Effect of Buccal Gap Distance on Alveolar Ridge Alteration After Immediate Implant Placement: A Microcomputed Tomographic and Morphometric Analysis in Dogs

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Alveolar ridge resorption is an inevitable remodeling process after dental extraction. The resorption is more pronounced at the buccal/facial than the lingual/palatal aspects of the ridge.[1–3] This may decrease the success rate of implant placement or impair the final restorative outcome.[4,5] In 1881, Roux suggested that alveolar bone resorption after tooth extraction is caused by disuse atrophy. The forces on the bone are reduced after tooth loss, and the parts of alveolar bone that are not sufficiently used are removed.[6]

Immediate implant placement was introduced as a mean to install implant immediately after tooth extraction, focusing on preserving the original conditions of alveolar bone dimensions and soft tissue contour after tooth loss.

Introduction: *The buccal bone resorption and the deformation of soft tissue contour are major problems of immediate implant treatment. This study aims to examine the changes of alveolar bone and soft tissue after immediate implant placement in different buccal gap distances.*

Materials and Methods: *Eight implants were placed randomly in the mandibular premolar sockets of 6 hybrid dogs with 1, 2, and 3 mm buccal gap distances. The dogs were killed after 2 or 4 months for morphometric and microcomputed tomography analyses.*

Discussion: *After 2 months, the 3-mm group had the highest buccal bone volume (BV), buccal bone/soft tissue thickness, and the lowest bone resorption. The wider the buccal gap, the more buccal bone and soft tissue were formed in this experimental setting. After 4 months, the buccal BV had decreased significantly in the 1-mm and the 2-mm groups, whereas the 3-mm group resisted to buccal bone resorption. This difference was more pronounced at the crest.*

Conclusion: *The 3 mm is the optimal gap distance among the groups examined, which drastically influences the healing of bone and soft tissue surrounding the implants. (Implant Dent 2015;24:70–76)*

Key Words: buccal gap, bone resorption, bone remodeling, implant position

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The main determinant of the success of immediate implant placement is an osseointegrated fixture suitable for functional restoration and esthetic outcome. Moreover, this technique also reduces the number of surgical procedures, eliminates the interval between tooth extraction and implant insertion, and adjusts ideal implant orientation during its installation.[7–11] Although immediate implant placement has been shown to integrate with a high success rate similar to the implant placed with a delayed approach,[12–18] recent studies have shown that implants placed into extraction sockets do not necessarily prevent alveolar ridge changes[12–15] and may often be subject to some labial gingival recession.[17–21] In a retrospective analysis of 42 single-tooth implants placed in the esthetic zone, a significant change in crown height due to marginal tissue recession of approximately 1 mm was noted.[19] Thin tissue biotypes showed a slightly greater recession than thick-tissue biotypes.[19] Other factors that can potentially influence the bone dimensional variation after immediate implant placement have subsequently been identified. They include the thickness of the buccal bone plate,[22,23] the dimensional position of implant,[22–24] bone grafting on the buccal periimplant marginal defect,[25] and flap elevation technique.[26,27] Furthermore, implant environments and patients' conditions such as the reason for extraction and smoking habits are factors influencing the results of alveolar bone resorption after immediate implant placement.[28,29]

The numerous dog studies[30–33] and human clinical trials[14,22,34,35] showed that the amount of bone loss varies depending on many factors. In general, the horizontal bone loss is greater than the vertical bone loss. The amount of bone loss is larger on the buccal than the lingual side because the buccal wall is typically thinner.[1,36] In human hard tissue, the typical bone resorption of an extraction socket is more severe in the horizontal dimension (3.79 ± 0.23 mm) than vertical dimension (0.84 ± 0.62 mm on mesial, 0.80 ± 0.71 mm on distal, and 1.24 ± 0.11 mm on buccal sites) after 6 months.[37] One of the important factors in determining implant success is the maintenance of the periimplant tissues. Buccal bone and soft tissue remodeling around implants placed into a fresh extraction site is important as their resorption results in gingival recession and poor esthetic outcome. Data are still lacking on what is the optimal buccal gap distance to maximize buccal bone fill and to minimize buccal bone and soft tissue losses.

