Subcrestal Positioning of Implants with a Convergent Hyperbolic Collar Profile: An Experimental Study in Dogs

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Purpose: To evaluate the influence on peri-implant soft and hard tissues of one-piece implants with a convergent hyperbolic profile collar placed at different depths with respect to the bone crest. *Materials and Methods:* Six dogs were included in the experiment. Three months after mandibular tooth extractions, two one-piece implants carrying a 2.8-mm–high convergent hyperbolic profile collar were placed in the alveolar crest with the coronal margin of the rough surface either 0.8 mm (test-1) or 1.8 mm (test-2) deeper with respect to the bone crest (Ct0). Two similar implants were instead placed flush to Ct0 as controls (control-1 and control-2, respectively). Healing screws were connected, and nonsubmerged healing was allowed. After 4 months, block sections were harvested, and histologic slides were prepared in a buccolingual plane. *Results:* In the histologic analyses, both the buccal crest and coronal level of osseointegration were located more coronally at the test compared to the control implants concerning the implant. However, the buccal bone crest with respect to Ct0 presented a loss of 0.8 ± 0.4 mm at the test-1 and 0.5 ± 0.4 mm at the control-1 implants ($P = .028$), and a loss of 2.0 ± 1.0 mm and 0.7 ± 0.4 mm at the test-2 and control-2 implants ($P = .028$), respectively. At the control implants, the collars were exposed above the peri-implant mucosa, while those of the test implants were not. However, the coronal level of the peri-implant mucosa with respect to Ct0 was located more apically at the test compared to the control implants. *Conclusion:* The placement of implants with a hyperbolic convergent profile collar in the subcrestal position resulted in higher buccal bone resorption and more soft tissue recession compared to the crestal implants with respect to the level of the bone crest at placement. *Int J Oral Maxillofac Implants 2022;37:1160–1168. doi: 10.11607/jomi.9642*

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The placement of implants deeper with respect to the alveolar bone crest has been claimed to allow better maintenance of the dimensions of the peri-implant soft and hard tissues.[1–4] The stability over time of the peri-implant hard and soft tissues was also proved at implants with a platform-switching conformation placed subcrestally.[5,6] However, an experiment in dogs[7] clearly showed that both crestal bone resorption and soft tissue recession were more pronounced in relation to the initial position of the bone crest in the deeper implants compared to the crestal implants after 8 weeks of healing. In that experiment, one-piece implants with a polished divergent profile collar were adopted. In clinical practice, this type of transmucosal implant is often placed with the shoulder close to the alveolar crest, aiming to provide sufficient peri-implant mucosa width and height that might guarantee good esthetic outcomes.[8,9] However, the placement of implants in a subcrestal position might induce marginal bone loss during the first periods of healing.[7,10] One-piece implants including a convergent collar profile have been introduced in clinical practice aiming to provide conditions that might result in improved esthetic outcomes compared to other abutment conformations. The rationale of this choice was based on the biologically oriented preparation technique (BOPT),[11–15] a concept that includes a feather-edge design with no finish line adopted for teeth preparation.[16,17]

The concept was subsequently conveyed to the implant design. This conformation, similar to the feather-edge preparation at teeth, allows the clinician to guide the levels of the peri-implant mucosa modifying the crown contour.[18–26] However, the effect of this collar profile on the marginal tissue levels around subcrestal implant delivery is still to be clarified.

Hence, the present study aimed to evaluate the influence on peri-implant soft and hard tissues of one-piece implants with convergent hyperbolic profile collars placed at different depths with respect to the bone crest.

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Fig 1 Clinical images at placement. The test implants were placed subcrestally either 0.8 mm (*a*; test-1) or 1.8 mm (test-2), while the respective control implants were placed flush to the buccal bone crest (*b*; control-1 and control-2).

