Crestal Bone Loss Minimized When Following the Crestal Preparation Protocol: A Histomorphometric Study in Dogs

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Initial breakdown of the implant-tissue interface generally begins at the crestal region in successfully osseointegrated implants. The purpose of this study was to evaluate the effect on crestal bone loss (CBL) around implants specially developed for immediate loading with a unique crestal drill. After 8 weeks postextraction, 6 young male mongrel dogs received 48 implants (XiVE) in the region corresponding to the 4 mandibular premolars. The implant sites were prepared according to the manufacturer’s protocol with conventional standard drills. Before implant placement, the crestal drill was used in the experimental group but not in the control group. After a healing period of 12 weeks, the dogs were sedated and euthanized. Through linear measurements, from the top of the implant to the first bone-implant contact, the amount of CBL was determined. The histomorphometric results of CBL (mean ± SEM) were 0.88 ± 0.13 mm (range 0.0–3.0 mm) in the experimental group and 1.69 ± 0.17 mm (range 0.0–4.2 mm) in the control group. The difference was statistically significant (P < .05) when the implants were used as the experimental units. The statistical analysis also revealed significance when the dogs were used as the experimental units (P < .05). When the median was used for analyses, the CBL was 0.44 mm for the experimental group and 1.91 mm for the control group. Crestal bone loss was minimized when the crestal preparation protocol was carefully followed by using the osseocondensating XiVE implant system.

Key Words
Bone remodeling
Crestal bone loss
Dental implants
INTRODUCTION

The success of dental implants is highly dependent on integration between the implant components and the hard and soft tissues. Initial breakdown of the implant-tissue interface generally begins at the crestal region in successfully osseointegrated dental implants.1-3

Possible etiological factors of early implant bone loss (from implant placement to 1-year post-loading) include surgical trauma, formation of biologic width, implant crestal module, and other factors.4 However, surgical trauma has been regarded as one of the most commonly suspected etiologies for early crestal bone loss (CBL).5 Implants that fail because of surgical trauma are often surrounded by a fibrous connective tissue or have an apical extension of the junctional epithelium.6 Heat generated at the time of drilling, elevation of periosteal flap, and excessive pressure at the crestal region during implant placement may contribute to implant bone loss during the healing period.

Eriksson and Albrektsson7 reported that the critical temperature for implant site preparation is 47°C for 1 minute or 40°C for 7 minutes. When the bone is overheated, the risk for implant failure is significantly increased. Periosteal elevation has also been speculated as one of the possible contributing factors for CBL. Wilderman and coworkers8 reported that mean horizontal bone loss after osseous surgery around teeth with periosteal elevation is approximately 0.8 mm and that the reparative potential is highly dependent on the amount of cancellous bone existing underneath the cortical bone.

Implant surgical techniques must be precise and atraumatic. This ensures congruent implant site preparation, which provides firm seating of the implant9 and avoids injury to the bone by excessive heat build-up.10 Structure and vascularization play an important role in the reaction of bone to the effect of surgical trauma. Well supplied with blood vessels, spongy bone dissipates the stress faster and has a greater capacity for repair than compact bone, which has a limited blood supply by comparison.11

A new implant system has been developed that focuses on implant site preparation in areas with different bone qualities. The macroscopic design of the implant and threads promotes considerable bone condensation during its placement. Specific site preparation is performed to the different bone densities to ensure a gentle and atraumatic implant insertion. A unique crestal drill, 0.2 mm wider than the final implant insertion drill, 0.2 mm wider than the final drill in sequence, is used to control the level of bony condensation during implant placement. The drill matches the shape of the implant and the collar flare. The use of the crestal drill influences the degree of internal bony condensation achieved by the implant during insertion. According to the manufacturer, depending on the bone quality, a varying insertion depth between 2 mm (for bone type IV) and 6 mm (for bone type I or II) is recommended for the crestal drill. The surgeon assesses bone density during initial site preparation with the pilot drill.12,13 If there is little or no resistance to the drill, bone density can be assumed to be low (bone type IV). This is taken into consideration during the use of the crestal drill. In sites with low bone quality, the preparation depth would be 2 mm. High resistance in the bone corresponds to bone type I, II, or III. In sites with dense bone, preparation is made to a depth of up to 6 mm.