The objective of this study was to determine the optimal horizontal implant position on alveolar ridge alteration after immediate implant placement. Immediate implants placed with different implant-buccal plate distances were evaluated by morphometric and microcomputed tomography analyses in dogs.

MATERIALS AND METHODS

Treatment

Six hybrid Beagle/Foxhound dogs, 1-year old and weighing 17 to 19 kg, were included in the experiment. The animal experiments were approved by the Institutional Animal Care and Use Committee of Tokyo Medical and Dental University. All surgical procedures were performed under general anesthesia. The following medications were used subcutaneously: acepromazine (0.25 mg/kg), atropine (0.04 mg/kg), and a 4% solution of sodium thiopental (25–30 mg/kg). After disinfection of the surgical site with 10% povidone-iodine solution, local anesthetic (Lidocaine HCl 2% with epinephrine 1:100,000) was administered at the respective buccal and lingual sites by infiltration. The second and third premolars (2P2 and 3P3) in both quadrants of the mandible were removed (Fig. 1). Minimal displacement of the tissue was performed to disclose the buccal and lingual hard tissue wall of the ridge. The teeth were extracted without mucoperiosteal flap elevation. Both the mesial and distal roots of the 2P2 and 3P3 sockets were used for implant placement. Implants (Laser-Lok, diameter 3.0 mm, length 10.5 mm; BioHorizons, Birmingham, AL) were installed in the fresh extraction sockets with minimal flap surgery. All implants were placed with the implant shoulder level with the marginal bone crest (equicrestal). Healing abutments were placed on the implants in a single-staged fashion. Three different implant positions were prepared at random positions on the mandible, including 4 experimental sites on each side of the arch.

1. Buccal position: 0 to 1 mm from buccal plate.
2. Middle position: >1 to 2 mm from buccal plate.
3. Lingual position: >2 to 3 mm from buccal plate.