Fig 2 *(Right)* The implant used (PRAMA, Sweden & Martina; Fig 2) had a tapered one-piece conformation with a moderately rough surface. The transmucosal collar was 2.8 mm high, composed of a straight cylindrical section 0.8 mm high at the apical region, and hyperbolic convergent geometry, 2.0 mm high, coronally. CM = collar margin; M = coronal margin of the rough surface.
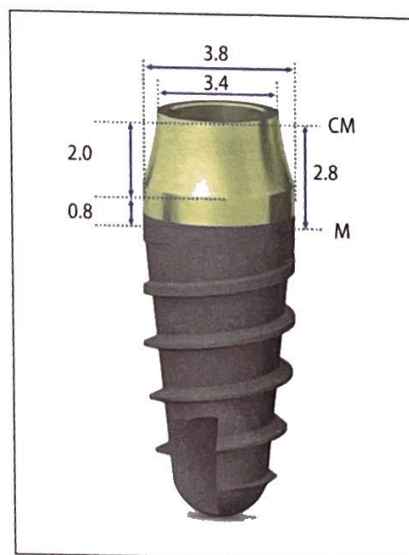
The hypothesis was that the deeper the implant is placed in relation to the bone crest, the higher the bone loss and soft tissue recession.

MATERIALS AND METHODS

Ethical Statement

The experimental protocol was approved by the Ethical Committee of the Faculty of Dentistry of the University of Medical Science of La Habana, Cuba (No. 06/2018, June 28, 2018). The rules for animal care adopted in Cuba were strictly followed. This study is reported according to the ARRIVE guidelines.

Experimental Animals

Six beagle dogs, approximately 6 years of age and 16 kg of weight, bred at center CENPALAB (Centro Nacional para la Producción de Animales de Laboratorio), Cuba, were included in the experiment.

Experimental Design

Four implants, two tests and two controls, were placed in the edentulous mandible. The test implants were placed subcrestally either 0.8 mm (Fig 1a; test-1) or 1.8 mm (test-2), while the respective control implants were placed flush to the buccal bone crest (Fig 1b; control-1 and control-2). Nonsubmerged healing was arranged, and 4 months of healing were allowed.

Sample Size

The data from a previous experiment on dogs were used for sample calculation.[5] In that experiment, six dogs were included and implants were placed with the rough margin of the surface either at bone level or 1.3 mm deeper. Higher buccal bone resorption was found at the deeper (1 mm) compared to the flush implants (0.5 mm). In the present study, in one group, implants were planned to be placed 1.8 mm deeper than the buccal bone crest. It was hypothesized that 0.5 mm more resorption of the buccal bone might have been expected compared to that obtained in the previous study, providing a difference of 1 mm between groups.[5] Six dogs were considered sufficient to reject the null hypothesis that the response difference was zero with a power = 0.9, α = .05.

Randomization, Allocation Concealment, and Blinding Procedures

The randomization was performed electronically at the website www.randomization.com by one author not involved in the surgeries (D.B.). The side of the mandible (right/left) and the position (mesial/distal) for the test implants was randomly allocated. The control implants were placed on the other side of the mandible, each opposite to its own test implant (test-1 vs control-1 and test-2 vs control-2).

The allocation of the treatments was secured in sealed opaque coded envelopes. The surgeon (T.M.) was blinded until flap elevation, when the envelopes were opened and the allocation treatment was revealed. The histologic slides were coded regarding test and control sites so that the histologic assessor (E.D.R.) was blinded about allocation treatment.

Implant Characteristics

The implant used (PRAMA, Sweden & Martina; Fig 2), had a tapered one-piece conformation with a surface sandblasted with zirconia and subsequently acid-etched (so-called "ZirTi"; Sweden & Martina)[27,28] presenting a moderate roughness (Sa = 1.7 μm; Sds = 0.065 1/μm²). The body of the implant was 8.5 mm long and 3.8 mm in diameter. The transmucosal collar was 2.8 mm high, composed apically of a straight cylindrical section 0.8 mm high and coronally of a 2.0-mm–high convergent neck with hyperbolic geometry, presenting
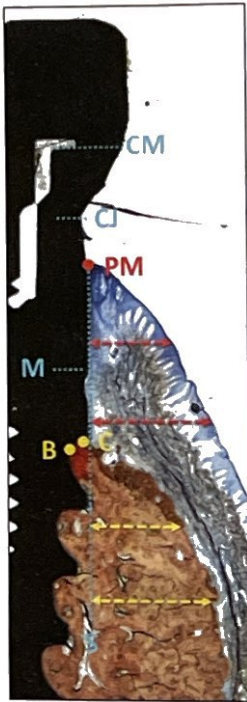
Fig 3 Landmarks used for histologic measurements. PM = top of the peri-implant mucosa; C = top of the bone crest; B = coronal level of bone contact at the implant surface; CM = collar margin; CJ = collar/ healing screw junction; M = coronal border of the rough surface (2.8 mm apically to CM); S = line drawn following the surface of the cylindrical portion of the collar. The horizontal width of the soft tissues, 1 mm and 2 mm apically to PM (red dashed lines), and of the buccal bone crest (yellow dotted lines), 1 mm and 2 mm apically to C, were also assessed from S to the outer contour of the soft and the hard tissues, respectively.

