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Comparison of Immediate and Delayed Implantation Using the Square-threaded and Resorbable-blasted-media-treated Surface Implant System

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Abstract. *A variety of dental implant systems are now available that optimize bone-to-implant contact. The present study was performed to compare the outcomes, by measuring peri-implant osseointegration, following immediate and delayed insertion of square-threaded and resorbable-blasted-media (RBM)-treated surface implants in the dog's mandible. Three dogs were used and four implants were inserted in each dog. All implants were used for histological and histomorphometrical evaluations. The contact lengths and osseointegrated areas following immediate implantation were 74.99% and 56.08%, and those following delayed implantation were 78.22% and 66.08%, respectively. The implantation method in dogs using the square-threaded and RBM treated surface implant system achieved higher percentages of osseointegration than previously reported and the two implantation techniques did not differentially influence osseointegration. Thus, immediate implantation of this implant system, which minimizes the number of surgical procedures, is an optimal clinical method to replace extracted teeth in dogs.*

Bone growth around the dental implant must be sufficient for successful oral implantation. Clinically, a minimal osseointegration rate of 60% was necessary for successful fixation (1). Implant diameter and thread design may be optimized to increase surface area by more than 300%; increased diameter may increase surface area by 20% to 30% (2). A comparative study of thread designs concluded that the square thread design exhibited significantly higher reverse torque values and bone-to-implant contact than the other designs (3).

Several implant systems with different surface treatments are currently available for the purpose of optimizing contact and osseointegration between bone-to-implant surfaces (4-6). Recent studies have shown that surface roughness increases bone-to-implant anchoring more than the traditional titanium surface, mainly in the earlier phase of bone formation and in areas of low-quality bone (7, 8). Several types of treatment have been proposed to increase implant roughness (9). The resorbable-blasted-media (RBM)-treated surface is roughened using only biocompatible media (calcium phosphate ceramic) that is fully resorbable, permitting its removal after manufacturing. This surface offers a 250% rougher surface than surfaces that were only machined or machined and acid-etched (9).

Certain design elements appear to influence the success or failure of an osseous implant, including length, diameter, surface and core characteristics (10). Furthermore, histological differences between immediate and delayed implantations are minimal (11). Thus, immediate implantation with the square-threaded and RBM-treated surface implant system may provide sufficient peri-implant osseointegration for long-term success. The purpose of this study was to compare immediate and delayed implantation using a new dental implant system in the mandible of dogs by measuring new bone formation, with the goal of reducing the number of surgical procedures.

Materials and Methods

Animals. Three male mongrel dogs of approximately 9.1 kg and a mean age of 2 years were used. None of the dogs had general or dental problems. Each dog's mandible was assigned to two groups (left for delayed implantation and right for immediate implantation) in this study. During the entire study period, all dogs were fed a soft diet (Merry dog®, Nestle Purina Co., Korea) and

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water *ad libitum*. This protocol was approved by the Animal Care Committee of Chungbuk National University.

Implants. Twelve titanium alloy square threaded implants (Division A, D1 implant system #104-110, Biohorizons Implant Systems, USA), 4.0 mm in diameter and 10 mm in length, were used in this study. The surfaces of the implants were treated with RBM (treated with calcium phosphate).

Implant placement. Prior to implantation, all teeth were scaled and cleaned and antibiotics (Procaine penicillin G 20,000 I.U./kg, Tardomyocel® comp. inj., Bayer, Korea) were administered intramuscularly. The dogs were premedicated with subcutaneous administration of atropine sulfate (0.04 mg/kg, Kwang-Myung Pharm, Co., Korea) and were sedated subcutaneously with 2% xylazine (2 mg/kg, Rompun®, Bayer, Korea). Anesthesia was induced and maintained with tiletamine and zolazepam (7.5 mg/kg, Zoletil®, Virvac, Korea).