The measurements of bone and soft tissue dimensions describing the

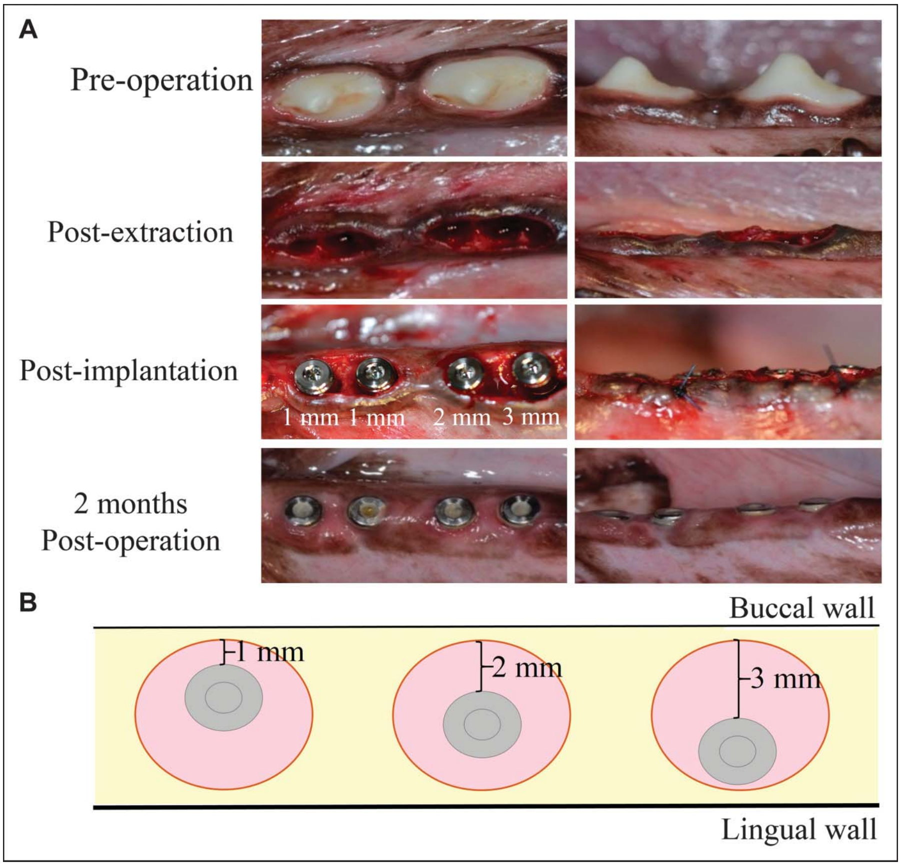

Fig. 1. A, Clinical photographs showing coronal and buccal views preoperation, postextraction, postimplantation, and 2 months after implant placement. Four implants were randomly inserted in the mesial and distal sockets of the second and third premolars at the crestal level. For instance, the implants were inserted at buccal gap distances 1, 1, 2, and 3 mm from left to right. **B**, Diagram showing implant position at 1, 2, and 3 mm measured from the implant shoulder to the inner wall of the buccal bone plate.

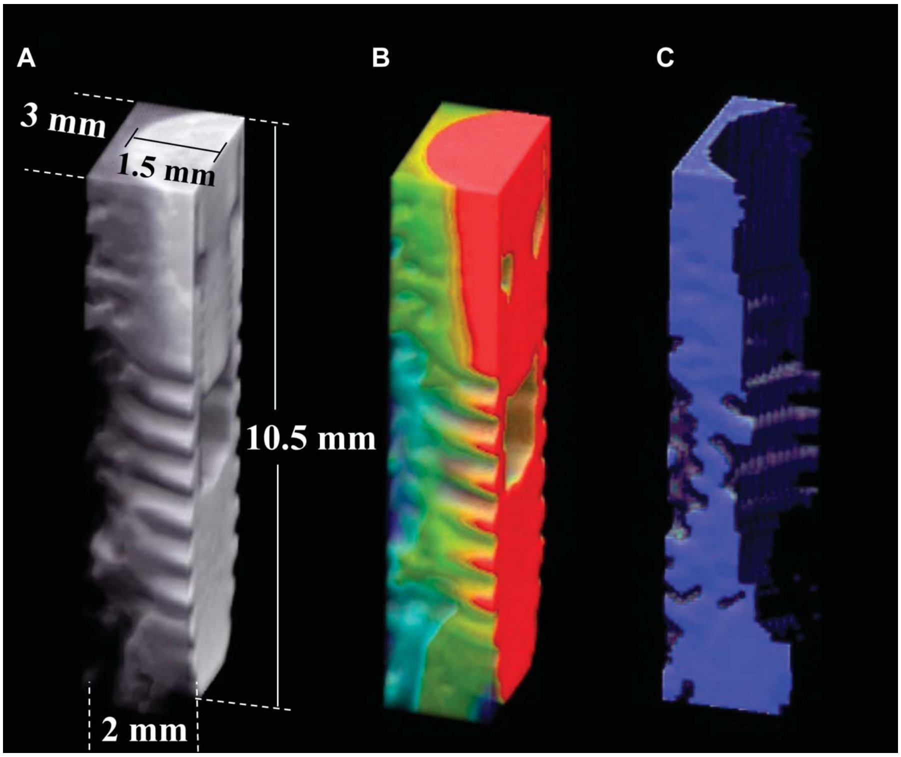

Fig. 2. A–C, Selection of ROI in micro-CT analysis. **A**, 3D volume reconstruction of buccal bone with the half-buccal implant (ROI: 2 mm in width, 3 mm in length, and 10.5 mm in height; implant size: 3 mm in diameter, 10.5 mm in length). **B**, Intensity and colors in an image show bone mineral densities and variances of newly formed bone and implant. **C**, Selection of 3D ROI extracted from the bone in blue color.

