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Crestal bone loss related to immediate implants in crestal and subcrestal position: a pilot study in dogs

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Abstract

Objectives: The aim of the present study was to compare crestal bone loss with different implant designs inserted immediately in crestal or subcrestal position in post-extraction sockets in a dog model.

Materials and Methods: The mandibular second, third, fourth premolars, and the first molars of six adult fox hound dogs were extracted bilaterally, and 48 implants were placed immediately in both hemi-arches of each dog. Randomly, eight implants (sky classic[®] and blue sky[®]) were inserted, four crestally (control group) and four 2 mm subcrestally (test group). Both groups were treated with a minimal mucoperiosteal flap elevation approach. After a 12-week healing period, the animals were sacrificed, and samples were obtained. Biopsies were processed for ground sectioning. Histomorphometric analysis was carried out to compare buccal and lingual bone height loss.

Results: All implants were clinically and histologically osseointegrated. Healing patterns examined microscopically at eight and 12 weeks for both groups (crestal and subcrestal) yielded similar qualitative bone findings. At 12 weeks, the distance from the top of the implant collar to the first BIC (ISBc) showed significant difference between implant positions (crestal or subcrestal) in the buccal aspect ($P = 0.1253$), values for the crestal group being higher (1.79 ± 0.3 mm) in comparison with the subcrestal group (0.89 ± 0.5 mm). Better results were achieved by both implant designs when implants were placed in the deeper position. No significant differences were found in BIC values ($P > 0.05$). The total BIC at 8 weeks was ($46.22 \pm 4.29\%$) for the crestal group and ($49.72 \pm 2.21\%$) for the subcrestal group; at 12 weeks, it was ($41.54 \pm 3.87\%$) for the crestal group and ($56.87 \pm 3.46\%$) for the subcrestal group.

Conclusions: Within the limitations of this study, the findings suggest that apical positioning of the top of the implant does not jeopardize bone crest and peri-implant tissue remodeling. However, less resorption of the lingual and buccal crest may be expected when implants are placed 2 mm subcrestally, but this is not related to implant design. Moreover, implants placed subcrestally produced better bone-to-implant contact measurements.

The technique of placing titanium oral implants in healing edentulous sites for prosthetic restoration has been the object of much research over the years, and one of its main aims has been to minimize treatment time. Bone loss around dental implants (peri-implant defects) in post-extraction or healed sites occurs during the first year following insertion (Lang et al. 2011). Bone loss and soft tissue modifications occurring after extraction can compromise the choice of implant type/design as well as the esthetic and functional outcomes (Tran et al. 2010). However, immediate implants placed in a

non-traumatic extraction socket preserve soft tissue and the dimensions of the alveolar ridge (Novaes et al. 2005; Botticelli et al. 2006). Crestal bone preservation increases the probability of papillae formation and is important for esthetic outcomes (Degidi et al. 2008).

The etiological factors for crestal bone loss remain unclear, but some studies have reported that one of the most important causes is surgical trauma (Esposito et al. 1998) and most research agrees that bone loss is influenced by the implant-abutment microgap and its potential for bacterial

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colonization of the peri-implant sulcus (Brogini et al. 2003). Furthermore, most research affirms that the establishment of biologic width and the design of the implant itself exert an influence on bone loss (Adell et al. 1981; Degidi et al. 2011; Fickl et al. 2010). Indeed, it has been shown that implant abutment design is critical for determining the amount of bone loss that will occur at the crestal bone level (Rodríguez-Ciurana et al. 2009; Calvo-Guirado et al. 2010). Experiments in dogs and humans have demonstrated that marked reduction in the height of the alveolar ridge occurs following tooth extraction as a consequence of this event (Schropp et al. 2003; Araujo & Lindhe 2005) and that implants placed in fresh extractions sockets have no effect on the bone-remodeling process (Araujo et al. 2005; Barros et al. 2009a,b). Normally, implants are placed subcrestally in esthetic areas, where primary stability cannot be attained by placement at the crestal bone level or whenever interocclusal height for the restoration and emergence profile is limited (Hammerle et al. 1996; Buser et al. 2007). There may also be a benefit in placing the implants subcrestally to compensate for crestal bone remodeling and to improve bone-to-implant contact in the implant neck region (Hammerle et al. 1996; Welander et al. 2009). Several studies have stated that the use of immediate implants is a predictable surgical approach (Novaes et al. 2012; Koh et al. 2011), and some have reported minimal loss bone around dental implants placed in subcrestal positions (Calvo-Guirado et al. 2010, 2013; Huang et al. 2012; Donovan et al. 2010).

The aim of the present study was to compare bone loss around implants positioned crestally vs. subcrestally in immediate extraction sockets in a dog model, using implants with different designs.

Materials and methods

Six American fox hound dogs of approximately 1 year of age, each weighing approximately 14–18 kg, were used in the experiment. The Ethics Committee for Animal Research at the University of Murcia, Spain, approved the study protocol, which followed guidelines established by the European Union Council Directive of November 24th, 1986 (86/609/EEC). Animals were quarantined for the application of anti-rabies vaccine and vitamins. The dogs were kept in kennel cages pre- and post-operatively, received appropriate veterinary care, and were

provided with free access to water and standard laboratory nutritional support throughout the trial period. All animals presented intact maxillae, without any general occlusal trauma or oral viral or fungal lesions. Clinical examination determined that the dogs were in good general health.