The left mandibular second and third premolars were extracted without injury using the closed extraction technique in the delayed implantation site (12). Implant placement was performed 12 weeks after the extraction. The right mandibular second and third premolars were extracted in the same manner as in the delayed implantation group. Bony canals were prepared for implantation sites with an implant unit (Expert Unit Micromoter, Anthogyr Instruments, France). The implant was inserted into the osteotomy site with a ratchet. The cover-screw was then connected to the implant, and the mucoperiosteal flap was closely attached, without tension, with 4-0 single interrupted absorbable sutures. Two implants were placed on each side of the mandible (n=6 implants in each group). Following all surgical procedures, the dogs were medicated for infection control with antibiotics (Procaine penicillin G, 20,000 I.U./kg, I.M. every 24 h for 6 days, Tardomyocel® comp. inj., Bayer Co., Korea) and anti-inflammatory pain control with steroids (dexamethasone, 2 mg/head, I.M. s.i.d day 1 and day 4, Voren® suspension, Boehringer Ingelheim Co., Korea). The oral cavities were rinsed daily with 0.12% chlorhexidine-digluconate for plaque control during the first two post-operative weeks (13).

Histological preparation. The dogs were sacrificed 12 weeks after implantation. The tissues around the implant were harvested and fixed in a 10% formalin solution for 24 hours at room temperature, and then dehydrated in increasing concentrations of alcohol (70% to 100%). The specimens were embedded in Technovit 7200. Tissue blocks were serially cut into 20-μm thick sections in the vertical plane parallel to the long axis of the implant (bucco-lingual cross section). The specimens were mounted and stained using hematoxylin and eosin staining (H&E stain).

Bone histomorphometrical analysis. Histomorphometry was analyzed using light microscopy (OLYMPUS BX51, Japan) equipped with a digital camera (KAPPA color CCD camera, PS30C). All microscopic measurements were made with the Scion Image® processing and analysis program (Scion Corporation, Maryland, USA, www.scioncorp.com) on a personal computer. The area within the implant thread surface was examined on each image to assess osseointegration. The percentage of contact length was calculated as the bone surface in direct contact with the implant divided by the perimeter of the threads. The percentage of osseointegrated area was calculated as the ratio of new bone formed in the implant threads.

Statistical analysis. Histomorphometrical differences (mean ± SD) between the immediate and the delayed implants were compared by using the Student's *t*-test. Statistical significance was determined at the level of $p<0.05$.

Results

All dogs were observed for mobility, inflammation, necrosis and other signs in the surrounding gingiva. No gross signs were found.

The histological observation showed prominent new bone formation in all experimental implants. Apposition and new bone growth into the implant thread were sufficient. The bone tissue in the area near the implant thread was characterized as morphologically normal and was composed of mature new lamellar bone and thicker trabeculae. No significant differences between the immediate and the delayed implantation group were detected (Figure 1).

The percentage of contact length as well as means and standard deviations in both groups are shown in Table I. The contact lengths in the delayed implantation group varied from 64.39% to 92.97% (28.58 was the difference between the maximum and minimum values). The contact lengths in the immediate implantation group ranged from 60.49% to 92.76% (32.27 was the difference between the maximum and minimum values). The mean contact length in the immediate implantation group (74.99%) was numerically inferior to the mean in the delayed implantation group (78.22%).

The percentage of osseointegrated area of each group is provided in Table II. In the delayed implantation group, the lowest osseointegrated area percentage was 52.84% and the highest was 78.29%, with an amplitude variation of 25.45. In the immediate implantation group, the osseointegrated area percentage ranged from 36.87% to 70.16%, with an amplitude variation of 33.29. The delayed implantation group had a higher mean osseointegrated area percentage (66.19%) than the immediate implantation group (56.08%). No significant histomorphometrical differences were found between the two types of implantation methods.

Discussion

The present study focused on the osseointegration around the dental implant. The new implant system investigated has a modified thread design and surface topography to optimize osseointegration for improved implant stability (9, 14). Immediate or early placement of implants following tooth extraction offers several advantages (15). In this study, we compared new bone ingrowth between threads of the new implant system inserted into alveolar bone following two implantation methods. Osseointegration was superior following immediate, as compared to delayed, implantation