a curved surface with ends directed apart from each other (Fig 2). The surface presented microthreads of 50 to 60 μm in width (Ultrathin Threaded Micro-surface; Sa = 0.6 μm; Sds = 0.077 1/μm^2).

Surgical Procedures

Implant placement was carried out by an expert surgeon (T.M.). At any surgical session, anesthesia was induced with sodium-thiopental IV (20 mg/kg; Farmahealth Laboratories Rofarma SA), and tramadol IV (2 mg/kg; Biocubafarma) was added to control pain. The anesthesia was maintained with isoflurane (2% to 3%; IsoFlo vet-use, Abbott Laboratories) and complemented locally in the experimental regions. Oxygen saturation and heart rate were monitored continuously.

During the first surgical session, the first molars were extracted bilaterally. After 3 months of healing, full-thickness flaps were elevated and the alveolar bone crest was exposed. Aiming to avoid a surgical trauma, no bone recontouring was performed to create a plateau, and the recipient sites were prepared using a series of drills.[29] The implant sites were first marked with a lanceolate drill followed by a pilot drill Ø 2.0 mm up to a depth that allows insertion of the implant at the desired crestal level. The coronal region of the osteotomy was widened with an intermediate step drill Ø 2.0/2.8 mm followed by a Ø 3.0-mm drill used again up to the required depth. The width of the bone crest allowed a buccal and lingual bone width > 1 mm in all osteotomies. Two implants were placed on each side of the mandible. The test implants were placed with the coronal margin of the rough surface either 0.8 mm (test-1) or 1.8 mm (test-2) deeper than the buccal bone crest. The two respective control implants (control-1 and control-2) were placed flush to the bone crest. The bone crest at the lingual aspect was located coronally to the rough surface margin. Healing screws were affixed onto the implants, and the flaps were sutured to obtain nonsubmerged healing.

Housing and Husbandry

After the surgery, oxytetracycline (20 mg/Kg; Oxitetraciclina LA, bela-farm) and flunixin meglumina (1.1 mg/kg; Megludyne, Virbac Mexico SA, imported by Montana SA) were injected intramuscularly. The dose was repeated after 3 days. The animals were kept in pairs in kennels with free access to water and fed with moistened balanced food. The biologic functions and disinfection of the wounds were performed daily by professionals during the first week after each surgery using gauze soaked in chlorhexidine. Afterward, the healing screw was cleaned with a toothbrush twice per week during the full period of the experiment.

Euthanasia

The animals were euthanized 4 months after implant placement. Anesthesia was performed with injections of sodium-thiopental IV (20 mg/kg i.v.; Farmahealth Laboratories Rofarma), and tramadol was also added (2 mg/kg i.v.; Biocubafarma), followed by sodium heparin 12 i.u./kg i.v. (Athena Pharma). Potassium chloride 25 mEq i.v. (Aica) was administered to arrest the heart. The mandibles were dissected in blocks and fixed in formaldehyde solution.

Histologic Preparation

Block sections containing the implant were placed in 4% formaldehyde. The blocks were dehydrated in a series of ascending graded ethanol and then impregnated in resin (Technovit 7200 VLC, Heraeus Kulzer). After polymerization, the specimens were cut in a buccolingual direction using a diamond band saw fitted in a precision slicing machine (Exakt Apparatebau). A central histologic slide from each implant was selected and consistently ground to a thickness of approximately 60 μm using grinding equipment (Exakt Apparatebau) and subsequently stained with Stevenel's blue and alizarin red.

