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Peri-implant bone reactions at delayed and immediately loaded implants: an experimental study

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Objective. The aim of this study was to compare the peri-implant bone reactions of implants subjected to immediate loading with those subjected to delayed loading.
Study design. In 6 mongrel dogs, bilateral edentulated flat alveolar ridges were created in the mandible. After 3 months of healing, 1 implant was placed in each side. On one side of the mandible, the implant was loaded immediately with a force of 20 N that was applied at a 120° angle from the tooth's longitudinal axis at the labial surface of the crown for 1800 cycles per day for 10 weeks. On the opposite side, after a delay of 3 months to allow osseointegration to take place, the implant was loaded with the same force used for the immediately loaded implant. Ten weeks after loading, microscopic computerized tomography at the implantation site was performed. Osseointegration was calculated as the percentage of implant surface in contact with bone. Bone height was measured in the peri-implant bone.
Results. The mean osseointegration was greater (65.5%) for the delayed-loading implants than for the immediately loaded implants (60.9%; $P < .05$). The mean peri-implant bone height was greater (10.6 mm) for the delayed-loading implants than for the immediately loaded implants (9.6 mm; $P < .05$).
Conclusion. The results indicate that when implants are immediately loaded, the immediate loading may decrease both osseointegration of dental implants and bone height. **(Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008; 105:144-8)**

Implant therapy is now well established, and there is an increasing need for shorter rehabilitation times.[1] Immediate loading appears to increase patient satisfaction and avoids the difficulty of wearing a conventional denture during the healing phase.[2]

To date, there are insufficient data concerning the consequences of immediate loading. The results of animal and clinical studies are discordant. Some studies have shown that the implant failure rate is significantly higher for immediately loaded implants compared with implants loaded after a healing period of 4 or 5 months.[3] Other studies have shown that there were no differences in implant stability and implant failure rate between delayed and immediate loading of im-

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plants.[4-8] Those studies focused primarily on reporting the survival of implants that had been immediately loaded with the provision of a suprastructure designed to receive an occlusal masticatory load. One of the main shortcomings in the studies has been the unrestricted occlusal loads that were exerted on the implants. For these reasons, we considered the use of a controlled force magnitude in the immediate loading experiments. This approach is able to provide comprehensive information for the creation of successful strategies for implants. The aim of the present study was to investigate peri-implant bone reactions, using the controlled force magnitude, in dogs whose implants were subjected to either immediate or delayed loads.

Fig. 1. Clinical features after prosthesis placement.

MATERIALS AND METHODS

Six adult female mongrel dogs, each weighing more than 15 kg (range 15-20 kg), were used in this experiment. The protocol was approved by the Animal Care and Use Committee of Yonsei Medical Center, Seoul, Korea. All procedures were performed under systemic (5 mg/kg ketamine and 2 mg/kg xylazine IM) and local (2% lidocaine with 1:80,000 epinephrine) anesthesia. All premolars in the maxilla and the mandible were removed to establish the space for implants. The edentulated alveolar ridge was allowed to heal for 3 months.

For the delayed-loading implant group, 1 dental implant (length 10 mm, diameter 4.1 mm; Osstem, Seoul, Korea) was placed within the edentulated ridge in 1 side of the mandible. A midcrestal incision was made and a mucoperiosteal flap reflected, exposing the underlying bone. Bone sockets were made with a low-speed bur (at a speed less than 1,000 rpm/min) using continuous external saline irrigation to minimize bone damage due to overheating. Placement of the implants was performed as described in the manual for the Osstem implant system. The mucosal flaps were closed with sutures and the implants were fully submerged. Insertion torques of the implants ranged from 35 to 50 N · cm. After a delay of 3 months to allow osseointegration to take place, the implant was loaded using a fixed provisional prosthesis. The prosthesis was shaped to allow the loading instrument to be placed on the implant surface (Fig. 1). The implant was loaded with a force of 20 N applied at a 120° angle from the implant's longitudinal axis at the labial surface of the crown, for 10 weeks (Fig. 2). The loading simulated mastication by applying a series of 1800 strokes to the implant, with the frequency of strokes being approximately 2 times per second, using a push-pull gauge (Imada Co., Toyohashi, Japan; Fig. 3). The load magnitude, loading rate, and number of loading cycles were established using data from published sources.[9-11] The animals were sedated for the loading cycles using ketamine (5 mg/kg IM) and xylazine (2 mg/kg IM).