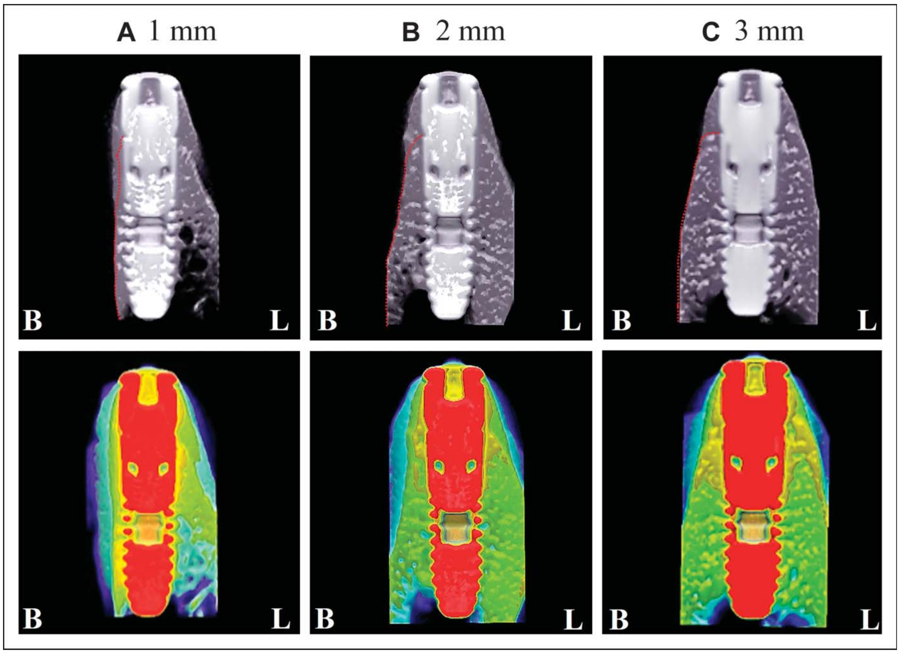

Fig. 3. A–C, Micro-CT images of 3D volume reconstruction and different mineral densities of the bone area around implants at the buccal gap distances of 1, 2, and 3 mm in a longitudinal section. Dashed lines indicate the outline of buccal bone plate, which had dramatically changed at 2 months postimplantation. The differential changes in BMD of newly formed bone were shown in different colors representing various mineral densities from 200 mg/cm^3 (shown in red)—800 mg/cm^3 (shown in green).

extraction site were made immediately after implant placement and at reentry, 2 or 4 months later. Antibiotics and analgesic were given postoperatively. The dogs received 20 mg nalbuphine subcutaneously, 2 times a day as an analgesic for 7 days. Three milliliters of benzathinepenicillin 150,000, procaine-penicillin G 150,000, were administered subcutaneously, once a day every 48 hours, for 7 days. In addition, 100 mg of the antibiotic gentamicin was given subcutaneously, 2 times a day on day 1 and the same dosage once a day from days 2 to 10. The dogs received 4 mg dexamethasone intramuscular once a day on days 1 and 4 to reduce swelling.

The sutures were removed after 2 weeks. The dogs were sedated with an agent containing RAAK½ rompun-xylazine (7.1 mg/mL), acepromazine (2.1 mg/mL), atropine (0.1 mg/mL), and ketamine (50 mg/mL), which was administered intravenously at 1.1 mL/15 kg body weight for suture removal.

The oral hygiene procedures included preoperative teeth scaling and postoperative mouth washing and abutment cleaning. Teeth scaling was done 2 weeks before the operation. Postoperatively, 0.2% chlorhexidine gel (Plak-Out Gel; Hawe Neos Dental, Biaggio, Switzerland) was used 2 times a week for mouth washing and abutment cleaning. A soft diet was maintained throughout the study.

Sacrifice

The animals were killed 2 and 4 months after the implantation procedures. After general anesthesia, the dogs were killed with an overdose of sodium thiopental (30 mg/mL; Abbot Laboratories, Chicago, IL) and perfused with a fixative containing a mixture of 5% glutaraldehyde and 4% formaldehyde through the carotid arteries.