Histologic Evaluations

An Eclipse microscope (Nikon Corporation) connected to a computer was used for histologic evaluation. The measurements were carried out with the software NIS-Elements D 5.11.00 (Laboratory Imaging, Nikon Corporation). The following landmarks were adopted (Fig 3): top of the peri-implant mucosa (PM); top of the bone crest (C); coronal level of bone contact at the implant surface (B); collar margin (CM); collar/healing screw junction (CJ); coronal border of the rough surface, 2.8 mm apically to
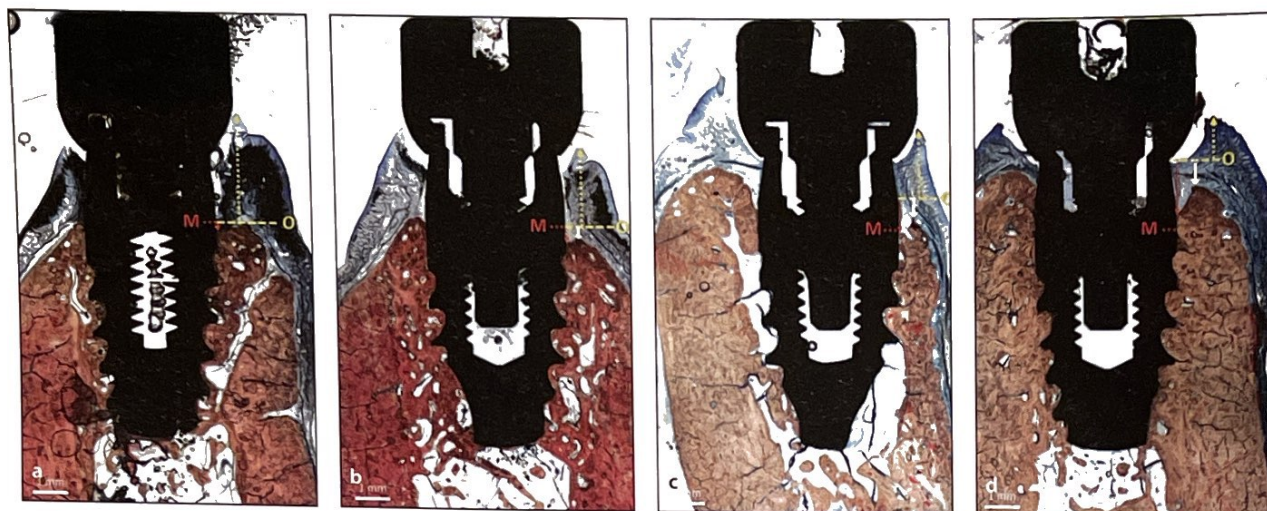
Fig 4 Photomicrographs representing healing after 4 months at the crestal implants (*a*, control-1; *b*, control-2) and at the subcrestal implants (*c*, test-1; *d*, test-2). M and the dashed red line indicate the margin between rough and smooth surface. O and the dashed yellow line indicate the original level of the bone crest at placement. The dotted arrows indicate the loss of bone in relation to O for bone crest (*white*) and coronal level of osseointegration (*red*) and the position of the peri-implant mucosa in relation to O.

CM (M); and the line drawn following the surface of the cylindrical portion of the collar (S). The following distances were evaluated: CM–C, CM–B, PM–C, PM–B, and PM–CM. The distances M–C and M–B were subsequently calculated. The buccal bone crest loss (bone loss) and the position of B and PM with respect to the level of the buccal bone crest at placement (Ct0, buccal bone crest at baseline) were evaluated. For exploratory purposes, lingual M–C and M–B were measured.

The horizontal width of the buccal bone crest, 1 mm and 2 mm apically to C, and of the soft tissues, 1 mm and 2 mm apically to PM, were also assessed from S to the outer contour of the soft and the hard tissues, respectively (Fig 3). Moreover, as an explorative aim, the distance CM–CJ was also evaluated.

Data Analysis

The histologic measurements were performed twice by an assessor (E.F.D.R.), and mean values were obtained. Before undertaking the measurements, calibration with another expert examiner (D.B.) was performed until an interclass correlation coefficient $\kappa > 0.9$ was achieved. The Wilcoxon test was applied for the analysis between the test and controls. The level of significance was set at $\alpha = .05$.