The success of this immediate-loading implant system is highly dependent on the use of this crestal drill preparation. However, little is known regarding its effect on crestal resorption during healing. Therefore, the purpose of this study was to evaluate early CBL around XiVE implants when the crestal preparation protocol was followed.

MATERIALS AND METHODS

The Animal Research Committee of the School of Dentistry of Ribeirão Preto, University of São Paulo, approved the experimental protocol. Six young male mongrel dogs, weighing approximately 15 kg each, were used in this study. The dogs had intact maxillae, had no mucosal lesions, and were in good systemic health as determined by a veterinarian after clinical examination.

The night before the surgery, the dogs received a combination of 20 000 IU penicillin and 1.0 g streptomycin per 10 kg body weight. Because each dose provides antibiotic coverage for 4 days, another dose was injected 4 days later, totaling 8 days of antibiotic coverage.14,15 In the first stage of the study, the dogs were sedated and anesthetized with 1 mL/kg thiopental (20 mg/kg thiopental diluted in 50 mL saline). After local anesthesia, full-thickness flaps were elevated bilaterally in the area of the first to fourth mandibular premolars. The teeth were sectioned in a bucco-lingual direction at the bifurcation so that the roots could be individually extracted without damaging the alveolus. After
repositioning of the periodontal flaps, the wound was closed with resorbable sutures. The dogs were maintained on a soft diet for 14 days. Healing was evaluated periodically, and the teeth were cleaned monthly with ultrasonic scalers. To try to achieve a bone with intermediate quality, a healing period of 8 weeks was allowed before the next surgical intervention. The dogs were anesthetized in the same manner as described before. The night before the second surgery, the dogs received another dose of antibiotics in the same manner as described before. Full-thickness flaps were elevated bilaterally in the area corresponding to the first to fourth mandibular premolars (Figure 1). Four blasted and acid-etched surface, self-tapping threaded implants (XiVE, Dentsply Friadent, Mannheim, Germany), 4.5 mm in diameter and 9.5 mm in length, were placed bilaterally in each dog. The crestal drill was used in the experimental group but not in the control group. The experimental and control sites were randomly selected by a coin toss. The implant sites were sequentially enlarged to 4.5 mm in diameter with the pilot and spiral drills according to the manufacturer’s standard protocol. After completion of the implant site preparation, crestal preparation of the bone in a vertical direction was performed in the experimental sites only. The crestal drill (Figure 2) with a cutting depth of 6 mm was used for this purpose. In this study, crestal preparation of 6 mm was chosen for producing a more representative field for histomorphometric analysis. The implants were placed at the bone crest according to the manufacturer’s instruction (Figure 3). The dogs were maintained on a soft diet for 14 days. Healing was evaluated periodically and the teeth were cleaned monthly with ultrasonic points. The dogs were sedated and then euthanized with an overdose of thiopental 12 weeks after implant placement. Hemimandibles were harvested, dissected, and fixed in 4% phosphate-buffered formalin pH 7 for 10 days and transferred to a solution of 70% ethanol until processing. The specimens were dehydrated in increasing concentrations of alcohol up to 100%, infiltrated, embedded in methylmethacrylate resin, and then hard
sectioned by the technique described by Donath and Breuner. The sections were prepared for histomorphometry and stained with Stevenell’s blue and Alizarin red S for optic microscopic analysis.

**Histomorphometric analysis**

Two 20- to 30-μm longitudinal histological sections from each implant were captured with a video camera Leica DC 300F (Leica Microsystems GmbH, Nussloch, Germany) joined to a stereomicroscope Leica MZFL III (Leica Microsystems GmbH). The images were analyzed through the Image J program (National Institutes of Health, Bethesda, Md), where CBL around the implants was determined. Through linear measurements, from the top of the implant to the first bone-implant contact, the amount of bone loss was determined (Figure 4). A blinded single examiner, with no knowledge if the sections were from experimental or control groups, made the measurements.

