Ridge Alterations following Immediate Implant Placement and the Treatment of Bone Defects with Bio-Oss in an Animal Model

Kuo-Mei Hsu, DDS;* Byung-Ho Choi, DDS, PhD;† Chang-Yong Ko;‡ Han-Sung Kim, PhD;§
Feng Xuan, MD;* Seung-Mi Jeong, DDS, PhD¶

ABSTRACT

Background: Conflicting data exist on the outcome of placing Bio-Oss® (Geitslich Pharm AG, Wolhausen, Switzerland) into extraction sockets. It is therefore relevant to study whether the incorporation of Bio-Oss into extraction sockets would influence bone healing outcome at the extraction sites.

Purpose: The aim of this study was to assess peri-implant bone changes when implants were placed in fresh extraction sockets and the remaining defects were filled with Bio-Oss particles in a canine mandible model.

Materials and Methods: Six mongrel dogs were used in the study. In one jaw quadrant of each animal, the fourth mandibular premolars were extracted with an elevation of the mucoperiosteal flap; implants were then placed in the fresh extraction sockets and the remaining defects were filled with Bio-Oss particles. After 4 months of healing, micro-computed tomography at the implant sites was performed. Osseointegration was calculated as the percent of implant surface in contact with bone. Additionally, bone height was measured in the peri-implant bone.

Results: Average osseointegration was 28.5% (ranged between 14.8 and 34.2%). The mean crestal bone loss was 4.7 ± 2.1 mm on the buccal aspect, 0.4 ± 0.5 mm on the mesial aspect, 0.4 ± 0.3 mm on the distal aspect, and 0.3 ± 0.4 mm on the lingual aspect.

Conclusion: The findings from this study demonstrated that the placement of implants and Bio-Oss® particles into fresh extraction sockets resulted in significant buccal bone loss with low osseointegration.

KEY WORDS: dental implants, immediate implant placement, osseointegration, wound healing

INTRODUCTION

In recent years, immediate implant placement into fresh extraction sockets has become a common clinical therapeutic approach as an alternative to a staged surgical protocol. The advantages of immediate implant placement have been reported to include a reduction in the number of surgical interventions, shorter treatment time, and high patient satisfaction.[1,2]

In terms of dimensional ridge alterations, it was suggested that immediate implant placement may counteract the process of bone resorption and maintain the original shape of the ridge.[3] Findings reported from an experimental trial by Araūjo and Lindhe[4] failed to support this hypothesis. The authors reported that when implants were placed in the sockets immediately after tooth extraction, the buccal bone plate underwent a major remodeling process. The authors concluded that immediate implant placement failed to prevent the remodeling that occurred in the walls of the socket.[4] Because implant installation did not prevent biological bone resorption from occurring after tooth extraction, it

*Department of Dentistry, Yonsei University Wonju College of Medicine, Wonju, South Korea; †professor, Department of Oral & Maxillofacial Surgery, College of Dentistry, Yonsei University, Seoul, South Korea; ‡Department of Biomedical Engineering, College of Health Science, Institute of Medical Engineering, Yonsei University, Wonju, South Korea; §associate professor, Department of Biomedical Engineering. College of Health Science, Institute of Medical Engineering, Yonsei University, Wonju, South Korea; ¶associate professor, Department of Dentistry, Yonsei University Wonju College of Medicine, Wonju, South Korea

Reprint requests: Prof. Byung-Ho Choi, Department of Oral and Maxillofacial Surgery, College of Dentistry, Yonsei University, 134 Shinchon-dong, Seodaemun-gu 120-752, Seoul, South Korea; e-mail: choibh@yonsei.ac.kr

DOI 10.1111/j.1708-8208.2010.00316.x

was suggested that the application of biomaterials could interfere with the resorption process. Deproteinized bovine bone (Bio-Oss®, Geitslich Pharm AG, Wolhausen, Switzerland) mineral has been the material of choice for grafting bone defects and extraction sockets.[5–7] Conflicting data exist on the outcome of placing deproteinized bovine bone mineral into extraction sockets. Some studies reported positive findings and concluded that the biomaterial could act as a scaffold for new bone formation.[5–8] However, Fickl and colleagues[9] reported that when placing deproteinized bovine bone mineral into extraction sockets, a marked resorptive process occurred during 4 months of healing at the buccal bone plate. The inconsistency of these results prompted the present study on the effect of incorporation of deproteinized bovine bone mineral into extraction sockets on bone healing.