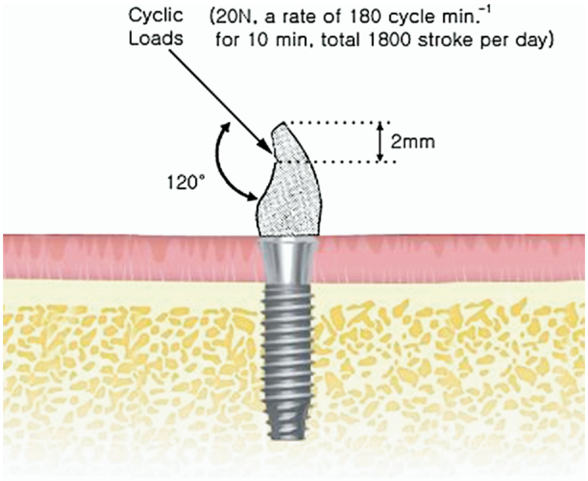

Fig. 2. Loading conditions of the implant.

For the immediately loaded implant group, the implant was inserted in the same manner as described for the delayed-loading implant group on the day of abutment connection for the delayed-loading implant group. Insertion torques of the implants ranged from 40 to 50 N · cm. The implant was loaded with the same force used for the delayed-loading implant.

Antibiotic therapy was administered 1 hour before surgery and once daily for 2 days after surgery. The exposed implant surfaces were cleansed daily with a soft toothbrush and 0.12% chlorhexidine digluconate–soaked gauze. The peri-implant mucosa in all implant sites had a clinically healthy appearance. The dogs were placed on a soft diet. Suture removal was performed after 7 days.

Ten weeks after loading, the dogs were killed, and bone blocks containing the implants were excised. Re-

Fig. 3. Photograph of a push-pull gauge.

sected bone specimens were fixed for 48 h in 10% buffered formalin and stored in 70% ethanol. A morphometric study using microscopic computerized tomography (micro-CT) (Skyscan 1076; Skyscan, Antwerpen, Belgium) was used to quantify the bone around the implants. The scan conditions were 100 kV with 400 ms integration time and 100 mA. Microtomographic slices were acquired at 500 projections and reconstructed with a spatial nominal resolution of 35 μm. The voxel size was 35 μm^3. After scanning, the titanium and bone were distinguished from each other by using different thresholds for bone and implant materials. The differences in density between titanium and bone permitted the separation of the bone from the titanium compartments in the 3-dimensional (3D) images. Osseointegration was calculated as the number of bone voxels in contact with the implant divided by the total number of titanium surface voxels. Bone height in the peri-implant bone was measured as the distance between the alveolar crest and the bottom surface of the implant.

Wilcoxon signed rank test for paired samples was used to calculate statistical differences between the groups.

Table I. Parameters (mean values and standard deviations) of bone- to-implant contact and bone height around dental implants with either immediate or delayed loading

	Immediately	*Delayed*	*P values*
Bone-implant contact (%)	60.9 ± 8.2	65.5 ± 8.8	<.05
Bone height (mm)	9.6 ± 0.5	10.6 ± 0.4	<.05

RESULTS

Healing after implant placement was uneventful in all of the dogs. No implants failed to integrate and were removed. Upon gross examination, the bone around the implants was more abundant at delayed-loading implant sites than at immediately loaded implant sites (Fig. 3). The results of micro-CT image analysis are presented in Table I. Average bone height was greater in the delayed-loading implant group (10.6 ± 0.4 mm) than in the immediately loaded implant group (9.6 ± 0.5 mm; $P < .05$; Fig. 4). Average osseointegration was significantly greater in the delayed-loading implant group (65.5 ± 8.8%) than the immediately loaded implant group (60.9 ± 8.2%; $P < .05$; Fig. 5). The delayed-loading implant group had significantly better vertical alveolar ridge height and more bone/implant contact than the immediately loaded implant group.

DISCUSSION

Yurkstas[12] reported that most foods required an average force ranging from 3 to 18 N for mastication. In the present study, the stability of implants was investigated when a load of just 20 N was applied to the implants. If the magnitude of the load is small, the effect of it on implants is also small. Therefore, the upper limit of the range was used in this study. The load magnitude, loading rate, and number of loading cycles were established using data from published sources.[9-11] To our knowledge, the present study is the first that used a controlled force magnitude.

Histologic comparisons have been reported in animal studies on implants that were immediately loaded versus implants in which loading was delayed. Those reports have variable conclusions on osseointegration in immediately loaded implants, with some papers showing more osseointegration, some less, and some the same as in delayed-loading implants.[5,13,14] In those studies, only immediate temporization and not immediate functional loading was studied. The key objective of the present study was to investigate peri-implant bone reactions in dogs whose implants were either immediately loaded or loaded after a delay with a force of 20 N for 1800 cycles per day. When implants were loaded using the controlled force magnitude, both the amount