**Statistical analysis**

Mean values and SEM were calculated. The data were grouped by using the implants and dogs as units for analysis. The mean differences of CBL between the groups were verified through the Mann-Whitney nonparametric test when the implants were used as the experimental units and through the Kruskal-Wallis test when the dogs were used as the experimental units, with a significance level of *P* ≤ .05. All calculations were performed by SPSS for Windows (SSP Inc, Chicago, Ill).

**RESULTS**

**Clinical findings**

Postextraction healing was uneventful in all dogs. At implant surgery 8 weeks later, the extraction sites appeared to have healed clinically. The alveolar ridge showed evidence of remodeling (Figure 1). During site preparation, resistance to the pilot drill
resembled type II or III bone qualities. Healing was also un-
eventful after implant placement, without complications through-
out the experimental period.

**Histologic observations**

The bone-implant interface had mineralized bone matrix in in-
timate contact with the implant surfaces in both the experimental
and the control groups. Crestal bone loss was more pronounced
in the control group (Figure 5) than in the experimental group
(Figure 6).

**Histomorphometric findings**

The histomorphometric mea-
surements CBL (mean ± SEM)
around the implants are shown
in Table 1. The data revealed that
the CBL was 0.88 ± 0.13 mm
(range 0–3.0 mm) in the exper-
imental group and 1.69 ± 0.17 mm
(range 0–4.2 mm) in the control
group. The differences were sta-
tistically significant (P < .05)
when implants were used as the
experimental units. The statistical
analysis also revealed statistical
significance when the dogs were
used as experimental units
(P < .05), as seen in Table 2. Figure 7
presents the implant-frequency
distribution in relation to the
CBL for the experimental and
control groups. The experi-
mental group showed 5 implants
without bone loss (0 mm), 5 implants with CBL of
1 mm, 9 implants with CBL of
3 mm, and 3 implants with CBL
of more than 3 mm. When the median was used for analyses,
eliminating the best and worst
results, the CBL was 0.44 mm for
the experimental group and 1.91
mm for the control group.

**DISCUSSION**

The current longevity of dental
implants is strongly dependent
on the interaction between im-
plant components and oral tissues
as a result of contemporary im-
provements in implant materials,
geometry and surfacing, and the
perfection of surgical techniques.
Early CBL is often observed after
the first year of function, followed
by minimal bone loss annually
thereafter. There is a lack of agree-
ment as to why greater bone
loss occurs during initial healing
and the first year of implant
function compared with the fol-
lowing years. Several possible
etiologies of early implant bone
loss (from placement to 1-year
postloading) are suggested. Sur-
gical trauma has been proposed
as one of the most commonly sus-
pected etiologies for early implant
failure. Implants that fail
because of surgical trauma are

| **TABLE 1**
| Crestal bone loss |
|-------------------|----------------|
| Crestal Bone Loss (mm) |     |
| Implant No. | Experimental Group | Control Group |
| 1 | 1.45 | 2.14 |
| 2 | 2.54 | 2.91 |
| 3 | 3.08 | 3.08 |
| 4 | 1.25 | 1.68 |
| 5 | 0.61 | 2.87 |
| 6 | 0.37 | 2.29 |
| 7 | 0.25 | 2.39 |
| 8 | 2.03 | 4.23 |
| 9 | 0.0 | 0.0 |
| 10 | 0.0 | 0.22 |
| 11 | 1.24 | 1.06 |
| 12 | 2.41 | 2.46 |
| 13 | 1.01 | 3.64 |
| 14 | 1.20 | 2.22 |
| 15 | 1.94 | 2.32 |
| 16 | 0.26 | 0.33 |
| 17 | 0.23 | 1.33 |
| 18 | 0.17 | 1.52 |
| 19 | 0.52 | 2.31 |
| 20 | 0.0 | 0.0 |
| 21 | 0.35 | 0.95 |
| 22 | 0.0 | 0.0 |
| 23 | 0.0 | 0.32 |
| 24 | 0.27 | 0.51 |

| Mean ± SEM* | 0.88 ± 0.13 | 1.69 ± 0.17 |
| SD | 0.92 | 1.22 |
| Median | 0.44 | 1.91 |

*SEM equals the SD divided by the
square root of the number of implants.

