Healing at Implants Placed in an Alveolar Ridge with a Sloped Configuration: An Experimental Study in Dogs

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ABSTRACT

Purpose: To study healing around implants placed in an alveolar ridge with a sloped lingual-buccal configuration.

Materials and Methods: Six Labrador dogs were used. Buccal bone defects were prepared in the mandible after extraction of premolars. Three months later, two test implants with a sloped marginal design and two control implants were placed in the chronic defect area with a sloped lingual-buccal configuration of each premolar region. The test implants were placed in such a way that the buccal margin of the implant coincided with the buccal bone crest. The lingual margin of the control implants was placed to a similar depth as the lingual margin of the test implants. Abutments were connected to the implants in the right mandibular premolar region and flaps were sutured around the neck of the abutments. In the left side of the mandible, cover screws were placed and the flaps were sutured to cover the implants. Biopsies were obtained 4 months later and prepared for histological examination.

Results: It was demonstrated that healing around implants placed in an alveolar ridge with a sloped lingual-buccal configuration resulted in the preservation of a vertical discrepancy between the lingual and buccal marginal bone levels around implants with either a regular cylindrical outline or a modified marginal portion that matched the slope of the alveolar ridge.

Conclusion: As the marginal buccal portion of the control implants with a regular design had no bone support, it is suggested that implants with a modified marginal portion may be considered in recipient sites with a sloped lingual-buccal configuration.

KEY WORDS: bone defect, dental implants, histology, preclinical, titanium

INTRODUCTION

Healing following implant installation involves different patterns of remodeling in the alveolar ridge. The ensuing result of such processes is characterized by the establishment of mature bone structures in contact with the implant and is recognized as osseointegration.[1,2] The early phases of healing will also generate changes in the marginal bone level around implants. Åstrand and colleagues[3] in a 5-year prospective study evaluated bone level changes following implant installation, abutment connection, and the delivery of the fixed reconstruction. It was reported that significant bone loss occurred following implant surgery and, to a less degree, also following abutment connection, while bone loss following connection of prosthesis and at annual follow-up examinations during the 5-year period was minor. Similar findings were presented in an experimental study in dogs by Berglundh and colleagues.[4] They studied bone response to implant installation and subsequent functional load and reported that substantial

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DOI 10.1111/j.1708-8208.2012.00460.x

bone loss took place after implant installation while minor bone loss was detected at later stages during the experiment.

Marginal bone level changes observed in radiographs are restricted to the interproximal aspects of the implants. Changes that occur at buccal and lingual aspects of an implant, however, are difficult to detect. While conventional radiographs may be insufficient tools in studies aiming at describing longitudinal changes in the marginal bone support at buccal and lingual aspects, surgical reentry procedures with clinical assessments have been introduced in clinical protocols.[5,6] Experimental models offer several advantages in relation to clinical protocols. In addition to conventional clinical and radiographic documentation, the histological preparation of tissue samples provides examinations of all possible aspect of an implant. Although histology is to be regarded as an end-point assessment, experimental studies have provided important information on healing around implants placed in extraction sockets or healed ridges with compromised dimensions.[7]

When implants are to be placed in recipient sites with a large discrepancy between the lingual and buccal bone, a resective approach with the aim of establishing optimal bone level conditions has to be considered. An opposite strategy of preserving a higher lingual ridge may cause esthetic problems and jeopardize integration of bone with the lingual aspect of the implant. In an experimental study in dogs, Carmagnola and colleagues[8] evaluated healing around implants that were placed in a ridge with a large discrepancy between the lingual and buccal bone. The implants were placed using the lingual ridge as a reference and the buccal and interproximal aspects of the 4 mm marginal portion of the implants had no bone contact following implant placement. The histological analysis of bone healing after 7 months at buccal and lingual aspects revealed that resorption had occurred at the lingual bone crest and that the resulting discrepancy between the buccal and lingual bone support was smaller than that at implant placement. A similar strategy was applied in a dog experiment by Welander and colleagues.[9] In the study referred to, however, the created discrepancy between the lingual and buccal bone was smaller and the implants were placed in such a way that the buccal bone crest was used as a reference. Despite the differences in experimental design between the two studies, Welander and colleagues[9] suggested that the preservation of the discrepancy between lingual and buccal bone levels that became established following healing is depending on the magnitude of the difference in bone height that existed at the time of implant placement. Considering the option of avoiding resection of the lingual bone and using the lingual bone crest as reference during implant installation without compromising the esthetic outcome, an implant with a matching design in relation to the discrepancy in bone height may be considered. The aim of the present experiment was to study healing around implants that were placed in an alveolar ridge with a sloped lingual-buccal configuration.