Surgical procedure

The animals were preanaesthetized with acepromazine (0.12%–0.25 mg/kg), buprenorphine (0.01 mg/kg), and medetomidine (35 µg/kg). The mixture was injected intramuscularly in the femoral quadriceps. Animals were then taken to the operating theater where, at the earliest opportunity, an intravenous catheter was inserted (diameter 22 or 20 gauge) into the cephalic vein, and propofol was infused at the rate of 0.4 mg/kg/min at a slow constant infusion rate. Conventional dental infiltration anesthesia (articaine 40 mg, 1% epinephrine) was administered at the surgical sites. These procedures were carried out under the supervision of a veterinary surgeon. Mandibular premolar and molar extractions (P, P, P, M1) were performed bilaterally. The teeth were sectioned in bucco-lingual direction at the bifurcation using a tungsten-carbide bur so that the roots could be extracted individually without damaging the remaining bony walls. The crestal incisions were performed bilaterally in the premolar–molar region of the mandible. Full-thickness mucoperiosteal flaps were elevated, and recipient sites in the molar regions on both sides of the mandible were prepared for the present experiment, while the other regions were used for different experimental purposes, the results of which are reported elsewhere. Prior to implant placement, the bony crest was flattened with a burr to obtain the same bone level at all aspects. Bucco-lingual (3.9 ± 0.37) and mesio-distal (4.3 ± 0.45) dimensions of the entrance to the fresh extraction sockets were measured using sliding calipers, and mean alveolar ridge measurements were determined. The extraction sockets' mean alveolar ridge measurements were as follows: 3.8 ± 0.21 (P2), 4.0 ± 0.5 mm (P3), 4.1 ± 1 mm (P4), 5.6 ± 0.07 mm (M1).

Tapered Blue Sky and Sky Classic implants (Bredent Medical, Senden, Germany) 10 mm long and 4 mm in diameter in the coronal aspect were inserted. Randomly, four tapered implants were placed on each side of the mandible, either with the margin of the rough surface flush with the buccal bony crest (control group) or 2 mm subcrestally

(test group), inserting them in the center of the mandibular molar and premolar sockets; then, healing screws were adjusted to allow a non-submerged healing protocol. No grafting materials were used in the gaps remaining between bony plates and implants. The flaps were closed to allow non-submerged healing using single non-resorbable sutures (Fig. 1).

Following surgery, the animals received antibiotics (Enrofloxacin 5 mg/kg twice daily) and analgesics (Meloxicam 0.2 mg/kg, three times a day) via the systemic route. The sutures were removed after 2 weeks. The dogs were fed a soft diet for 7 days following the surgical procedure. Healing was evaluated weekly, and plaque control was maintained by the application of a chlorhexidine spray. The animals were kept in kennels and in concrete runs at the university's field laboratory; they were provided with free access to water and fed with moistened balanced dog chow. The wounds were inspected daily for clinical signs of complications, and the healing screws were cleaned. The animals were euthanized 12 weeks after surgery administering an overdose of Pentothal Natrium (Abbot Laboratories, Madrid, Spain) and then perfused with a fixative (formaldehyde) through the carotid arteries.

Radiographic evaluation

Conventional dental radiographs were taken at the time of implant placement and after a 12-week healing period to assess the changes to post-surgical crestal bone levels. The images were digitalized and parallelized, and the distance between the fixture shoulder and the apical level of marginal bone in contact with the implant was measured. The measurements were made on both the mesial and distal aspects, and the mean value for each implant was calculated (Fig. 2).

Histological sample preparation

Specimens were washed in saline solution and immediately fixed in 10% buffered formalin. They were then processed to obtain thin ground sections using the Precise 1 Automated System (Assing, Rome, Italy) following Piattelli et al. (1997) recommendations. The specimens were dehydrated in an ascending series of alcohol rinses and embedded in glycol methacrylate resin (Technovit 7200 VLC, Kulzer, Wehrheim, Germany). After polymerization, the specimens were sectioned along their longitudinal axis using a high-precision diamond disk to about 150 µm thickness and then ground down to about 30 µm using a specially designed grinding

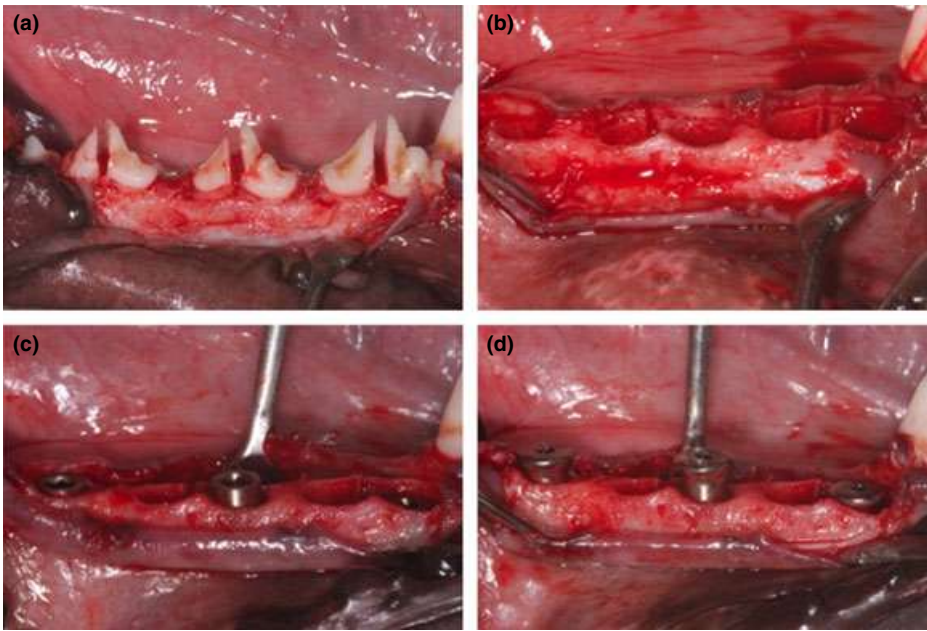


Fig. 1. (a) A crestal incision performed bilaterally in the premolar region of the mandible with teeth odonto sections; (b) Alveolar ridge post-extraction sockets; (c) Crestal and subcrestal blue sky and sky classic implants immediately placed; (d) 3-mm healing abutments placed on immediate submerged and non-submerged implants.