Microcomputed Tomography Analysis

The high-resolution 3-dimension images, volume, and mineral density of newly formed bone were evaluated using polychromatic x-rays microcomputed tomographic (CT) scans. Bone specimens were scanned in a fix position on a rotary stage. They were rotated in 0.4-degree increments on a holder, with each scan requiring 3.5 minutes. The specimens were scanned with a high-resolution micro-CT system (ScanX-mate D090S105; Comscan, Kanagawa, Japan). X-rays passed through an image intensifier and penetrate the mandible. Then, they were captured by a camera and produced 18-μm thickness of 2D slices. After raw image, normalization and defective detector pixel correction were performed, cross-sectional images were reconstructed into a 3D structure by a host computer. The volume and-mineral density of the newly formed bone around each implant were measured using TRI/3D-BON (Ratoc System Engineering Co. Ltd., Tokyo, Japan) image analysis software. The newly formed bone was characterized by bone volume (BV; in cubic millimeters), bone mineral density (BMD; in milligrams per cubic centimeter), and bone thickness (in millimeters). The new bone area was a $2 \times 3 \times 10.5$ mm region that covered both the newly formed buccal bone area and the length of the implant (Fig. 2). The buccal bone thickness was measured at 0, 1, 2, and 3 mm below the implant shoulder. The new bone formation results were analyzed and evaluated statistically.

Bone and Soft Tissue Morphometric Measurement

The alveolar bone and soft tissue thicknesses were measured at 2 mm apical to the implant shoulder before and after implantation to determine the resorption rate of hard and soft tissues around the implant. Spring caliper with blunt ends (YDM Corporation, Tokyo, Japan) was used to measure buccal and lingual ridges thickness and an endodontic file with stopper was used to measure soft tissue thickness under local anesthesia.

Statistical Analysis

The results were reported as the mean and the standard deviation (mean ± SD). Two-way analysis of variance (ANOVA) was employed to determine the effects of 2 independent variables (gap distance and time period; Fig. 4, A and B), and one-way ANOVA was used to determine the effects of 1 independent variable (gap distance, Fig. 4, C–F and Fig. 5). Then, the significantly different results concerning newly formed bone, soft tissue, and dimensional changes of alveolar contour were analyzed among groups using Bonferroni *post hoc* test (Figs. 4 and 5, $*P < 0.05$). The differences between the preoperation and postoperation of each group were compared using Student *t* test (Fig. 5, $*P < 0.05$).

Results

Clinical Observations

All implants integrated successfully, and the soft tissue healing after implant placement was uneventful in all dogs. At the 2-month and 4-month examination intervals, the gingiva surrounding all implants was free of signs of inflammation. The healing abutments were changed to the taller size if soft tissue grew over the healing abutments. There were no complications throughout the experimental period.

Micro-CT Examination

Two months after the immediate implant installation, we observed remarkable hard tissue alterations (Fig. 3). The marginal gap between the implant and the wall of the socket was filled. In the comparison among the 1-mm, the 2-mm, and the 3-mm groups, the wider the buccal gap, the more buccal bone was formed. The buccal bone profile was the thickest in the 3-mm group (Fig. 3, A–C). The buccal defect was filled with newly formed bone from inside the gap shown in the yellow area (BMD ≅ 300 mg/cm^3) at the marginal bone crest. The mature bone was more mineralized and shown in green color (BMD ≅ 800 mg/cm^3). The degradation from the outer buccal wall in