MATERIALS AND METHODS

Six Labrador dogs, about 1 year old, were used. The Regional Ethics Committee for Animal Research, Göteborg, Sweden, approved the experimental protocol. All surgical procedures were performed using general anesthesia induced with propofol (10 mg/ml, 0.6 ml/kg) intravenously and sustained with $N_2O : O_2$ (1 : 1.5–2) and isoflurane using endotracheal intubation. All mandibular premolars and the first, second, and third maxillary premolars were extracted at the start of the experiment. Immediately after tooth extraction, buccal and lingual full thickness flaps were raised in both sides of the mandible and a 2-mm-deep groove was prepared between the extraction sockets. A second preparation was made in a perpendicular alignment from the buccal aspect and about 2 mm apical of the bone crest. The marginal 2-mm buccal bone portion of the extraction sockets was removed. The bone defect thereby created resulted in a buccal-lingual dimension of the alveolar crest of about 3 to 4 mm. The flaps were adjusted and sutured.

Three months after tooth extraction and defect preparation, mucoperiosteal flaps were once again elevated in both sides of the mandible. Osteotomy preparations, 11 mm deep, were made in four sites in each premolar region. Four test implants (Profile™ OsseoSpeed 5.0 mm, length 11 mm; Astra Tech Implants® Dental System, Astra Tech AB, Mölndal, Sweden) with a sloped marginal design (Figure 1) were used together with four control implants (OsseoSpeed™ 5.0 mm, length 11 mm; Astra Tech Implants Dental System) in each animal. Two test and two control implants were placed in a randomized sequence in each premolar compartment (Figure 2). Owing to the defect morphology in the recipient sites and the design of the

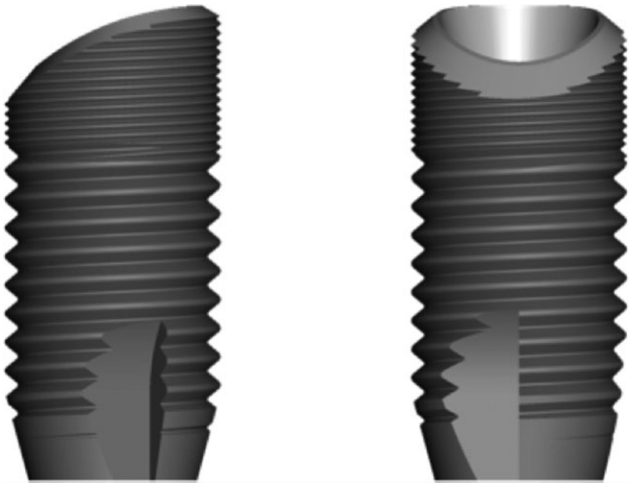

Figure 1 Design of the test implant. Interproximal and buccal aspects.

test implant, the test implants were placed in such a way that the buccal margin of the test implant coincided with the bone crest at the buccal aspect. The lingual part of the test implant was located at the level of or apical of the lingual bone crest. The lingual margin of the control implants was placed to a similar depth as the lingual margin of the test implants. Thus, the buccal margin of the control implants was located about 1.6 mm coronal of the buccal bone crest. Abutments and healing caps (Uni abutment, 2 mm; Astra Tech Implants Dental System) were connected to the implants in the right mandibular premolar region and flaps were adjusted and sutured around the neck of the abutments. In the left side of the mandible, cover screws were placed and the flaps were sutured to cover the implants.