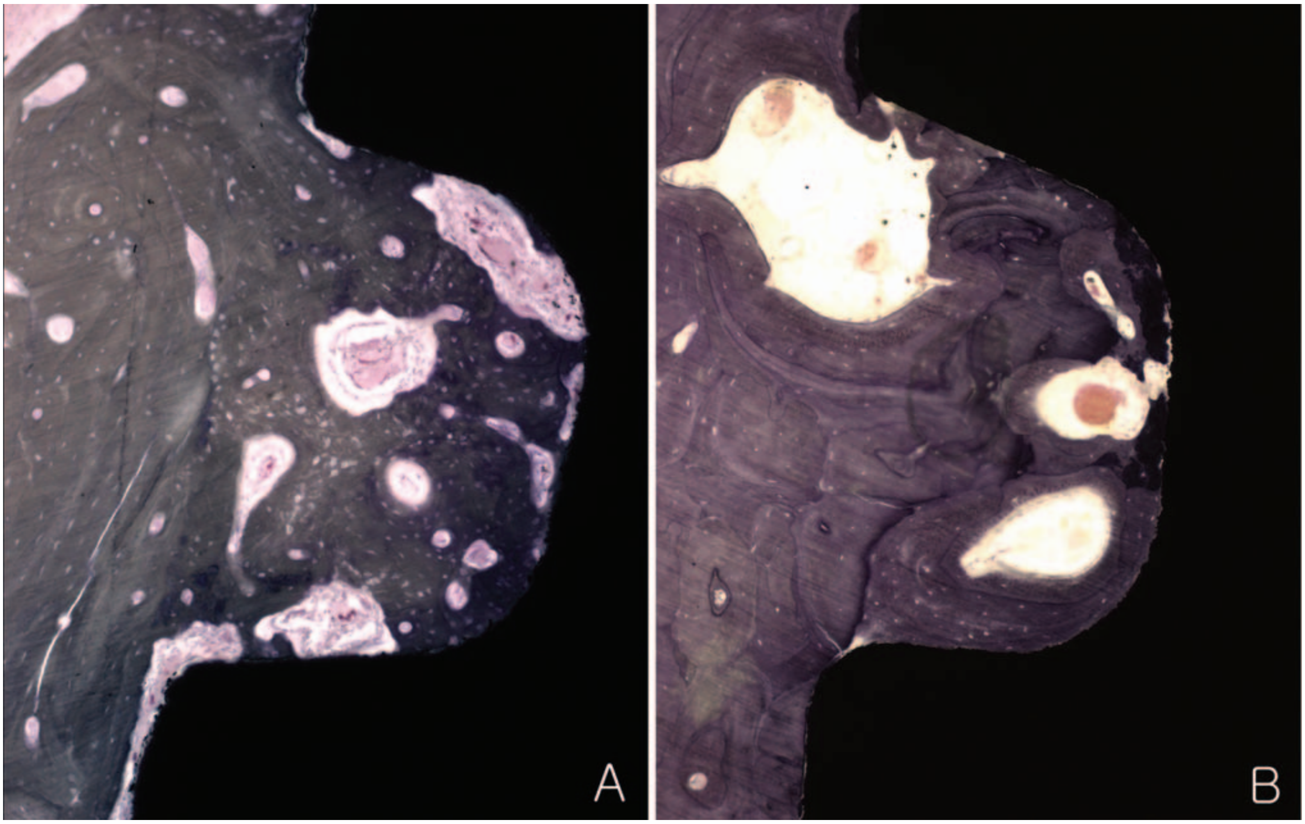

Figure 1. *Photomicrographs, delayed implantation (A) and immediate implantation (B) at 12 weeks after insertion, taken from the bone-to-implant contact zone. Normal bone structure extended into the peri-implant region with direct apposition to the implant surface in all cases. Hematoxylin and eosin staining, x100.*

Table I. *Percentages of contact length between alveolar bone-to-implant surface.*

Implant No.	Implantation	
	Delayed	Immediate
1	64.39	70.60
2	84.17	74.21
3	73.69	92.76
4	89.33	83.85
5	92.97	68.05
6	64.78	60.49
Mean	78.22	74.99
SD	12.40	11.60

p-value =0.65.

Table II. *Percentages of osseointegrated area.*

Implant No.	Implantation	
	Delayed	Immediate
1	62.17	64.23
2	70.59	36.87
3	61.69	45.06
4	71.58	70.16
5	52.84	61.12
6	78.29	59.05
Mean	66.19	56.08
SD	9.05	12.56

p-value =0.14.

of the newly designed implant system. New bone grew between the threads that closely apposed the implants.