The primary variables were the buccal bone crest resorption and the buccal soft tissue levels with respect to the level of the buccal bone crest at placement. As secondary variables, the width and height of soft tissue and the width of the buccal bone crest were used. Two-tail Spearman correlation coefficients ($\alpha = .05$) were assessed between PM–C and widths of the bone crest and soft tissues. The software GraphPad Prism (version 9.1.2 for Windows, GraphPad Software, www.graphpad.com) was used for the statistical analyses.

RESULTS

The control implants were placed with M at the level of C, while for the test implants, M was placed 0.8 mm (test-1) or 1.8 mm (test-2) deeper. After 4 months, proper histologic healing was observed at both the control (Figs 4a and 4b) and the test implants (Figs 4c and 4d).

At the buccal aspect, the distance M–C was 0.0 mm at test-1 and 0.5 mm at control-1 ($P = .028$; Table 1). M–C was 0.2 mm at test-2 and 0.7 mm at control-2 ($P = .249$). However, the resorption of the buccal bone crest with respect to Ct0 was higher at both test implants compared to their respective controls. In fact, due to the flush position to Ct0, the control implants registered a bone loss of 0.5 mm at control-1 and 0.7 mm at control-2, data that correspond to the distance M–C. For test-1 and test-2 implants, the depth of the implant placement has to be added to the distance M–C so that a total of 0.8 mm (0.0 + 0.8 mm) and 2 mm (0.2 + 1.8 mm) of bone loss was registered, respectively. The differences in bone loss between test and control implants were 0.3 mm ($P = .028$) and 1.3 mm ($P = .025$) in favor of control-1 and control-2 implants, respectively.

The distance M–B at the buccal aspect was 0.6 and 1.2 mm at test-1 and control-1 implants ($P = .141$), and 0.5 and 0.9 mm at the test-2 and control-2 implants ($P = .249$), respectively. However, B was located closer to Ct0 at the control compared to the test implants. At the control implant, the distance B–Ct0 corresponds to the distance M–B. However, at the test implants, the implant placement depth with respect to Ct0 had to be added to M–B so that the distance Ct0–B was 1.4 mm and 2.3 mm at test-1 and test-2, respectively. The differences in Ct0–B between test and control implants were not statistically significant.

Table 1 Histometric Evaluation of the Peri-implant Hard Tissues at the Buccal Aspect

	M-C	M-B	Ct0-C (bone loss)	Difference in bone loss	Ct0-B
Test-1	0.0 ± 0.4*	0.6 ± 0.9	0.8 ± 0.4*	0.3 ± 0.3*	1.4 ± 0.9
Control-1	0.5 ± 0.4*	1.2 ± 0.9	0.5 ± 0.4*		1.2 ± 0.9
Test-2	0.2 ± 1.1	0.5 ± 1.1	2.0 ± 1.0*	1.3 ± 1.0*	1.3 ± 1.1
Control-2	0.7 ± 0.4	0.9 ± 0.5	0.7 ± 0.4*		0.9 ± 0.5

Data are reported as mean ± SD (mm). *$P < .05$ between test and control sites. M = coronal border of the rough surface; C = top of the bone crest; B = coronal level of bone contact at the implant surface; Ct0 = level of the buccal bone crest at placement. Bone loss was calculated with respect to Ct0.

Table 2 Histometric Evaluation of the Peri-implant Soft Tissues at the Lingual Aspect

	M-C	M-B
Test-1	−0.9 ± 0.8*	0.2 ± 0.8*
Control-1	0.4 ± 0.9*	1.0 ± 0.7*
Test-2	−0.6 ± 1.0	0.0 ± 1.1
Control-2	0.1 ± 0.4	0.3 ± 0.4

Data are reported as mean ± SD (mm). *$P < .05$ between test and control sites. M = coronal border of the rough surface; C = top of the bone crest; B = coronal level of bone contact at the implant surface.