AIM

The aim of this study was to assess peri-implant bone changes when implants were placed in fresh extraction sockets and the remaining defects were filled with deproteinized bovine bone mineral, and to contribute to the comprehensive body of information used to formulate successful strategies for implant therapy after tooth extraction.

MATERIALS AND METHODS

Six adult female mongrel dogs, each weighing more than 15 kg (range of 15–20 kg), were used in this experiment. The study protocol was approved by the Animal Care and Use Committee of Yonsei Medical Center, Seoul, Korea.

All surgical procedures were performed under systemic (5 mg/kg ketamine and 2 mg/kg i.m. xylazine) and local (2% lidocaine with 1:80,000 epinephrine) anesthesia. In one mandibular jaw quadrant of each animal, sulcular incisions were made starting near the distobuccal edge of the third premolars to the mesiobuccal edge of the first molars. A vertical relieving incision was made in both the mesial region of the first molar and the distal region of the third premolar. The full-thickness buccal flaps were elevated to disclose the marginal 10 mm of the hard-tissue wall of the ridge. The fourth premolars were hemisected with a carbide fissure bur mounted on a low-speed handpiece and removed with minimal trauma in order to preserve the walls of the sockets. One dental implant (length, 10 mm; diameter, 3.5 mm; GSII, Osstem, Seoul, Korea) was placed at the center of the extraction sockets. Osteotomies for inserting the implants were performed to ensure that the fixture shoulder was placed at the level of the marginal portion of the buccal plate (Figure 1). After connecting the healing abutments to the implants, the remaining defect of the extraction socket was filled with Bio-Oss® particles (Geistlich Pharm AG; Figure 2). The flaps were then repositioned and sutured with 4-0 silk sutures. Antibiotic therapy was administered 1 hour before surgery and once daily for 2 days following the surgery. The exposed implant surfaces were cleansed daily with a soft toothbrush and 0.12% chlorhexidine digluconate-soaked gauze. The dogs were placed on a soft diet. Clinical evaluation was performed before hygienic treatment in order to evaluate the health of the peri-implant mucosa and document any signs of inflammation.

The animals used in the study were sacrificed 4 months after implantation. At the time of sacrifice, the

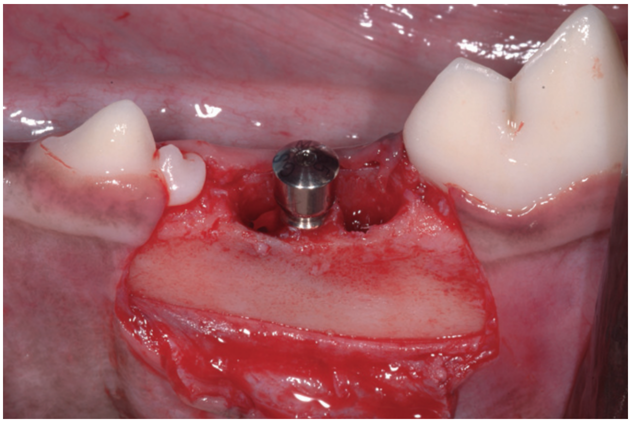

Figure 1 Clinical features after the placement of implants into fresh extraction sockets.

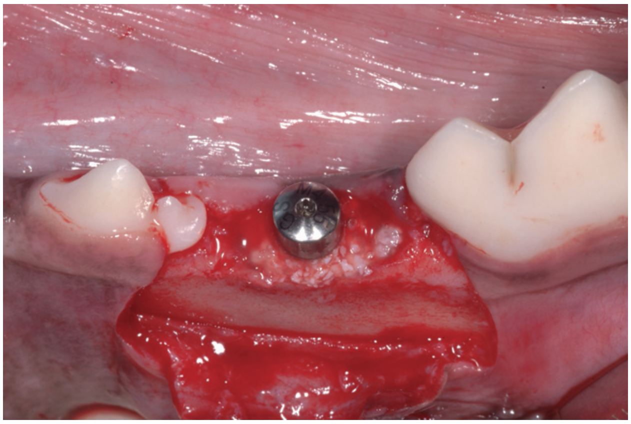

Figure 2 Clinical features after filling the remaining defects of the extraction sockets with Bio-Oss® particles.

flaps were performed to have gross examination of peri-implant bone changes. The bone blocks that contained the implants were excised. The resected bone specimens were fixed for 48 hours in 10% buffered formalin and then stored in 70% ethanol. A morphometric study, using micro-computed tomography (micro-CT) (Skyscan 1076, Skyscan, Antwerpen, Belgium), was used to quantify the bone around the implants. Microtomographic slices were acquired at each 35-µm interval, and computerized three-dimensional reconstruction was performed by accumulating traces of each implant, following the method described by Akagawa and colleagues.[10] Osseointegration was calculated as the percent of implant surface in contact with bone. Additionally, bone height in the peri-implant bone was measured as the distance between the fixture shoulder and the apical level of the marginal bone in contact with the implant. Measurements of bone height were made at the buccal, lingual, mesial, and distal aspects of each fixture.