Dental implants may influence bone remodeling to create a rigid bone-to-implant interface (16). Design elements such as length, diameter and surface and core characteristics influence osseointegration (10). The most important aspects of implant design are the presence or absence of threads, additional macro-irregularities as well as the shape/outline of the implants (17). The square thread design implant had a larger functional surface area and reduced shear forces as compared with the V-thread or reverse-buttress thread implant designs (3). The functional surface area per unit length of the implant may be modified by varying thread geometry parameters (18). Bone-to-implant fixation was promoted rapidly in this study by the square-thread type implants, which increase surface area up to 150% over conventional V-thread type implants, while also enhancing the bone response (BioHorizons Implant System, D1 Implant System) (19).

The functional surface area of implants can be increased by modifying the implant surface conditions. Rough surfaces have been shown to better promote early bone-to-implant contact percentages compared to smooth surfaces (20, 21). Rough surface implants increase the rate of osseous adaptation to implants, give greater initial rigid fixation, increase the surface of bone contact, increase the amount of lamellar bone and better strengthen the coronal bone around the rough surfaces compared with smooth surfaces (9, 22). We chose the RBM-treated surface implant system in this investigation to obtain superficial roughness. According to the manufacturer, RBM treatment creates an optimal surface texture (75 μ Ra average) without leaving imbedded particles on the implant. The biocompatible calcium phosphate ceramic creates a textured surface by blasting a traditional machined titanium implant dissolved during the passivation phase of manufacturing, leaving an ideal roughness profile on a pure titanium oxide surface without the need for acid etching to remove residual media (22). The RBM-blasted surface implant system was shown to promote bone-to-implant contact compared to other surface-treated implant systems (9, 23).

Numerous investigators have recently proposed immediate implantation into fresh extraction sockets in order to reduce healing periods and maintain the bone crest width (24). Advantages and disadvantages of immediate, compared to delayed, implant placement have been reported (11, 15, 25). Here we compared the osseointegration into the threads of the square-threaded and RBM-treated surface implant system that were inserted immediately after tooth extraction with placement after the extraction socket healed. The implant system was designed to optimize bony tissue ingrowth for improved fixation. Because the healing period following delayed implantation in the mandible is approximately 3 months (26), peri-implant bone growth was examined histologically and histomorphometrically 12 weeks post-implantation.

Microscopically, inflammation was not found near the implants in either implantation group, suggesting adequate bone-to-implant fixation following both techniques. The area was covered by newly formed bone and foreign particles or residual peri-implant foreign body reactions were not detected (27). Thus, all the implants allowed for uninterrupted healing. In the modeling and remodeling cycle in canine cortical bone (16, 28), woven bone first apposes the dental implant, followed by the lamellar compaction process, which turns into a compact bone structure (11).

Evans *et al.* (29) and Novaes *et al.* (30) suggested conducting histomorphometrical analysis in the middle third of the implants. The coronal third and the apical third can be avoided due to the loss of crestal bone and epithelium down-growth adjacent to the polished collar of implants, which is common in dogs (31-33), and due to the approximation or slight penetration of the implants into the superior wall of the inferior alveolar canal (30, 34). Results reported by Novaes *et al.* (9) indicated that 29.4% to 87.6% (mean ± SD 68.5% ±18.8) of the surfaces of SBM (Soluble Blasting Media) implants (same treatment with RBM Implant system but differently expressed) were apposed by bone 12 weeks after delayed implantation. The bone contact length values of delayed inserted implants in this study (64.39% to 92.97%) are higher values than those reported previously. However, differences in the implant system used in this study compared with that used by Novaes *et al.* (9) make direct comparisons difficult. In the present study, the bone contact percentages and osseointegrated area ratio of the delayed implantation group were slightly but not significantly higher than in the immediate implantation group. These results are similar to those reported by Schultes *et al.* (11), who compared immediate to delayed implantation using the smooth surface implant system over a longer healing period (8 months). The similar patterns of these two studies, despite the different implantation duration, may indicate that development and remodeling of bone apposing dental implants in dogs continue for up to 24 months (35).

The intended effect of the square-threaded and RBM-treated surface implant system was to increase the ratio of bone-to-implant contact and the ratio of osseointegrated area following immediate implantation in order to improve implantation methods. Based on our histological and histomorphometrical observations, osseointegration was sufficient following immediate implantation of the square-threaded and RBM-treated surface implant system. Therefore, we recommend immediate implantation with this implant system.

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