The sutures were removed after 14 days and a 4-month plaque control period was initiated at the implants that were placed using a nonsubmerged installation procedure, that is, the right side of the mandible. The plaque control program included cleaning of implants and teeth with a toothbrush once a day, 5 days a week. Clinical examinations were performed during the course of the experiment. Radiographs were obtained at implant installation and at the termination of the experiment. Four months after implant placement, the dogs were euthanized with a lethal dose of Sodium-Pentothal® (Hospira Enterprises B. V., Hoofddorp, the Netherlands) and perfused through the carotid arteries by a fixative.[10] The mandibles were removed and placed in the fixative. Each implant site including the implant and the soft and hard peri-implant tissues was dissected using a diamond saw (Exakt®, Kulzer, Germany). Radiographs were obtained in buccal-lingual plane from each block biopsy prior to histological processing.

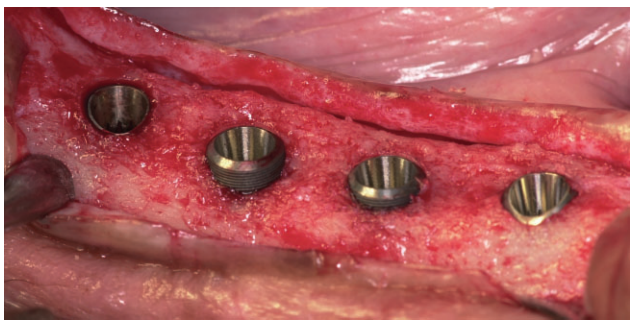

Figure 2 Clinical photograph illustrating test (left and right positions) and control (two central positions) implants after implant installation.

Histological Preparation and Analysis

From each premolar region, one test and one control implant unit was processed for ground sectioning.[11,12] The remaining two biopsies were processed using a modification of the fracture technique as described by Berglundh and colleagues.[13,14] Implant blocks designated for ground sectioning were dehydrated in serial steps of alcohol concentrations and subsequently embedded in methacrylate resin (Technovit 7200 VLC, Exakt). Using a cutting-grinding unit (Exakt Apparatebau, Norderstedt, Germany) and a microgrinding system (Exakt Apparatebau), the blocks were cut in a buccolingual plane and two central sections from each implant were produced and ground to a final thickness of approximately 30 µm. The sections were stained in toluidine blue[15] or fibrin stain of Ladewig. The tissue samples designated for the "fracture technique" were placed in ethylene diamine tetraacetic acid (EDTA). Before the hard tissue was fully decalcified, mesial and distal incisions – parallel with the long axis of the implant – were made through the peri-implant tissues and one buccal and one lingual tissue portion was obtained. Decalcification was completed in EDTA. The specimens were dehydrated in serial steps of ethanol concentrations, defatted in xylene, rinsed in absolute ethanol (99.9%), and subsequently embedded in LR White Resin (Hard grade) (London Resin Company Ltd, Reading, Berkshire, England). Sections were produced with the microtome set at 3 µm and stained in Periodic Acid-Schiff (PAS) and toluidine blue.[16]

The analysis was performed using a Leica DM-RBE microscope (Leica, Heidelberg, Germany) equipped

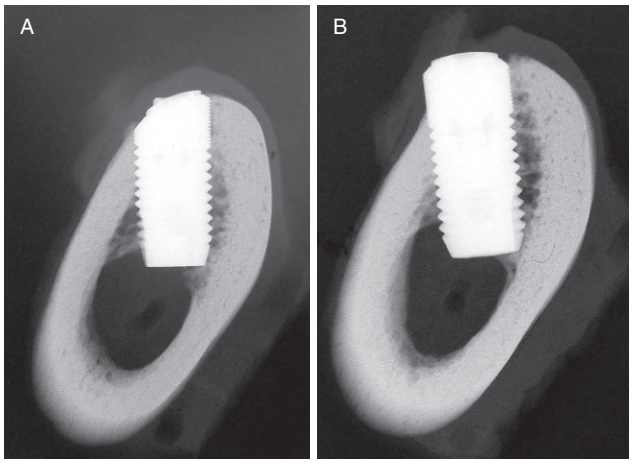

Figure 3 Buccal-lingual radiographs from test (A) and control (B) implants representing submerged sites obtained following biopsy procedures. Note the test implant design matching the sloped configuration of the alveolar ridge.