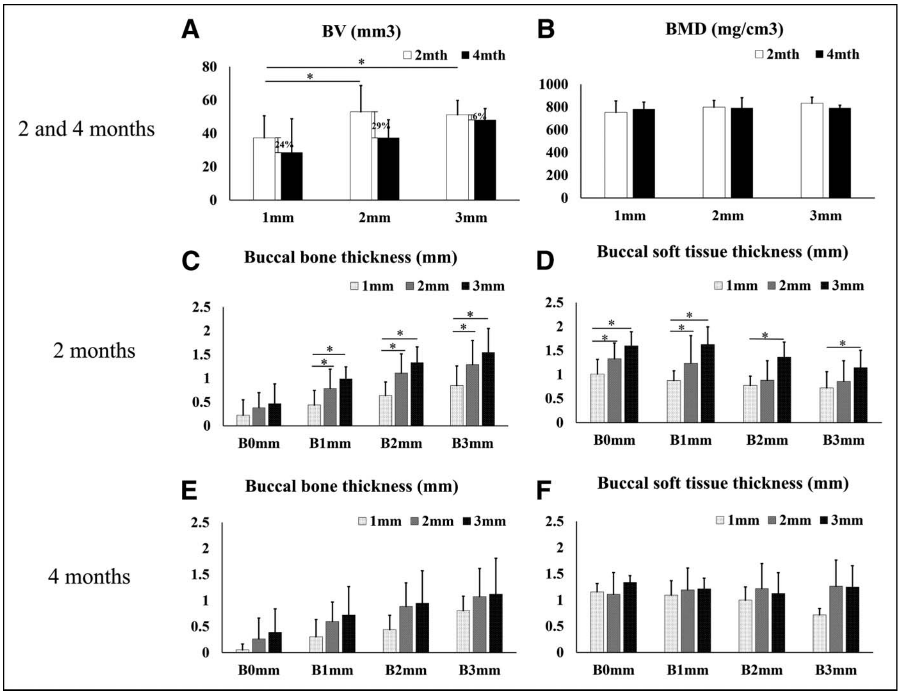

Fig. 4. Graphs of the Micro-CT data in buccal bone and soft tissue response to the different buccal marginal gaps as a function of treatment groups: 1, 2, and 3 mm (a buccal distance measured from the implant shoulder to the inner wall of the buccal bone plate). The values are reported as the mean and the SD: (**A**) BV (in cubic millimeters) and the percentage of the decreases of new bone formation between 2 and 4 months postimplantation were shown, (**B**) BMD (in milligrams per cubic centimeter), (**C** and **D**) buccal bone and soft tissue thicknesses (in millimeters) at 2 months postimplantation at B 0 mm, B 1 mm, B 2 mm, and B 3 mm (a bone level measured at the different positions on the buccal bone wall, B 0 mm = at the bone crest, B 1 mm = at 1 mm apical to the implant shoulder, B 2 mm = at 2 mm apical to the implant shoulder, and B 3 mm = at 3 mm apical to the implant shoulder), (**E** and **F**) buccal bone and soft tissue thicknesses (in millimeters) at 4 months postimplantation at B 0 mm, B 1 mm, B 2 mm, and B 3 mm ($*P < 0.05$).

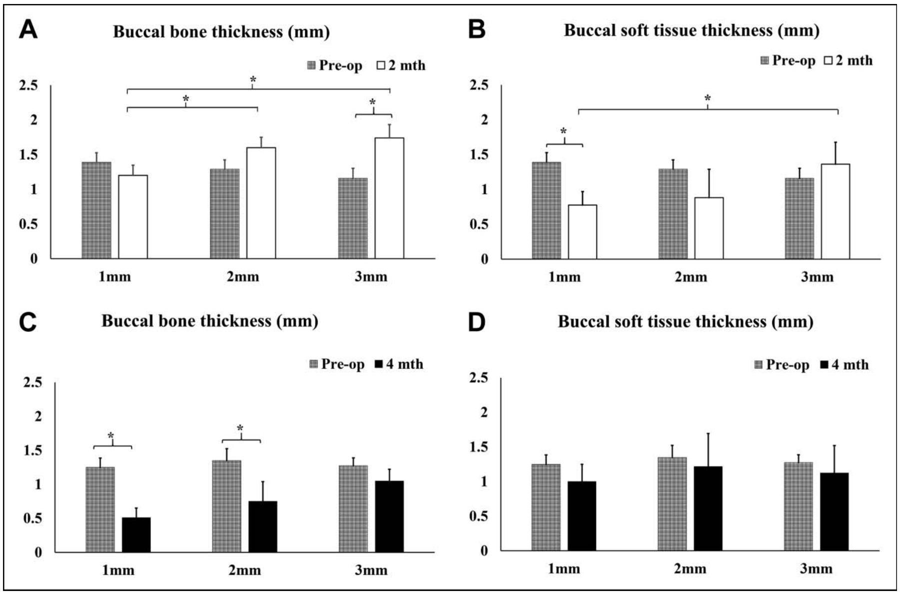

Fig. 5. Dimensional changes of the morphometric measurement in the buccal bone and soft tissue contours of the 1-, 2-, and 3-mm (a buccal distance measured from the implant shoulder to the inner wall of the buccal bone plate) groups at 2 months and 4 months postimplantation. The buccal bone and soft tissue thicknesses were measured at 2 mm apical to the implant shoulder before and after implantation. The values are reported as the mean and the SD. **A**, The buccal bone thickness at preoperation and 2 months postimplantation (in millimeters); **B**, The buccal soft tissue thickness at preoperation and 2 months postimplantation (in millimeters); **C**, The buccal bone thickness at preoperation and 4 months postimplantation (in millimeters); **D**, The buccal soft tissue thickness at preoperation and 4 months postimplantation (in millimeters). The data which did not have significant difference were not shown for the sake of clarity (*$P < 0.05$).