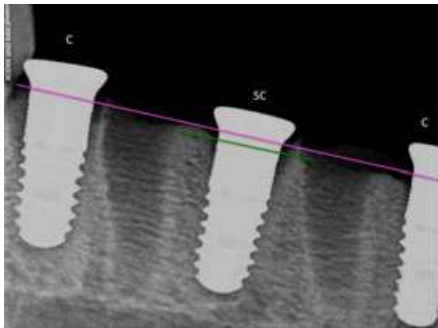


Fig. 2. Digital radiographs of crestal (C) and subcrestal (SC) placement after implant insertion. The pink line marks the implant shoulders of implants placed crestally, and the green line marks the implant shoulder of an implant placed subcrestally.

machine. A total of two slides per implant were obtained, which were stained with acid fuchsin and toluidine blue. The slides were observed in normal transmitted light under a Leitz Laborlux microscope (Leitz, Wetzlar, Germany) and under polarized light microscopy (Leitz).

Histomorphometric evaluation

Buccal bone wall resorption in relation to the lingual bone wall was expressed as a linear measurement (relative measurement). The buccal and lingual bone plates were also measured from the implant shoulder (top of the smooth collar) to the first point of bone-to-implant contact and to the top of the bone crest (absolute measurements). Two millime-

ters were subtracted from the measurements for the subcrestal group samples. A bone-to-implant contact percentage of native as well as newly formed bone was also measured throughout each implant perimeter in the coronal osseointegration area on both the buccal and lingual aspects, excluding the apical portion of the implant from measurement. The total amount of bone in contact with the implant was calculated as the sum of native bone and newly formed bone (BIC %). Histomorphometry of the percentages of bone-to-implant contact was carried out using a light microscope (Laborlux S, Leitz) connected to a high-resolution video camera (3CCD, JVC KY-F55B, JVC, Yokohama, Japan) interfaced to a monitor and PC (Intel Pentium III 1200 MMX, Intel, Santa Clara, CA, USA). This optical system was associated with a digitalizing pad (Matrix Vision GmbH, Oppenweiler, Germany) and a histometry software package with image capture capabilities (Image-Pro Plus 4.5, Media Cybernetics Inc., Immagini & Computer Snc Milan, Italy). Landmark points were identified, and linear measurements between points were made ($\times 10$ magnification) as follows: implant shoulder (IS), the most coronal bone crest (A), the most apical bone crest (B), difference between the lingual and buccal bone crest (B-L), distance from the top of the implant collar to the first BIC in the buccal aspect (IS-Bc), and distance from the top of the implant collar to the first BIC on the lin-

gual aspect (IS-Lc). Calculations were based on the measurements of the distances B-L, A-Bc, A-L, and A-Lc (Fig. 3).

A final analysis was performed by batch processing of the prepared images. Two types of bone in direct contact with the implant surface were differentiated: newly formed bone and native bone. The total amount of bone in contact with the implant was calculated as the sum of native bone and newly formed bone.

The following measurements were made as follows:

- D1: difference between buccal bone crest and lingual bone crest (B-L).
- D2: distance from the top of the implant collar to the buccal bone crest (IS-B).
- D3: distance from the top of the implant collar to the first BIC in the buccal aspect (IS-Bc).
- D4: distance from the top of the implant collar to the lingual bone crest (IS-L).
- D5: distance from the top of the implant collar to the first BIC in the lingual aspect (IS-Lc).

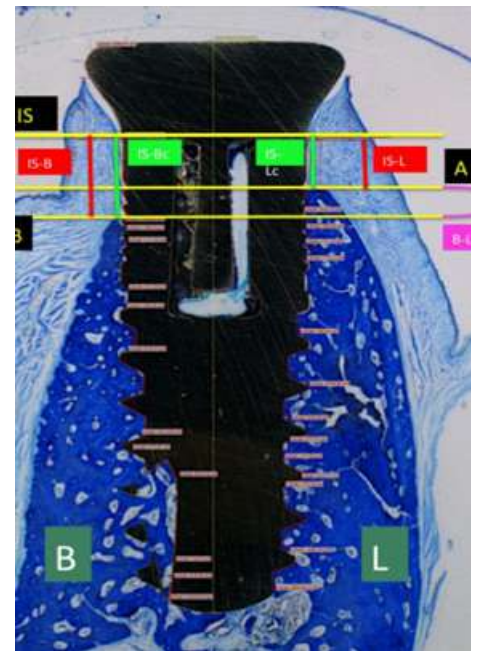


Fig. 3. Schematic slide describing the different points from which histomorphometric measurements were taken: the implant shoulder (IS); the most coronal bone crest (A); the most apical bone crest (B); distance from the top of the implant collar to the buccal bone crest (IS-B); distance from the top of the implant collar to the lingual bone crest (IS-L); difference between the buccal and lingual bone crest (B-L); distance from the top of the implant collar to the first BIC in the buccal aspect (IS-Bc); distance from the top of the implant collar to the first BIC in the lingual aspect (IS-Lc). Analysis was based on the measurement of B-L, IS-B, IS-L, IS-Bc, and IS-Lc. ($\times 10$ magnification).