RESULTS

Healing after implant placement was uneventful in all animals. Overt signs of soft-tissue inflammation (swelling and redness) were seen during the first 2 weeks of healing, but after 4 months, the mucosa adjacent to the implants and teeth appeared to be clinically healthy (Figures 3 and 4). The rough surfaces of the implants were covered by mucosa at all the sites. Upon gross examination of the specimens, buccal bone resorption was significant and the apical level of the marginal bone on the buccal aspect was consistently located at the apical level of the fixture shoulder (Figures 3 and 4). At three of the six implant sites, implant threads greater than 5 mm in length were exposed on the buccal aspects of the implants (Figure 5). The results of micro-CT image analysis are presented in Table 1. The mean crestal bone loss was 4.7 ± 2.1 mm on the buccal aspect, 0.4 ± 0.5 mm on the mesial aspect, 0.4 ± 0.3 mm on the distal aspect, and 0.3 ± 0.4 mm on the lingual aspect (Figure 6). Average osseointegration was 28.5% (ranged between 14.8 and 34.2%; Figure 7).

DISCUSSION

The findings from the present study demonstrated that a marked resorptive process had occurred at the buccal bone plate during the 4 months of healing following placement of the implants and deproteinized bovine bone mineral into the fresh extraction sockets. The

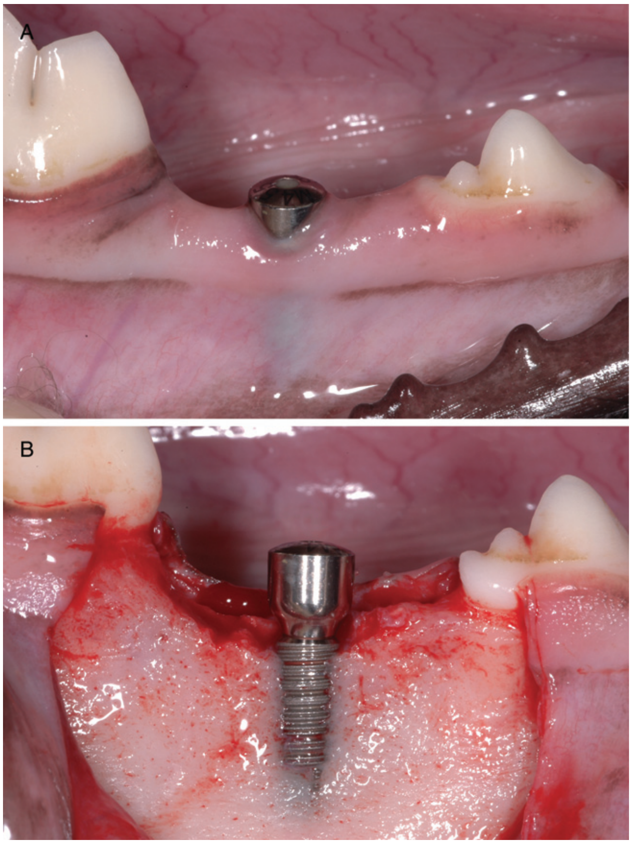

Figure 3 Dog 1, who underwent placement of implants and Bio-Oss® particles into fresh extraction sockets. (A) Clinical features of the mucosa adjacent to the implants at 4 months. Note the normal condition of the mucosa. (B) Photograph of the mandible showing buccal bone loss around the implants.

placement of the implants and deproteinized bovine bone mineral into the fresh extraction sites failed to prevent the remodeling of the buccal wall of the socket. Vertical bone loss at the buccal aspect ranged from 1.7 to 7.6 mm, with a mean bone loss of 4.7 mm. At three of the six implant sites, implant threads greater than 5 mm in length were exposed on the buccal aspects of the implants. The manifest resorption at the buccal aspect was more pronounced than the data previously reported.[1,4,9] Fickl and colleagues[9] assessed bone changes in dogs 4 months following the removal of the distal roots of mandibular premolars and incorporation of Bio-Oss Collagen® into the extraction sockets. Histometric analysis revealed that vertical bone loss at the buccal aspect amounted ranged from 2.8 to 3.3 mm. Araūjo and Lindhe[4] examined dimensional alterations that occurred in dogs during a 3-month interval following implant placement in fresh extraction sockets. The authors reported that vertical bone loss at the buccal aspect was approximately 2.6 mm. A study by de Sanctis