the 1-mm group resulted in a very thin buccal bone around the implant. The new formation of the buccal bone of the 1-mm group was compromised, compared with that in the 2-mm and the 3-mm groups. In Figure 4, A, we compared the newly formed BV by limiting the region of interest (ROI: 2 mm in width, 3 mm in length, and 10.5 mm in height; implant size: 3 mm in diameter, 10.5 mm in length; Fig. 2). Both the 2-mm and the 3-mm groups gained higher BV than the 1 mm group. However, micro-CT was not able to detect a significant difference in the BMD in a quantitative analysis of the immature bone in this ROI among the 1- to 3-mm groups (Figs. 3 and 4, B). Buccal bone and soft tissue thicknesses were measured on buccal side at the bone crest (B 0 mm), 1 mm (B 1 mm), 2 mm (B 2 mm), and 3 mm (B 3 mm) apical to implant shoulder. The preoperative buccal bone plate thickness was ≤2 mm at all sites. The buccal bone thickness at B 1 mm, B 2 mm, and B 3 mm apical to the implant shoulder were increased, with a greater BV around the implants in the 2-mm and the 3-mm groups than the 1-mm group at 2 months postimplantation (Fig. 4, C). The soft tissue thickness of the 3-mm group was the highest among all the groups at B 0 mm, B 1 mm, B 2 mm, and B 3 mm apical to implant shoulder (Fig. 4, D).

At 4 months postimplantation, there was no significant difference in BV, BMD, buccal bone, and soft tissue thicknesses among the 1-, 2-, and 3-mm groups (Fig. 4, A, B, E, F). The BV decreased by 24%, 29%, and 6% between 2-month and 4-month periods in the 1-mm, the 2-mm, and the 3-mm groups, respectively (Fig. 4, A). The buccal BV decreased significantly in the 1-mm group, whereas the 3-mm group was resistant to the buccal bone resorption (Fig. 4, A and E). The buccal soft tissue thickness increased at 4-month healing period but no difference among all groups (Fig. 4, F).

Bone and Soft Tissue Morphometric Measurement

The dimensional changes of bone and soft tissue of buccal ridge in the 1- to 3-mm groups 2 and 4 months postimplantation are shown in Figure 5.

After 2 months, there was a dramatic bone resorption of the buccal bone plate only in the 1-mm group (Fig. 5, A). The width of buccal bone plate in the 1-mm group decreased prominently after 2 months, compared with the formation of buccal bone plate increased in the 2-mm and the 3-mm groups. In addition, we observed a significant difference in buccal soft tissue thickness between the 3-mm and the 1-mm groups (Fig. 5, B). Buccal hard and soft tissue in the 3-mm group was the highest among all groups, whereas the severe resorption of buccal bone thickness occurred in the 1-mm group at 2 and 4 months postimplantation (Fig. 5, A–C).

After 4 months, the buccal bone resorption was increased, and the thickness of the newly formed bone reduced in all the 1- to 3-mm groups (Fig. 5, C). However, the 3-mm group resisted to the bone resorption and the bone thickness remained similar to that in the preoperation period (Fig. 5, C). The buccal soft tissue thickness recovered to the original thickness in all groups at 4 months postimplantation (Fig. 5, D). Notably, there was no difference in the lingual ridge thickness in all groups at 2 and 4 months postimplantation.

DISCUSSION

Recent animal and clinical studies reported that immediate implant placement into fresh extraction sockets will not prevent the occurrence of the alveolar ridge alteration.[14,38,39] However, buccal bone alterations may be reduced by the careful selection of implant position and buccal gap distances.