Statistical analysis

Means and standard deviations were calculated for each outcome variable and differences by means of a descriptive test between mean values, which were evaluated with repeated measures for two factors: site and time. Values were recorded as mean $\pm$ standard deviation. The Wilcoxon test was applied to the comparison of mean averages and to quantify relationships between differences ($P < 0.05$). Equal means were regarded as the null hypothesis, while the existence of significant differences between means acted as an alternative hypothesis.

The medians of differences between groups were analyzed using the Brunner–Langer test (nonparametric repeated measures analysis of variance) for both groups ($n = 24$ control group, $n = 24$ test group) considering data from a single dog to be dependent. To determine the resorption of the alveolar crest during bone remodeling, the location of the implant shoulder in relation to the bone crest was considered. Consequently, the measurements of the distances from the implant shoulder (IS) to the alveolar bone crest (BC) can be expressed in absolute or relative terms.

All histomorphometric parameters were analyzed using descriptive methods (SPSS 19.0 for Windows; SPSS Inc., IBM Corporation, Chicago, IL, USA). For all the tests performed, the confidence level chosen was 5%.

Results

Buccal bone walls were thinner than lingual walls. Bundle bone was present only in the marginal portion of the buccal and lingual walls. When the buccal, lingual, mesial, and distal dimensions of the entrances to the fresh extraction sockets were measured prior to implant placement, mean alveolar ridge measurements were 3.8 ± 0.21 (P2), 4.0 ± 0.5 mm (P3), 4.1 ± 1 mm (P4), and 5.6 ± 0.07 mm (M1).

Clinical and histological observation

The surgical sites healed uneventfully, and all implants were available for histological analysis. In both groups (crestal and subcrestal), marginal gaps between buccal walls and implants had disappeared with the migration of connective tissue as a result of bone fill and resorption of the bone crest. After 8- and 12-week post-operative periods, all implants had osseointegrated and so were available for histological and histomorphometric analysis. Modeling in the marginal defect region was accompanied by marked decreases in the dimensions of both the delicate buccal walls

and the more substantial lingual bone walls. Direct contact was observed between living bone and all implants. The bone-to-implant contact established during the early phase of socket healing following implant placement was partly lost as the buccal bone walls underwent ongoing resorption. For all implants, keratinized oral epithelium was continuous with junctional epithelium facing the implants and healing screw surfaces. Subjacent connective tissue was observed with a dense network of collagen fibers, with few vascular structures and scattered inflammatory cells, mainly adjacent to the implant-to-cover screw junction (Figs 4–7).

Histomorphometric analysis

No differences in B-L, IS-B, and IS-L measurements were found between groups ($P < 0.05$).

Healing after eight weeks

Buccal bone walls were thinner than lingual walls. Bundle bone was present only in the marginal portion of the buccal and lingual walls. Newly formed bone was present in the periimplant area and between implant threads. Comparing the control (sky classic)

and test groups (blue sky), the difference between buccal bone crests and lingual bone crests (B-L) was not significant (control group: 0.85 ± 0.1 mm; test group: 0.83 ± 0.8 mm).

Comparing the control and test groups for the two implant types, the difference between buccal bone crests and lingual bone crests (B-L) was not significant (control group: 0.85 ± 0.1 mm; test group: 0.83 ± 0.8 mm). The distance from the top of the implant collar to the buccal bone crest (IS-B) did not show significant difference ($P > 0.05$), mean values being 1.21 ± 0.2 mm for the crestal group and 1.38 ± 0.3 mm for the subcrestal group. The distance from implant collar to lingual bone crest (IS-L) showed significant difference between implant positions for both implant designs ($P = 0.1982$), values for the crestal group being lower (0.42 ± 0.2 mm) in comparison with the subcrestal group (0.71 ± 0.5 mm). Better results were achieved by both implant designs when implants were placed in the crestal position. The distance from the top of the implant collar to the first point of BIC (IS-Bc and IS-Lc) was representative of the vertical size of the