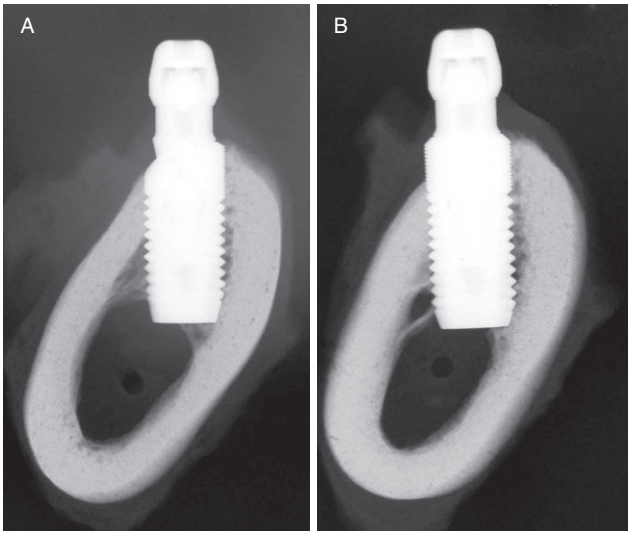

Figure 4 Buccal-lingual radiographs from test (A) and control (B) implants representing nonsubmerged sites obtained following biopsy procedures. Note the test implant design matching the sloped configuration of the alveolar ridge.

with an image system (Q-500 MC, Leica). In the ground sections, the following landmarks were identified and used for linear measurements: the implant rim, that is, the most marginal and external position of the implant (IR), the marginal level of bone-to-implant contact (B), and the position of the bone crest (BC). The distances between the landmarks were assessed in a direction parallel to the long axis of the implant. Ground sections and decalcified specimens from nonsubmerged sites were used for the analysis of soft tissue dimensions and the following landmarks were identified: the position of the mucosal margin (PM), the apical termination of the barrier epithelium (aJE), and the marginal level of bone-to-implant contact (B).

Data Analysis

Mean values for all variables were calculated for each implant in each animal. Differences were analyzed between implant types using the Student's *t*-test for paired samples ($n = 6$). The null hypothesis was rejected at $p < .05$.

RESULTS

Five initially submerged implants (two control and one test implants in one dog and two control implants in a second dog; five out of 24) penetrated the mucosa early after implant placement. Healing was uneventful in all other implant sites. Buccal-lingual radiographs from test and control implants representing nonsubmerged and submerged sites are presented in Figures 3 and 4.

Ground sections from test and control implants that were placed using a nonsubmerged technique are illustrated in Figures 5 and 6. The results of the linear measurements made in the ground sections are presented in Tables 1 and 2. The distance IR-B of the submerged test implants was 1.84 mm at the lingual aspect and 0.23 mm at the buccal aspect. The corresponding distances at the control implants were 1.06 and 1.58 mm, respectively (see Table 1). The IR-B distance at nonsubmerged implants was 1.12 mm at the lingual aspect of test implants and 1.55 mm at the control implants. The corresponding distances at the buccal aspect were 0.15 (test) and 1.91 mm (control) (see Table 2). The differences in buccal bone position between test and control implants were statistically significant.

In five out of 12 test implants, the marginal position of bone-to-implant contact at the buccal aspect was identified on the shoulder part of the implant. The buccal implant rim (IR) at the test implants was on the average between 0.30 and 0.56 mm apical of the bone crest (BC), while at control implants the buccal rim was positioned between 1.52 and 1.86 mm coronal of the bone crest. At lingual sites, the IR was located between 0.55 (control) and 0.73 mm (test) coronal of BC at submerged implants. The corresponding distances at nonsubmerged implants were 0.69 and 0.46 mm, respectively.