**TABLE 2**

| **Crestal bone loss with dogs as experimental units** |
|-------------------|----------------|
| Crestal Bone Loss (mm) |     |
| Dog No. | Experimental Group | Control Group |
| 1 | 2.08 | 2.45 |
| 2 | 0.81 | 2.95 |
| 3 | 0.91 | 0.93 |
| 4 | 1.10 | 2.12 |
| 5 | 0.23 | 1.29 |
| 6 | 0.15 | 0.44 |
| Mean ± SEM | 0.88 ± 0.28 | 1.69 ± 0.39 |
| SD | 0.69 | 0.96 |
often surrounded by a fibrous connective tissue capsule or have an apical extension of the junctional epithelium. Heat generated at the time of osteotomy preparation, elevation of a periosteal flap and excessive pressure at the crestal region during implant placement may contribute to implant bone resorption during the healing period. Preparation of the bone and subsequent implant placement damages blood vessels that provide nutrition to the surrounding bone, which in turn may compromise the adjacent bone. Another explanation for early bone loss may be related to stresses that are placed on the bone immediately surrounding the implant. These stresses may cause microfractures in the bone and stimulate bone turnover, which, without contiguous blood supply as a result of the implant body, may result in resorption.

The marginal bone loss that has been reported in vivo may also be caused by high stress concentrations in the crestal region. When bone is overheated, the risk of implant failure is significantly increased. Overheating may be generated by excessive pressure at the crestal region during implant surgery. Wiskott and Belser also attributed CBL to increased pressure on the osseous bed during implant placement, establishment of a physiologic “biologic width,” stress shielding, and lack of adequate biomechanical coupling between the load-bearing implant surface and the surrounding bone.

Implant countersinking below the alveolar crest was recommended in the Branemark surgical protocol to minimize the risk of implant exposure during healing and to accommodate the platform to enhance the emergence profile for implant prostheses at the expense of crestal bone. To reduce the stress on crestal bone during implant placement, a new approach with a self-tapping implant and a crestal preparation protocol was developed.

Analysis between the experimental and control groups showed statistically significant differences in CBL in favor of the experimental group (0.88 mm for experimental group and 1.69 mm for control group) measured from the top of the implant to the first bone-implant contact. Additional observations revealed that 14 of the 24 implants in the experimental group had CBL between 0 and 1 mm and only 3 implants had CBL of 3 mm, whereas 8 implants in the control group had CBL between 0 and 1 mm and 12 implants had CBL between 3 and 4 mm. The better distribution achieved in the experimental group reveals advantages in favor of the crestal preparation protocol. When median values were used, the CBL was 0.44 mm for the experimental group and 1.91 mm for the control group, thus increasing the difference in favor of the experimental group. The crestal preparation protocol led to less traumatic implant placement reducing the CBL, which is a common finding in dogs.

The macrodesign of the XiVE implant with the core and thread pattern is intended to achieve high primary stability during placement. Very high torque may occur particularly in the mandible because of the high proportion of cortical bone. Compression may compromise the in vivo periosteal blood supply, lead to necrosis, and increase the risk of bone resorption. The crestal drill controls the degree of internal compression; therefore, the correct use of the crestal drill must be observed to avoid excessive CBL. The depth of crestal preparation should vary depending on the bone quality. A varied insertion depth of 2 mm in bone type IV, 3 mm in bone type III, and 6 mm in bone types I and II is recommended. The internal condensation effect induced by the thread design is particularly desirable in spongy bone. In contrast, internal condensation is not required to increase the primary stability in more cortical bone.

**Conclusion**

Crestal bone loss was minimized when the crestal preparation protocol was carefully followed in conjunction with the placement of the osseocondensing XiVE implant system.

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CRESTAL BONE LOSS MINIMIZED FOLLOWING CRESTAL PREP PROTOCOL