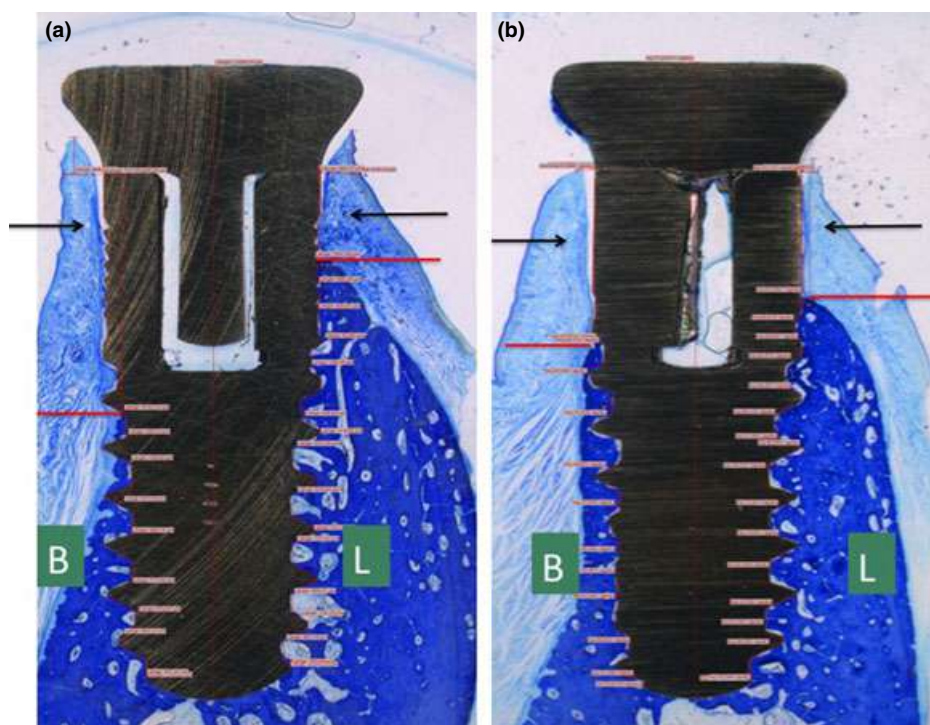


Fig. 4. (a) Buccal-lingual section after 8 weeks of healing in crestal group of blue sky implants. In apical direction, the thin barrier epithelium is continuous with a connective tissue with scattered inflammatory cells. Newly formed bone in the crestal region is close to the smooth surface reaching the second thread on the buccal aspect and the first thread on the lingual aspect. (b). Buccal-lingual section after 8 weeks of healing in crestal group of sky classic implants. The margin of the peri-implant mucosa is located slightly coronal of the implant shoulder. The connective tissue lateral as well as apical to the barrier epithelium is free of inflammatory cell infiltrates. The bone crest also exhibits new bone formation as far as the polished titanium collar on both buccal and lingual aspects. Red arrows show first bone-to-implant contact at bone crest level; black arrows show the barrier (junctional) epithelium. Acid fuchsin and toluidine blue staining. ($\times 10$ magnification).

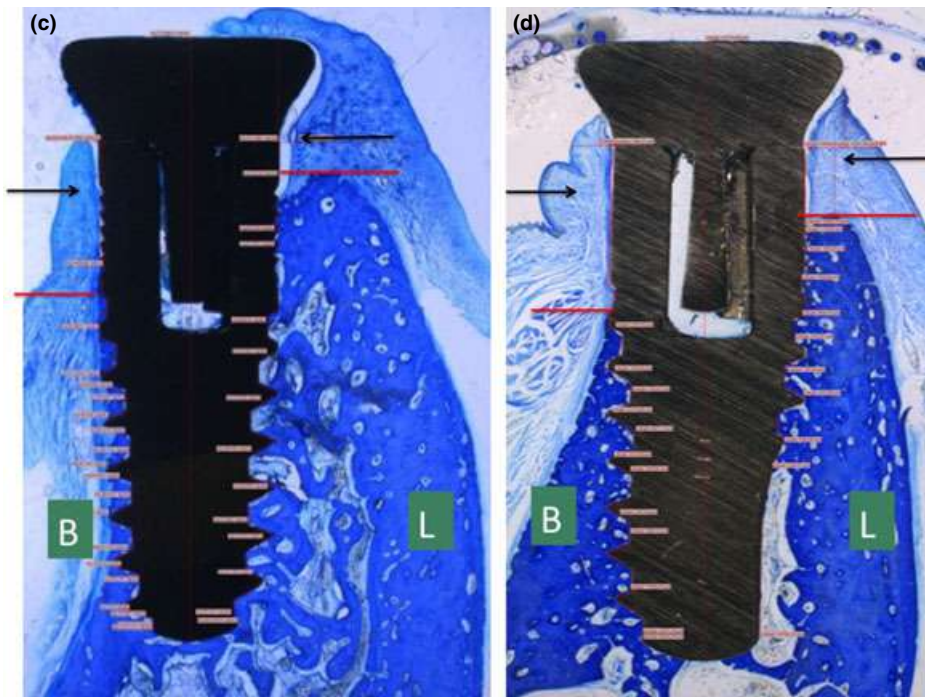


Fig. 5. (c) Crestally placed Blue Sky implants after 12 weeks of healing (left). In apical direction, the thin buccal plate is continuous with connective tissue with scattered inflammatory cells. Newly formed bone in the crestal region is close to the smooth surface, reaching the second thread on the buccal aspect and the first thread on the lingual aspect; (d) Crestally placed Sky Classic implants after 12 weeks of healing. Red arrows show first bone-to-implant contact at crestal bone level; black arrows show the barrier (junctional) epithelium. Acid fuchsin and toluidine blue staining. ($\times 10$ magnification).