A further analysis of the linear measurements revealed that the vertical discrepancy between the

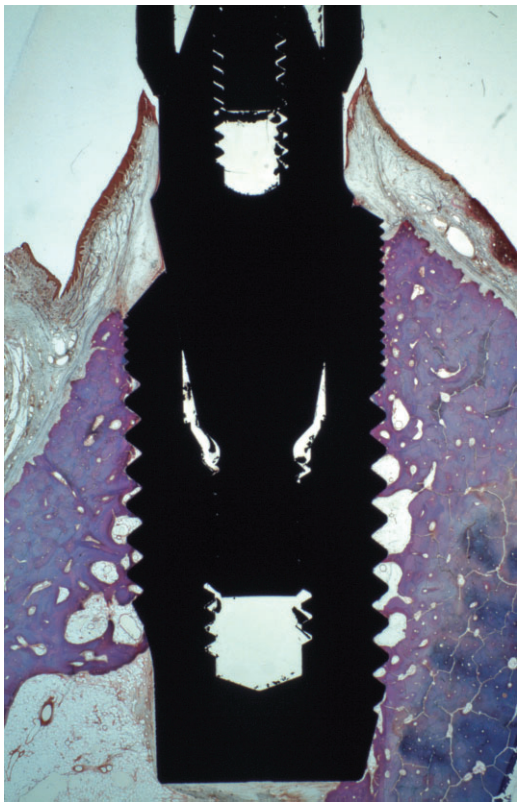

Figure 5 Buccal-lingual ground section of a test implant (nonsubmerged site). Note the marginal bone level in relation to the modified marginal portion of the implant.

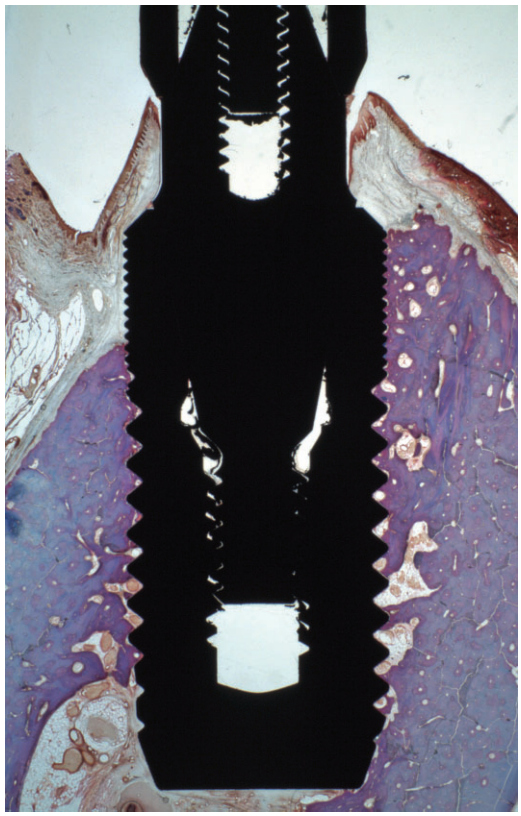

Figure 6 Buccal-lingual ground section of a control implant (nonsubmerged site). Note the discrepancy in marginal bone levels between the buccal and lingual aspects of the implant.

lingual and buccal rim (IR) of the test implants was on the average 1.82 ± 0.09 mm. Furthermore, the marginal bone level at buccal aspects was consistently identified at a more apical position than that at lingual aspects. This discrepancy was more pronounced at nonsubmerged sites than at submerged implant sites of the test implants (0.85 mm vs 0.21 mm). The corresponding data for the control implants were 0.36 (nonsubmerged) and 0.52 mm (submerged).

The results from the analysis of the soft tissue dimensions are presented in Table 3. The height of the peri-implant mucosa (PM-B) in test and control sites was 3.10 and 3.01 mm (lingual) and 3.70 and 3.58 mm (buccal), respectively. The length of the barrier epithelium (PM-aJE) was 2.29 and 1.82 mm at buccal aspects of test and control sites. This difference was statistically significant. On lingual aspects of test and control sites, the epithelial dimensions were 2.00 and 2.20 mm, respectively.