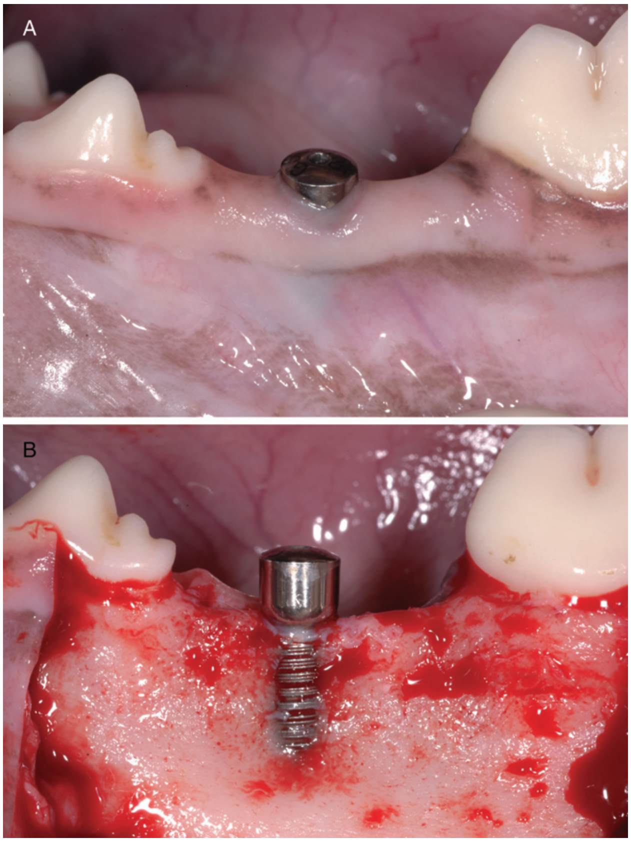

Figure 4 Dog 2, who underwent placement of implants and Bio-Oss® particles into fresh extraction sockets. (A) Clinical features of the mucosa adjacent to the implants at 4 months. Note the normal condition of the mucosa. (B) Photograph of the mandible showing buccal bone loss around the implants.

TABLE 1 Results from Micro-CT Measurements Describing Crestal Bone Loss per Dog

Dog	Buccal	Lingual	Mesial	Distal
1	7.6	0.7	0.7	0.8
2	6.3	0	0	0
3	4.2	0.6	1.2	0.6
4	1.7	0	0	0
5	3.2	0	0	0
6	5.0	0.6	0.6	0.6
Mean	4.7	0.3	0.4	0.4
Standard deviation	2.1	0.4	0.5	0.3

and colleagues[1] reported that the mean vertical loss of the buccal bone plate was approximately 2.5 mm. An explanation for the greater amount of buccal bone loss in the present study might be the size of the extraction socket. The whole socket of the premolar was chosen as the implant-recipient site in the present study, whereas only the distal socket of two-rooted premolar was chosen as the implant-recipient site in the previous studies. Adult dog premolar distal roots have mesiodistal dimensions ranging from 4.1 to 5.4 mm, whereas adult human premolars have mesiodistal dimensions ranging from 6.7 to 7.2 mm.[11] The whole socket of the dog premolar has the advantage of allowing the creation of similar bone defects to that used for immediate implant placement in humans. Therefore, the present study

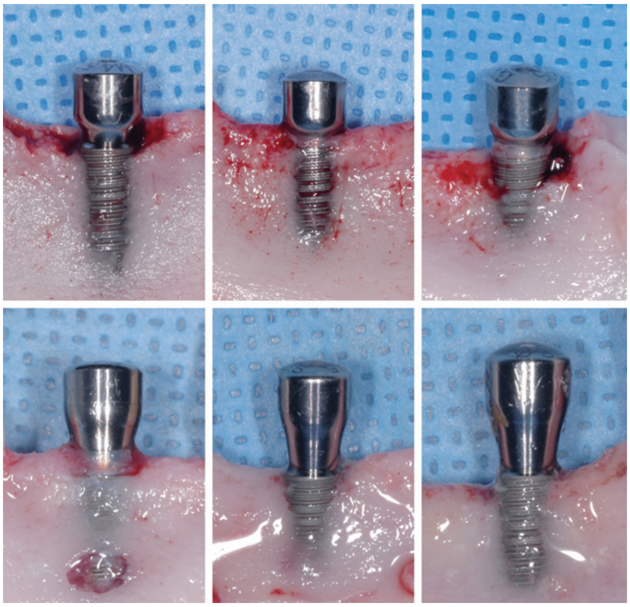

Figure 5 Photograph of the dog specimens.