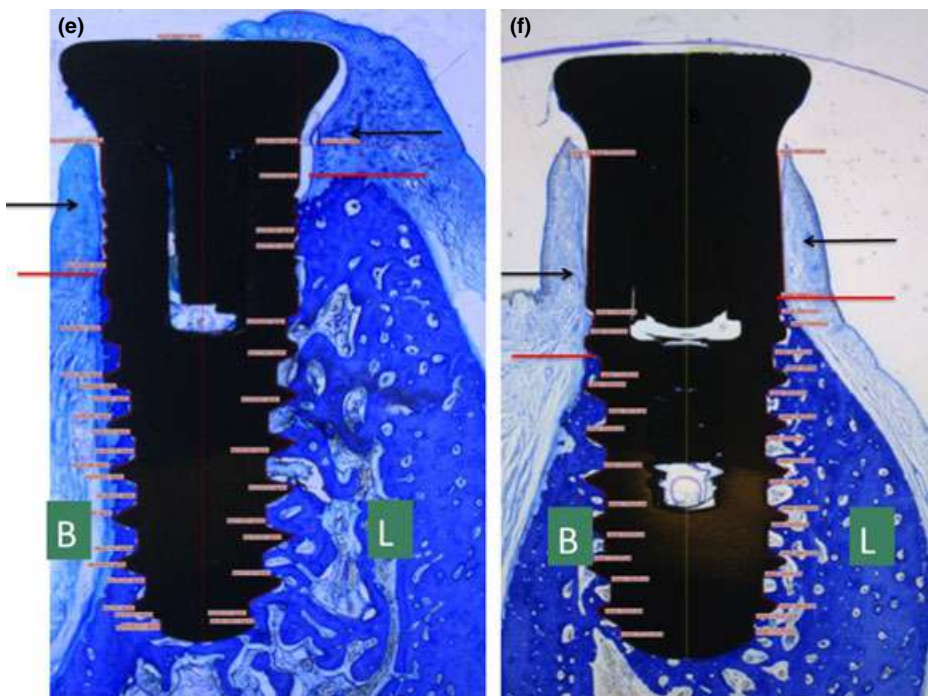


Fig. 6. (e) Buccal-lingual section after 8 weeks of healing in subcrestal group of blue sky implants. The newly formed bone in the crestal region reaches up to the edge of the micro-threads on the buccal aspect and reaches over all microthreads on the lingual aspect. (f). Buccal-lingual section after 8 weeks of healing in subcrestal group of sky classic implants. The margin of the peri-implant mucosa is located apically of the implant's polished shoulder. The bone crest exhibits new bone formation as far as the implant's polished collar on both buccal and lingual aspects. Red arrows show first bone-to-implant contact at bone level crests; black arrows show the barrier (junctional) epithelium. Acid fuchsin and toluidine blue staining. ($\times 10$ magnification).

bone defect for both implant types (sky classic and blue sky); lower values were observed when implants were inserted in the deeper position.

The distance from the base of the implant collar to the first point of BIC on the lingual aspect (A-Lc) showed a significant difference ($P = 0.1982$) between implant positions (crestal or subcrestal), values for the crestal group being higher (1.69 ± 0.2 mm) in comparison with the subcrestal group (1.45 ± 0.2 mm). The distance from the base of the implant collar to the first BIC in the buccal aspect (IS-Bc) also showed significant difference ($P = 0.1253$) between implant positions (crestal or subcrestal), values for the crestal group being higher (1.69 ± 0.8 mm) in comparison with the subcrestal group (1.64 ± 0.7 mm). Better results were achieved by both implant designs when implants were placed subcrestally (Table 1).

Healing after twelve weeks

A comparatively larger portion of the implant surface was in direct contact with bone, in both buccal and lingual aspects, after 8 weeks of healing for both control and test implants. Post-extraction defects were still distinguishable in histological sections. However, there appeared to be more new bone in the defect area. Comparing the control and test groups for the two implant types, the difference between the buccal bone crest and the lingual bone crest (B-L) was not significant (0.95 ± 0.2 mm control group; 0.93 ± 0.3 mm test group).

The distance from the top of the implant collar to the buccal bone crest (A-B) did not show significant difference ($P > 0.05$); mean values were 1.72 ± 0.3 mm for the crestal group and 0.79 ± 0.4 mm for the subcrestal group. However, the distance from the top of the implant collar to the lingual bone crest (IS-L) did show significant difference between implant positions for both implant designs ($P = 0.1982$), values for the crestal group being higher (0.89 ± 0.6 mm) in comparison with the subcrestal group (0.81 ± 0.4 mm). Better results were achieved by both implant designs when implants were placed in the deeper position.

The distance from the top of the implant collar to the first point of BIC (IS-Bc and IS-Lc) was representative of the vertical size of the bone defect for both implant types (sky classic and blue sky); lower values were observed when the implants were inserted in the deeper position.

The distance from the base of the implant collar to the first point of BIC on the lingual