DISCUSSION

The present experiment was performed to evaluate healing around implants placed in an alveolar ridge with a sloped lingual-buccal configuration. Using implants with either a regular cylindrical outline or a modified marginal portion that was designed to match the slope in the lingual-buccal direction, it was demonstrated that healing resulted in the preservation of a vertical discrepancy between the marginal bone level at the lingual and buccal aspects.

TABLE 1 Results (Millimeter) from the Linear Measurements Made in the Ground Sections from the Submerged Implant Sites

	Test	Control
Lingual aspect		
IR-B	1.84 (1.23)	1.06 (1.37)
IR-BC	0.73 (0.71)	0.55 (1.20)
Buccal aspect		
IR-B	0.23 (0.85)*	1.58 (1.02)
IR-BC	−0.56 (0.78)*	1.52 (0.94)

*Statistically significant difference compared to control. $p < .05$ ($n = 6$). Negative values indicate bone landmark coronal of IR. Mean values and standard deviation.
B = marginal level of bone-to-implant contact; BC = position of the bone crest; IR = implant rim, that is, the most marginal and external position of the implant.

TABLE 2 Results (Millimeter) from the Linear Measurements Made in the Ground Sections from the Nonsubmerged Implant Sites

	Test	Control
Lingual aspect		
IR-B	1.12 (0.76)	1.55 (1.16)
IR-BC	0.46 (0.65)	0.69 (0.83)
Buccal aspect		
IR-B	0.15 (0.68)*	1.91 (1.17)
IR-BC	−0.30 (0.95)*	1.86 (1.13)

*Statistically significant difference compared to control. $p < .05$ ($n = 6$). Negative values indicate bone landmark coronal of IR. Mean values and standard deviation.
B = marginal level of bone-to-implant contact; BC = position of the bone crest; IR = implant rim, that is, the most marginal and external position of the implant.

Healing around implants placed in a chronic defect with large discrepancies between the buccal and lingual bone was studied by Carmagnola and colleagues.[8] They prepared large buccal bone defects in beagle dogs concomitant with the extraction of mandibular premolars. Implants were placed in the defect area 8 months later. While the lingual aspects of the implants were completely invested in bone, the interproximal and buccal aspects of the marginal 4 mm portion of the implants had no bone support. Biopsies were obtained 7 months later and the histological analysis revealed that bone regrowth had occurred at the buccal aspect, while a considerable bone resorption was evident at the lingual aspect of the implants. The model presented by Carmagnola and colleagues[8] and the experimental design applied in the present study have many features in common. Although the vertical dimension of the chronic defect that was prepared in the study by Carmagnola and colleagues[8] was larger than that produced in the current experiment (4 vs 2 mm), the placement of implants in the defect area with the lingual aspects of the implants initially invested in bone was similar. The healing that occurred around the nonsubmerged control implants in the present study resulted in a discrepancy of marginal bone levels between the buccal and lingual aspects of 0.36 mm, while in the study by Carmagnola and colleagues[8] the corresponding data were about 1.0 mm. The discrepancy between the buccal and lingual bone levels that become established following healing may to some extent be depending on the magnitude of the initial buccal-lingual bone height discrepancy. On the other hand, the test implants in the present study, which were designed with a marginal sloped configuration that was intended to match the bone defect morphology, presented a discrepancy in buccal and lingual bone levels in the nonsubmerged sites that was on the average 0.85 mm. Considering the difference between test and control implants in the current study, it may be suggested that the design of the implant may improve the preservation of buccal-lingual bone height discrepancies. In this context, it should be pointed out that the results from the submerged implant sites did not support this concept. The lingual bone levels at the test implants of the submerged sites were situated at a more apical position than that at the test implants of the nonsubmerged sites. One reason for the difference in lingual bone levels between submerged and nonsubmerged implant sites may be related to the fact that some initially submerged implants penetrated the mucosa early after implant placement.

TABLE 3 Results (Millimeter) from the Linear Measurements Made in the Ground Sections and Decalcified Specimens Representing the Nonsubmerged Implant Sites

	Test	Control
Lingual aspect		
PM-B	3.10 (0.49)	3.01 (0.22)
PM-aJE	2.00 (0.54)	2.20 (0.44)
Buccal aspect		
PM-B	3.70 (0.63)	3.58 (0.31)
PM-aJE	2.29 (0.54)*	1.82 (0.38)

*Statistically significant difference compared to control. $p < .05$ ($n = 6$). Mean values and standard deviation.
aJE, apical termination of the barrier epithelium; B, marginal level of bone-to-implant contact; PM, position of the mucosal margin.