Table 3 Histometric Evaluation of the Peri-implant Soft Tissues at the Buccal Aspect

	PM-C	PM-B	PM-CM	PM-Ct0
Test-1	2.9 ± 0.5	3.5 ± 1.3	0.0 ± 0.6*	2.0 ± 0.6
Control-1	2.7 ± 0.6	3.3 ± 0.9	−0.6 ± 0.7*	2.2 ± 0.7
Test-2	3.2 ± 0.9	3.6 ± 1.0	0.2 ± 0.4*	1.2 ± 0.4*
Control-2	2.9 ± 0.5	3.1 ± 0.6	−0.6 ± 0.7*	2.2 ± 0.7*

Data are reported as mean ± SD (mm). *$P < .05$ between test and control sites. PM = peri-implant mucosa; C = top of the bone crest; B = coronal level of bone contact at the implant surface; CM = collar margin (collar height = 2.8 mm); Ct0 = level of the buccal bone crest at placement.

Table 4 Histometric Evaluation of the Horizontal Width of the Peri-implant Hard and Soft Tissues at the Buccal Aspect: Evaluation at 1 and 2 mm Apical to the Top of the Peri-implant Mucosa (PM) and Bone Crest (C), Respectively

	Bone crest width		Mucosa width	
	1 mm	2 mm	1 mm	2 mm
Test-1	1.2 ± 0.2	1.7 ± 0.2	1.4 ± 0.3	1.6 ± 0.3
Control-1	1.4 ± 0.3	2.1 ± 0.4	1.2 ± 0.7	1.6 ± 0.8
Test-2	1.5 ± 0.4	2.0 ± 0.4	1.2 ± 0.3	2.1 ± 0.7
Control-2	1.4 ± 0.3	2.1 ± 0.3	1.0 ± 0.2	1.6 ± 0.2

Data are reported as mean ± SD (mm). None of the differences between test and control was statistically significant ($P < .05$). All differences between the measurements performed at 1 mm and 2 mm were statistically significant ($P < .05$).

At the lingual aspect, the mean bone crest was located coronally to M in both test implants (Table 2). A statistically significant difference was found between test-1 and control-1 for both M–C and M–B.

The peri-implant soft tissues presented similar dimensions in all groups, and no statistical differences were found between test and control implants (Table 3). PM was located apically to CM in both control implants so that the collar resulted in exposure above the mucosa by 0.6 mm. At the test implants, PM was located flush to CM at test-1 and 0.2 mm coronally to CM at test-2. The differences between test and control implants were both statistically significant ($P = .046$). However, PM was located more apically at the test compared to the control implants with respect to Ct0. PM was 2.2 mm coronally to Ct0 at both control implants, while at the test implants, PM was 2.0 mm coronal to Ct0 at test-1 ($P = .463$) and 1.2 mm at test-2 ($P = .027$). The difference between the two subcrestal implants was also statistically significant ($P = .016$).

No statistically significant differences were found between test and control implants for the bone crest and peri-implant soft tissue widths at both 1 mm and 2 mm (Table 4). The width at 2 mm was always statistically significantly larger compared to that at 1 mm in all implant groups.

At the test-1 implants, the correlation coefficients between PM-C and the mucosa width measured at 1 mm and 2 mm were 0.77 ($P = .103$) and 0.66 ($P = .175$), respectively. All the other groups presented negative or no correlations.

At test-1 implants, the correlation coefficients between PM–C and the bone crest width measured at 1 mm and 2 mm were 0.43 ($P = .419$) and 0.77 ($P = .103$), respectively. At test-2 implants, the correlation coefficients between PM–C and the bone crest width measured at 1 mm and 2 mm were 0.31 ($P = .564$) and 0.54 ($P = .297$), respectively. The crestal implants showed negative correlations.

The overall mean distance CM–CJ ranged between 0.8 and 0.9 mm.

DISCUSSION

The present study aimed to compare the healing of peri-implant soft and hard tissues at implants with a convergent collar placed crestally or subcrestally. The subcrestal implants were placed at two different depths with respect to the original bone crest (Ct0); ie, either 0.8 mm (test-1) or 1.8 mm (test-2). After 4 months of healing, the top of the buccal bone crest (C) and the most

coronal contact of the bone to the implant (B) were located more coronally at the subcrestal compared to the crestal implants with respect to the coronal margin of the rough surface (M). Only the M–C difference between test-1 and control-1 was statistically significant.