In this study, the micro-CT images showed the differences in BV and mineral density, which can be detected at the early bone healing period (Fig. 3). Wider buccal gap distances between the implant shoulder and the internal socket wall resulted in the formation of thicker buccal bone and resistance to buccal bone resorption (Fig. 4). We measured the changes in

BV, BMD, and bone/soft tissue thickness of buccal/lingual ridges. A greater amount of buccal bone and soft tissue losses were observed in the 1-mm group. These losses were reduced in the 3-mm group (Fig. 5). Thickening of the buccal bone in the 2- and 3-mm groups occurred at 1 to 3 mm apical to the implant shoulder (B 1–3 mm; Fig. 4, C), whereas that of the soft tissue occurred at the gingival crest and at 1 to 3 mm apical to the implant shoulder (B 0–3 mm; Fig. 4, D). The same trend was observed in bone and soft tissue responses but was less pronounced at 4 months due to progressive bone resorption after immediate implant placement (B 0–3 mm; Fig. 4, E and F). The buccal BV especially at the crestal bone decreased significantly because of severe resorption of bone and soft tissue in the 1-mm and the 2-mm groups, whereas the 3-mm group was resistant to the buccal bone resorption (Fig. 4, E and F). The 3-mm group not only showed the highest volume and thickness of buccal bone and soft tissue at 2 months, but also had the highest resistance to bone resorption at 4 months during the bone remodeling period. Based on the results of this study, implant should be placed at least 3 mm away from the internal socket wall for allowing optimal buccal bone and soft tissue thicknesses to form. This distance also prevented buccal bone resorption in the early healing period.

This prospective study provided extensive data for analyzing the effects of buccal bone and soft tissue changes around unloaded implants under a nonsubmerged environment. The bone degradation from the outer buccal wall in the 1-mm group resulted in a very thin buccal bone around the implant, and the new formation of the buccal bone of the 1-mm group was unsubstantial, compared with that in the 2-mm and the 3-mm groups (Fig. 4, C and E and Fig. 5, A and C). In addition, the reduction of the ridge is greater along the buccal surface than the lingual surface, causing the center of the edentulous site to shift toward the lingual aspect of the ridge resulted in more resorption on the buccal surface. Implant placement in the 1-mm buccal gap distance is close to the buccal plate, which resorbed over time. Therefore, placing implant close to buccal plate (a buccal gap distance <1 mm) is not recommended. It is likely to be harmful to the bone remodeling process and provide unsubstantial bone and soft tissue healing.

It was noted that buccal bone losses increased, especially at 4 months post-implantation (Fig. 4, E). Long span edentulous ridge is one of the factors that resulted in long-term bone and soft tissue resorption of the alveolar ridge. In this study, the buccal bone plates of the dogs were ≤2 mm in every cases. In humans, the mean width of 87% of the buccal bony wall is ≤1 mm, and 3% of the wall is ≤2 mm wide in the premolar site.[40] Recent literature on this topic reported thinner buccal bone crests resulted in more bone resorption.[30,31,41] Spray et al[42] demonstrated that a buccal bone crest thickness <2 mm in width doubled the resorption of a buccal bone crest width >2 mm in width. Long edentulous ridge and thin buccal plate are important factors causing severe bone and soft tissue resorption in immediate implant placement. Furthermore, the Laser-Lok (laser-microtextured implant collar) implant was used in this study; it has been shown to promote attachment of connective fibers and reduce probing depth and periimplant bone loss when compared with machined or smooth collars.[43,44] Therefore, the experiment was designed focusing on the differences of buccal gap distances, although strictly controlling other conditions by using same type of implant, applying the minimal flap technique, preserving gingival health condition, and the periimplant environment. However, the future studies of the effects of long edentulous ridge, the thickness of buccal bone crest, the different types of implant surfaces and long-term implant treatment are necessary to determine the success of this technique to overcome the buccal bone resorption.

Conclusion

The implant should be placed at 3 mm away from the internal socket wall. The 3-mm buccal gap distance is the optimal implant position among the groups examined, which drastically influences the healing of bone and soft tissue surrounding the implants. This gap distance was more resistant to buccal bone resorption and allowed for increasing buccal bone thickness and soft tissue levels than smaller gap distances in the early healing period. Lingual bone and soft tissue changes did not have a significant difference in this study.

Disclosure

The authors claim to have no financial interest, either directly or indirectly, in the products or information listed in the article.

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