The finding on preserved discrepancies in buccal and lingual bone levels following placement of implants in bone defect areas was reported in another experimental study in dogs by Welander and colleagues.[9] They placed two-part implants in chronic defects in the mandibular premolar region in such a way that the implant margin coincided with the buccal bone crest, while the lingual bone crest became situated about 2 mm coronal of the implant margin. Using the installation technique with a "subcrestal" implant position, Welander and colleagues[9] demonstrated that it was possible to obtain different marginal bone levels at buccal and lingual aspects following healing. Despite the differences in implant

design between the implants in the study by Welander and colleagues[9] and the test implants in the present study, the installation procedure was carried out in such a way that the buccal rim of the implant was positioned in level with the buccal bone crest. While the sloped design of the test implants in the current experiment made it possible to bridge the discrepancy in bone height between buccal and lingual aspects, the lingual bone contact in the study by Welander and colleagues[9] was established to the transmucosal (abutment) part of the implant.

The present experiment introduced an implant with a modified marginal configuration, the geometry of which was intended to follow the lingual-buccal slope of the alveolar ridge. Implants with a modified marginal design were also used in an experimental study by Choi and colleagues.[17] They analyzed healing around implants with a scalloped design that were placed in beagle dogs. As the scalloped design presented the highest level of the implant at the interproximal aspects and the lowest level toward the lingual and buccal aspects, the analysis in the study by Choi and colleagues[17] was confined to the interproximal surfaces of the implants. Thus, the current experiment differed from the study by Choi and colleagues[17] not only with respect to the design of implants but also regarding comparisons made between buccal and lingual aspects of the implants. In this context, it should also be realized that the design of the test implant in the current experiment influenced the installation procedure in regard to the positioning of the buccal margin of the implants in relation to the buccal bone crest. Thus, the midbuccal part represented the lowest position of the test implant margin and during implant placement the rotation of 360° resulted in a 0.66-mm additional vertical depth. In the majority of sites in the present study, the buccal margin of the test implant coincided with the buccal bone crest after installation, while in few sites the buccal margin was positioned at most 0.3 mm apical or coronal of the buccal bone crest.

In the present study, healing following implant installation occurred with implants placed in both submerged and nonsubmerged positions. The purpose of using this protocol was to unravel whether the establishment of bone levels at the buccal and lingual aspects of the implants placed in the defect sites was influenced by the dimensions of the soft tissue seal. Thus, in the analysis of mucosal dimensions at nonsubmerged sites in the present study, small differences were found between test and control implants regarding the overall height of the peri-implant mucosa, while the barrier/junctional epithelium was significantly longer at the buccal aspect of the test implants than that at control implants. On the other hand, comparisons made between lingual and buccal aspects of both test and control implants revealed larger dimensions of the mucosa at the buccal aspect than at the lingual aspect. The difference in the height of the mucosa between buccal and lingual aspects was smaller than the corresponding discrepancy in bone levels. Similar observations were made in the experimental studies by Carmagnola and colleagues[8] and Welander and colleagues.[9] In both publications referred to, it was reported that the position of the soft tissue margin was not influenced by the discrepancy in bone levels between the lingual and buccal aspects of the implants.

In summary, healing around implants placed in an alveolar ridge with a sloped lingual-buccal configuration resulted in the preservation of a vertical discrepancy between the marginal bone level at the lingual and buccal aspects around implants with either a regular cylindrical outline or a modified marginal portion that was designed to match the slope of the alveolar ridge. As the marginal buccal portion of the control implants with a regular design had no bone support, it is suggested that implants with a modified marginal portion may be considered in recipient sites with a sloped lingual-buccal configuration when bone augmentation is not indicated.

ACKNOWLEDGMENT

This study was supported by grants from Astra Tech AB, Mölndal, Sweden.

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