These outcomes are in agreement with the data reported in systematic reviews with meta-analyses[9,30,31] and in animal studies.[2,32] However, it has to be pointed out that the studies cited above have been used as references for measurements of the implant margin. These measurements did not consider another important reference; ie, the level of the bone crest at placement (Ct0). In a previously cited study in dogs,[7] similar to the present experiment, Ct0 was included in the analyses. Implants with a divergent polished collar 1.3 mm in height were placed with the coronal level of the rough surface (M) flush (control) or 1.3 mm subcrestally (test) with respect to the bone crest. After 8 weeks of healing, the bone crest was located 0.5 mm apically to M at the crestal implants, while at the subcrestal implants, C was 0.3 mm coronal to M at the buccal aspect, resulting in a difference of 0.8 mm in favor of the subcrestal implants. However, when the subcrestal position (–1.3 mm) was included in the evaluation, buccal bone resorption in relation to Ct0 of 1 mm and 0.5 mm was observed at the subcrestal and crestal implants, respectively.

This is in complete agreement with the results of the present study, despite the different conformation of the necks, divergent in that study[7] and convergent in the present study, in which the differences in bone loss in favor of the crestal implants were 0.3 mm for group 1 (0.8 mm) and 1.3 mm for group 2 (1.8 mm), both statistically significant.

These outcomes are also in agreement with another aforementioned experimental study in which the test implants were placed 1.5 mm subcrestally and immediately loaded.[2] In the histologic analyses, after 8 weeks of healing, the bone crest in the mesiodistal sites was located more coronally at the subcrestal compared to the crestal implants. However, if the depth of 1.5 mm is included in the calculation, bone crest resorption from the original position results to be 0.6 to 0.8 mm higher at the subcrestal compared to the crestal implants.

In an immediate implant placement study cited earlier,[32] implants were placed 2 mm deeper within the alveoli. When these data are included in the calculation, the bone crest loss at the subcrestal implants is 1.1 mm higher compared to the crestal implants.

Similar consideration should be made for the coronal level of osseointegration (B) with respect to the bone crest level at placement. In the present study, even though the distance M–B was shorter at the subcrestal compared to the crestal implants, an opposite result was obtained when the position of Ct0 was considered, resulting in B being closer to Ct0 at the crestal

compared to the subcrestal implants (Table 1). Similar outcomes can also be obtained in the studies discussed earlier.[2,7,32]

This, in turn, means that, after healing, not only the level of the bone crest but also that of the coronal level of osseointegration are located more apically at the subcrestal compared to the crestal implants in relation to Ct0.

In the present study, the heights of the peri-implant soft tissues (PM–C and PM–B) were similar in both groups (Table 3). At the crestal implants (control), the collars were exposed by 0.6 mm above the mucosa (PM), while those of subcrestal implants were completely covered by the mucosa. However, the position of PM with respect to Ct0 was more apical at the subcrestal compared to the crestal implants by 0.2 mm at the test-1 implants and 1 mm at the test-2 implants. Clinically, this might be interpreted as a greater recession of the soft tissues and, consequently, as an increased crown length at the subcrestal compared to the crestal implants.

A convergent profile collar allows a larger base for the supracrestal soft tissues compared to cylindrical and divergent profiles. A positive association between the papilla base width and the height of the mucosa was shown for both teeth[33] and implants.[34] In the present study, despite the positive correlation for the subcrestal implants, the distance PM–B (range: 3.1 to 3.6 mm) was similar to that reported in another experiment (3.1 to 3.5 mm) in which three different implants with cylindrical or divergent collar profiles were placed in the mandibles of dogs.[35] To explain the failure in finding differences in peri-implant soft tissue height in the present study, several limitations should be considered. The spontaneous growth of the peri-implant mucosa in humans has been reported in several clinical studies.[36–41] However, the reasons that might explain this increase in dimensions of the soft tissue over time are still unclear. Different phenomena have been advocated, such as the inflammatory theory.[42] In the present study, no evident inflammatory infiltrates were observed within the soft tissues, so this condition had limited or no effect on soft tissue growth. Another suggestive hypothesis is the effect produced by the intraoral negative pressure that occurs during swallowing in humans[41,43,44] on inaccessible spaces,[45] defined as unattainable regions around teeth or implants by the tissues of the lips, cheeks, or tongue.[41,45] However, crowns presenting a buccal convexity aiming to create a recessed area at the collar region were not applied in the present study. The healing screw created a recessed space of limited dimensions, and the time allowed for healing was limited to a few months. Most importantly, the swallowing process acts differently in dogs compared to humans.[46–48] In dogs, the tongue participates in chewing by putting food