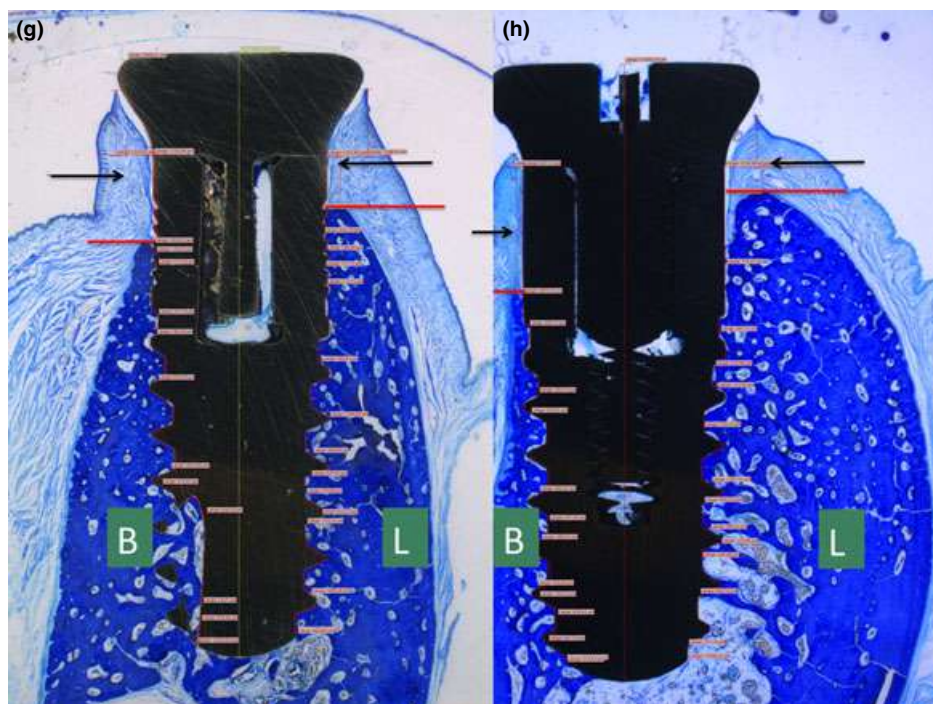


Fig. 7. (g) Buccal-lingual section after 12 weeks of healing in subcrestal group of blue sky implants. The margin of the peri-implant mucosa is located slightly apical of the implant shoulder and reaches down to the second implant microthread. The surface of the bone crest exhibits signs of ongoing remodeling. On the lingual aspect of the implant, signs of newly formed bone can be observed covering all microthreads. The buccal crest shows less resorption than in the crestal group. On the lingual aspect, the first bone-to-implant contact (BIC) is located close to the edge of the rough surface. (h) Buccal-lingual section after 12 weeks of healing in the subcrestal group of sky classic implants. On the buccal aspect, the margin of the peri-implant mucosa is located level with the polished collar. In the buccal aspect, the bone crest, at the lower edge of the polished collar, exhibits signs of resorption, while the lingual bone crest reaches the middle of the polished collar. Red arrows show first bone-to-implant contact at bone level crests; black arrows show the barrier (junctional) epithelium. Acid fuchsin and toluidine blue staining. ($\times 10$ magnification).

aspect (IS-Lc) showed significant difference ($P = 0.0892$) between implant positions (crestal or subcrestal), values for the crestal group being higher (1.79 ± 0.1 mm) in comparison with the subcrestal group (1.74 ± 0.3 mm). Better results were achieved by both implant designs when implants were placed in the deeper position.

The distance from the base of the implant collar to the first BIC on the buccal aspect (ISBc) also showed significant difference ($P = 0.1253$) between implant positions (crestal or subcrestal), values for the crestal group being higher (1.79 ± 0.3 mm) in comparison with the subcrestal group (0.89 ± 0.5 mm). Better results were achieved by both implant designs when implants were placed in the deeper position (Table 1).

No significant differences were found in lingual bone-to-implant contact measurements ($P > 0.05$), lingual BIC being $43.54 \pm 10.22\%$ for the crestal group and $56.33 \pm 10.72\%$ for the subcrestal group (Table 4).

No significant differences were found in total BIC values ($P > 0.05$) in relation to crestal

or subcrestal implant position, BIC being $41.54 \pm 3.87\%$ for the crestal group and $56.87 \pm 3.46\%$ for the subcrestal group. (Table 2) In this way, no significant differences were found in buccal BIC ($P > 0.05$) (buccal BIC being $41.45 \pm 11.23\%$ for crestal group and $42.65 \pm 10.83\%$ for the subcrestal group [Table 3]) or lingual BIC ($P > 0.05$) (lingual BIC being $48.68 \pm 11.22\%$ for the crestal group and $61.43 \pm 11.62\%$ for the subcrestal group) (Table 4).

Radiographic observation

When radiographs taken at 12 weeks were examined, for sky classic implants, the distance from the implant platform to the crestal bone line was higher in the crestally positioned samples (0.7 ± 0.12 mm) compared with the subcrestal group (0.3 ± 0.1 mm); for blue sky implants, values in the crestal group were also higher (2.8 ± 0.2 mm) compared with the subcrestal group (0.5 ± 0.2 mm). In the subcrestal position, there was minimal bone loss with either implant design; however, when

implants were placed crestally, blue sky implants showed higher levels of crestal bone loss (Table 5).

Discussion

The dog model has been widely used to investigate bone responses to implants placed in simulated or actual extraction defects (Araujo & Lindhe 2005; Calvo-Guirado et al. 2011a), whereas human histological studies have been limited to case reports (Wilson & Higginbottom, 1998; Wilson et al. 2003). While there is strong histological evidence to show successful bone regeneration and integration of newly formed bone when the implant is placed in a submerged healing protocol (Warrar et al. 1991), the use of a non-submerged one-stage surgical protocol can be based on other research (Jung et al. 2008; Botticelli et al. 2005, 2006), in which comparisons of the two surgical protocols in an animal dog model have failed to identify significant differences in the healing of marginal defects.

The removal of single teeth followed by immediate implant placement results in marked alterations to buccal ridge dimensions as well as horizontal and vertical gaps between the bone walls and the implant (Sanz et al. 2010). The present study showed marked hard tissue alterations during the 12-week healing period following tooth extraction and immediate implant placement, which affected both buccal and lingual bone plates. Resorption of the buccal plate was seen to be more pronounced; this bone dehiscence following implant placement corroborates findings reported in previous dog experiments (Spray et al. 2000; Araujo & Lindhe 2005; Araujo et al. 2005; Cardaropoli et al. 2006; Calvo-Guirado et al. 2010; 2011b). Nevertheless, A-Bc and A-Lc values were lower for the subcrestal group. The early phases of tissue integration for implants placed in fresh extraction sockets have been described in detail. The start of bone formation is concomitant with a marked bone resorption, and socket dimensions would appear to influence the bone healing process (Vignoletti et al. 2009a,b). Moreover, an experimental study designed to determine whether the reduction in the alveolar ridge that occurs following tooth extraction and implant placement is influenced by the size of the hard tissue walls of the socket found that the marginal gap that was present between the implant and the walls of the socket at implantation disappeared as a result of bone fill and resorption of the bone crest.