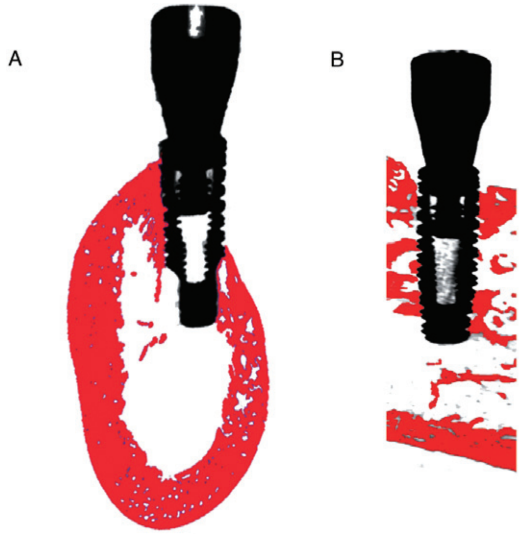

Figure 6 A micro-CT image showing the bone (red) around the implants (black). (A) Bucco-lingual section. (B) Mesio-distal section.

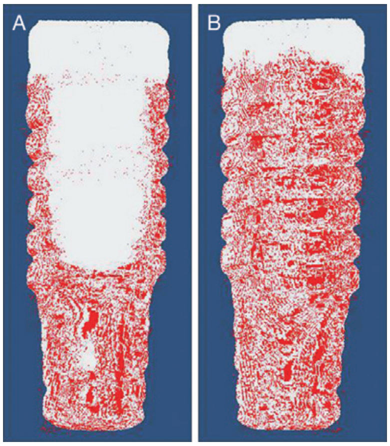

Figure 7 A micro-CT image showing the bone-to-implant contact area (red) around the implant surface (white). (A) Buccal side of the implants. (B) Lingual side of the implants.

design could yield more possible answers to questions on the healing of extraction sockets following placement of implants into fresh extraction sockets, as compared with the previous study design.

There is some concern that implant threads that remain exposed because of incomplete bone coverage can irritate the adjacent peri-implant soft tissues, and possibly lead to gingival recession, progressive bone resorption, and loss of the implant. However, in the present study, clinical examinations at 4 months showed a normal condition of the mucosa even at the implant sites where implant threads greater than 5 mm in length were exposed on the buccal aspects of the implants. Further studies involving a longer time interval are necessary to further determine soft tissue changes with time. Atieh and colleagues[8] reported that immediate single implant restoration in extraction sockets in the aesthetic zone was associated with a significantly higher risk of implant failure. Chen and Buser[12] also reported that the recession of the facial mucosal margin was common with immediate implant placement.

Several clinical studies have reported that limited marginal bone loss or gain occurred following immediate implant placement into fresh extraction sockets.[13–16] One reason for the underestimated bone loss in those studies might be the fact that peri-implant bone changes in those studies were assessed using a conventional radiograph. It is well documented that the partial evaluation of bone loss at the mesial and distal aspects of teeth and/or implants is not sufficient for the overall evaluation of bone loss. In the present study, micro-CT was used for the three-dimensional assessment of peri-implant bone loss. The micro-CT gave a definite advantage for a detailed quantitative analysis of the entire implantation site. Mean crestal bone loss on the mesial and distal aspects was 0.4 mm, showing that the crestal bone loss at the buccal sites were significantly different from those at the mesial and distal sites.

A study by de Sanctis and colleagues[1] reported that mean osseointegration ranged from 58.5 to 72.1% after immediate implant placement. In the present study, the average osseointegration was only 28.5%. These marked differences were most likely dependent on the fact that more pronounced buccal bone loss occurred in the present study than those reported in the previous study. This result suggests that immediate implants in the present study might have a deficiency in the strength needed for clinical function because a minimum osseointegration of 40% is considered necessary for the clinical functioning of implant fixtures.[17–20]

CONCLUSION

This experimental study demonstrated that the placement of implants and deproteinized bovine bone mineral into fresh extraction sockets results in significant buccal bone loss and low osseointegration. Therefore, these findings must be considered in conjunction with implant placement in fresh extraction sockets.