posteriorly and impacting it with the backside of the tongue against the palate. The swallowing is then activated, and a peristaltic wave creates suction that moves the food toward the pharynx, allowing the food to be swallowed. This process can be simulated by swallowing with the mouth open, such as when patients try to swallow when a dental rubber dam is applied. The way of swallowing in dogs does not allow the establishment of any intraoral negative pressure in the teeth regions. This, in turn, means that in the present study, no suction effects occurred on the peri-implant soft tissues, so no tissue growth could result through this phenomenon.

Another limitation that should be considered in the present study was the absence of adjacent teeth, a condition that might have yielded higher buccal bone resorption and soft tissue recession compared to sites with the presence of adjacent teeth.[49,50] The slight shrinkage of the soft tissues that occurred during histologic preparation might have yielded data showing increased recessions. However, these two limitations affected both crestal and subcrestal implants. Finally, the healing screw was closer to the bone crest at the subcrestal compared to the crestal implants, decreasing the space for the soft tissues, a fact that might have yielded higher bone resorption at the former compared to the latter implants. It might be argued that a healing screw on the top of the margin collar should have been used to increase the distance from the bone crest and provide more space for the soft tissues. However, in this case, the concept of the feather-edge design with no finish line adopted from teeth preparation would have been lost. On the other hand, the horizontal width of the papilla would have been increased, influencing papilla height.[33,34] The microgap between the healing screw and implant collar would have been further from the bone crest, a fact that might have improved bone levels.[51] The concept of platform switching[52] took into consideration the fact of keeping the microgap away from the bone crest. Indeed, it was shown that bone levels were located more coronally at implants that included the concept of platform switching compared to those that did not.[53,54]

Several collars presented osseointegration at the subcrestal implants, mainly at the lingual aspect. The osseointegration might have been favored by the microthreads of 50- to 60-μm width prepared on the surface of the collar. However, this speculation cannot be confirmed due to the lack of control sites with a non-treated surface.

Further studies might be performed to evaluate the longer healing time and immediate placement of crowns, even though the biologically oriented preparation technique principles might not be expressed properly in dogs for the reasons discussed earlier. The placement of implants with a hyperbolic convergent profile collar in a subcrestal position resulted in higher buccal bone resorption and more soft tissue recession compared to the crestal implants with respect to the level of the bone crest at placement, as evaluated after 4 months of healing. However, bone crest, osseointegration, and peri-implant mucosa levels were located more coronally at the subcrestal compared to the crestal implants when the margin between rough and smooth surfaces was used as reference.

The interpretation of the data from the literature and from the present study allow a conclusion that implants with necks of any conformation among those tested subcrestally will present higher bone loss and soft tissue recession compared to crestal implants in relation to the original level of the alveolar bone crest at placement. The present study does not provide data on hard and soft tissue stability over time.

The clinical prosthetic implications resulting from the supracrestal exposure of the collars at the crestal implants and the bone crest resorption and soft tissue recession at the subcrestal implants have to be considered to select the most suitable bone crest level in which to place the implants. The clinical relevance of this experimental study is related to the observation of higher buccal bone resorption and soft tissue recession at the subcrestal compared to the crestal implants in a situation without the use of crowns. The immediate placement of a crown aiming to create an inaccessible space[41,45] might limit bone resorption and soft tissue recession and increase soft tissue height over time.

CONCLUSIONS

The placement of implants with a hyperbolic convergent profile collar in the subcrestal position resulted in higher buccal bone resorption and more soft tissue recession compared to the crestal implants with respect to the level of the bone crest at placement.

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