of implant and osteotomy dimensions, woven bone was observed through an intramembranous-like healing.[25–27] The rationale for implant geometries allowing both initial contact between the implant and bone along with healing chambers is to provide initial stability in tandem with woven bone formation in the healing chambers. From a theoretical standpoint, biomechanical stability would be improved through rapid woven bone formation in the healing chambers during bone dieback[25–27] as a result of surgical trauma and compression that takes place at regions where the classic appositional healing pathway occurs. Controlled biomechanical investigations are desirable between implant designs to validate such a theory.

The similar bone morphology observed for both surfaces supports that both were biocompatible and osteoconductive and is in agreement with previous investigations.[25–27] The noticeable difference in bone spatial distribution within healing chambers, where more uniform distribution within the chamber and close proximity between the chamber and implant surface was observed only for the DAA surface, suggests that surface roughness provided a more favorable scenario for blood clot establishment and stabilization, which is key for intramembranous-like healing.[25–27]

The surgical technique employed in the present study allowed a gap of approximately 1 mm between the implant and buccal alveolar wall, and comparisons between surfaces were made in the same region per subject. No residual defect was observed in any of the specimens, and all gaps were closed after 4 weeks of healing, as reported previously for self-containing defects around immediate implants.[11,12,16–18,20,21,24,27] When linear measurements of buccal and lingual bone loss were considered, no significant differences were observed between surfaces. The lingual bone loss was almost identical between surfaces, and the mean buccal bone loss difference was approximately 0.2 mm, suggesting that the well-characterized higher osteoconductivity of rough implant surfaces compared to as-machined surfaces[6–8] was not effective in minimizing bone loss after immediate implantation. In agreement with previous reports,[13–18] both groups presented significantly higher buccal bone loss compared to lingual bone loss, and such differences may be accounted to the difference in cortical thickness between buccal and lingual plates.

Conclusion

None of the parameters evaluated were indicative of an implant surface effect in hindering immediate implant bone loss for the implant macrogeometry investigated.

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