DISCLOSURE

The authors do not have any financial interest in the company or materials used in this study. This study was self-funded.

ACKNOWLEDGMENT

This research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (R13-2003-013-03002-0).

REFERENCES

1. de Sanctis M, Vignoletti F, Discepoli N, Zucchelli G, Sanz M. Immediate implants at fresh extraction sockets: bone healing in four different implant systems. J Clin Periodontol 2009; 36:705–711.
2. Bilhan H, Sönmez E, Mumcu E, Bilgin T. Immediate loading: three cases with up to 38 months of clinical follow-up. J Oral Implantol 2009; 35:75–81.

3. Paolantonio M, Dolci M, Scarano A. Immediate implant placement in fresh extraction sockets. A controlled clinical histological study in man. J Periodontol 2001; 7211:1560–1571.
4. Araũjo MG, Lindhe J. Dimensional ridge alterations following tooth extraction. An experimental study in the dog. J Clin Periodontol 2005; 32:212–218.
5. Cardaropoli G, Araũjo M, Hayaciara R, Sukekava F, Lindhe J. Healing of extraction sockets and surgically produced-augmented and non-augmented-defects in the alveolar ridge. An experimental study in the dog. J Clin Periodontol 2005; 32:435–440.
6. Carmagnola D, Adriaens P, Berglundh T. Healing of human extraction sockets filled with bio-oss. Clin Oral Implants Res 2003; 14:137–143.
7. Cornelini R, Cangini F, Martuscelli G, Wennström J. Deproteinized bovine bone and biodegradable barrier membranes to support healing following immediate placement of transmucosal implants: a short-term controlled clinical trial. Int J Periodontics Restorative Dent 2004; 24:555–563.
8. Atieh MA, Payne AGT, Duncan WJ, Cullinan MP. Immediate restoration/loading of immediately placed single implants: is it an effective bimodal approach? Clin Oral Implants Res 2009; 20:645–659.
9. Fickl S, Zuhr O, Wachtel H, Bolz W, Huerzler MB. Hard tissue alterations after socket preservation: an experimental study in the beagle dog. Clin Oral Implants Res 2008; 19:1111–1118.
10. Akagawa Y, Wadamoto M, Sato Y, Tsuru H. The three-dimensional bone interface of an osseointegrated implant: a method for study. J Prosthet Dent 1992; 68:813–816.
11. Agenter MK, Harris EF, Blair RN. Influence of tooth crown size on malocclusion. Am J Orthod Dentofacial Orthop 2009; 136:795–804.
12. Chen ST, Buser D. Clinical and esthetic outcomes of implants placed in postextraction sites. Int J Oral Maxillofac Implants 2009; 24(Suppl):186–217.
13. Kan JY, Rungcharassaeng K, Lozada J. Immediate placement and provisionalization of maxillary anterior single implants: 1-year prospective study. Int J Oral Maxillofac Implants 2003; 18:31–39.
14. Norton MR. A short-term clinical evaluation of immediately restored maxillary TiOblast single-tooth implants. Int J Oral Maxillofac Implants 2004; 19:274–281.
15. Botticelli D, Berglundh T, Lindhe J. Hard-tissue alterations following immediate implant placement in extraction sites. J Clin Periodontol 2004; 31:820–828.
16. Cornelini R, Cangini F, Covani U, Wilson TG. Immediate restoration of implants placed into fresh extraction sockets for single-tooth replacement: a prospective clinical study. Int J Periodontics Restorative Dent 2005; 25:439–447.
17. Buser D, Schenk RK, Skinemann S. Influence of surface characteristics on bone integration of titanium implants: a histomorphometric study in miniature pigs. J Biomed Mater Res 1991; 25:889–901.
18. Gottlander M, Albrektsson T. Histomorphometric studies of hydroxyapatite-coated and uncoated cp titanium threaded implants in bone. Int J Oral Maxillofac Implants 1991; 6:399–404.
19. Keller JC, Young FA, Natiella JR. Quantitative bone remodelling resulting from the use of porous dental implants. J Biomed Mater Res 1987; 21:305–319.
20. Weinlander M, Kenney EB, Lekovic V. Histomorphometry of bone opposition around three types of endosseous dental implants. Int J Oral Maxillofac Implants 1992; 7:491–496.