Table 1. Brunner–Langer test (nonparametric repeated measures analysis of variance) applied to median values (mm ± standard deviation)

Placement Position	B-L mean (mm) + SD	IS-B mean (mm) + SD	IS-Bc mean (mm) + SD	IS-L mean (mm) + SD	IS-Lc mean (mm) + SD
Crestal (8 weeks)	0.85 ± 0.1	1.21 ± 0.2	1.69 ± 0.8	0.42 ± 0.2	1.69 ± 0.2
Subcrestal (8 weeks)	0.83 ± 0.8	1.28 ± 0.3	1.64 ± 0.7	0.71 ± 0.5	1.45 ± 0.2
Crestal (12 weeks)	0.95 ± 0.2	1.72 ± 0.1	1.79 ± 0.3	0.89 ± 0.6	1.79 ± 0.1
Subcrestal (12 weeks)	0.93 ± 0.3	0.79 ± 0.4*	0.89 ± 0.5	0.81 ± 0.4	1.74 ± 0.3
P value	0.07392	0.02763*	0.1253	0.1982	0.0892

The level of significance was set at $P < 0.05$. B-L, difference between buccal bone crest and lingual bone crest; A-B, distance from the top of the implant collar to the buccal bone crest; A-Bc, distance from the top of the implant collar to the first bone to implant contact in the buccal aspect; A-L, distance from the top of the implant collar to the lingual bone crest; A-Lc, distance from the top of the implant collar to the first bone to implant contact in the lingual aspect; SD, Standard deviation. (*differences between values achieving statistical significance).

Table 2. Total bone-to-implant contact (Total BIC) values (% ± standard deviation [SD]) at different time periods

	Crestal group		Subcrestal group	
	Mean values (%) + SD	P-value	Mean values (%) + SD	P-value
8 weeks	46.22 ± 4.29	0.0732	49.72 ± 2.21	0.0921
12 weeks	41.54 ± 3.87	0.0863	56.87 ± 3.46	0.4321

Table 3. Buccal bone-to-implant contact (Buccal BIC) values (% ± standard deviation [SD]) at different time periods

	Crestal group		Subcrestal group	
	Mean values (%) + SD	P-value	Mean values (%) + SD	P-value
8 weeks	39.61 ± 13.42	0.0327*	48.87 ± 10.98	0.1623
12 weeks	41.45 ± 11.23	0.0453*	42.65 ± 10.83	0.2012

*Statistically difference $P < 0.05$.

Table 4. Lingual bone-to-implant contact (Lingual BIC) values (% ± standard deviation [SD]) at different time periods

	Crestal group		Subcrestal group	
	Mean values(%) + SD	P value	Mean values (%) + SD	P value
8 weeks	43.54 ± 10.22	0.0635	56.33 ± 10.72	0.0764
12 weeks	48.68 ± 11.22	0.0821	61.43 ± 11.62	0.4356

Table 5. Radiographical observations

Radiographic crestal bone loss (mm) N = 48	Sub-crestal mean ± SD mm	Crestal mean ± SD mm
Sky classic n = 24	0.3 ± 0.1	0.7 ± 0.12
Blue – Sky n = 24	0.5 ± 0.2	2.8 ± 0.2

The modeling in the marginal defect region was accompanied by marked attenuation of the dimensions of both the delicate buccal and the wider lingual bone wall. At the buccal aspect, this resulted in some marginal loss of osseointegration (Araujo et al. 2006).

Clinically, implants are normally placed at the crestal bone level in either a submerged or a non-submerged position. Subcrestal placement of implants may be utilized in esthetic areas, where it has been suggested

that implants should be placed subcrestally to minimize the risk of metal exposure and to allow for enough space in the vertical dimension to develop an adequate emergence profile (Buser et al. 2007; Negri et al. 2012a,b). In this way, subcrestal placement of an implant may also provide an advantage by facilitating earlier bone-to-implant contact at the neck of the implant. Huang et al. (2012), in a clinical trial using multilevel, multivariate models to evaluate the influence of placement depth on bone remodeling around implants with two different types of tapered internal implant abutments (IAI) positioned crestally or subcrestally, found that tapered internal IAI configuration had no significant effect on crestal bone resorption. Moreover, subcrestal placement of tapered internal IAI had a positive impact on bone preservation around the cervix of the implant. The present

study revealed greater depth of crestal bone resorption at the lingual aspects when the implants were placed at crestal level. When the implants were placed subcrestally, the Lc and the Bc showed less resorption. This outcome corroborates the results of previous studies (Weng et al. 2008; Pontes et al. 2008). In this study, the extent of buccal and lingual resorption was similar, and values decreased when the implants were inserted in the deeper position. This agrees with a study carried out by Barros et al. 2009a,b; which evaluated bone remodeling around contiguous Morse cone-connection implants placed at different depths (equicrestally and 1.5 mm subcrestally). The subcrestal group index for crestal bone resorption was significantly lower than that of the equicrestal group. This finding agrees with a study carried out by Calvo-Guirado et al. 2013, which evaluated bone-to-implant contact and bone remodeling dynamics after immediate implant placement at different levels (equicrestally and 2 mm subcrestally). The subcrestal group showed less bone resorption than the crestal group.

Conclusions

The results of this pre-experimental study in dogs suggest that the apical positioning of the top of the implant does not jeopardize remodeling of the bone crest and peri-implant tissues. However, less resorption of the lingual and buccal crest can be expected when the implants are placed 2 mm subcrestally on both the lingual and buccal aspects. When the implants were inserted at a deeper position, the results were better for either of the implant designs tested. There are reasons to suggest that either crestal bone loss or its preservation may be partly due to a series of factors: crestal or subcrestal implant position, surgical trauma resulting from the minimal mucoperiosteal flap elevation approach; implant surface treatment; variations in alveolar ridge width unrelated to implant design.

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