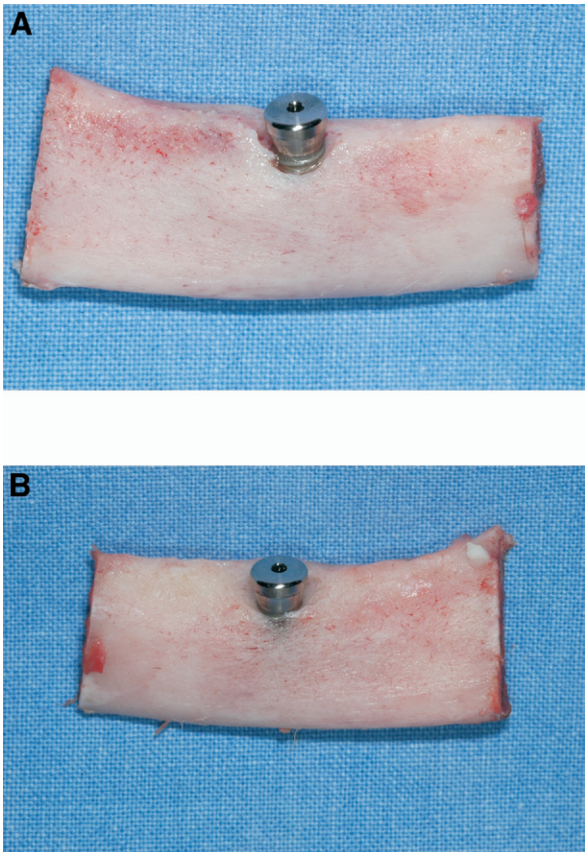

Fig. 4. Photograph of the mandible showing the bone around the implants: **A,** immediately loaded site; **B,** delayed-loading site.

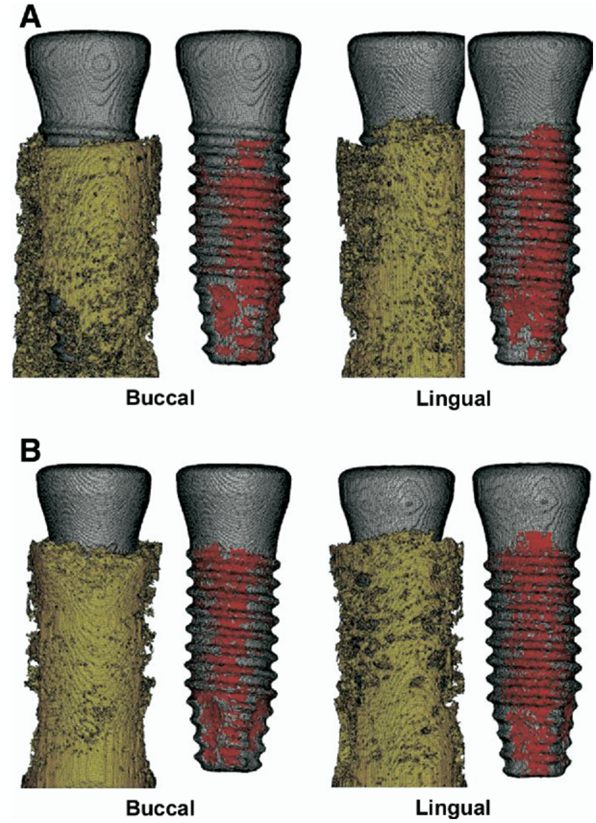

Fig. 5. Three-dimensional micro-CT showing the bone (*yellow*) and the bone-to-implant contact area (*red*) around the implants (*gray*): **A,** immediately loaded implant; **B,** delayed-loading implant. *Buccal*, buccal side of the alveolus; *lingual*, lingual side of the alveolus.

of osseointegration and the bone height around the implants were significantly greater in delayed-loading implants than in immediately loaded implants. This enhancement is probably due to the fact that a load of 20 N for 1800 cycles per day on the implant may interfere with the process of osseointegration in immediately loaded implants. It has been shown that the magnitude of the load forces between the implant and the bone determined the implant success.[15] Therefore, 1 key to success for immediately loaded implants seems to be the magnitude of the immediately loaded forces that are exerted on the implants.

Most studies have used histology to evaluate the bone structure around an implant. It is well recognized, however, that partial evaluation of some sections is not sufficient for an overall evaluation of the bone structure. The present study attempted to evaluate the 3D bone structure around the implants using micro-CT. In 1989, Feldkamp et al.[16] introduced an x-ray micro-CT system to create 3D images. More recent developments have allowed the creation of higher-resolution 3D images and quantitative measurements of the trabecular bone structure.[17] Micro-CT was validated as a method for 3D assessment and analysis of cancellous bone in 1998 by Muller et al.,[18] who compared the morphometric results of conventional histomorphometry to micro-CT scans. Those authors demonstrated the strength of 3D representations of trabecular bone architecture in comparison with conventional 2D histology and found excellent correlation for the indices assessed. Recent studies have proposed the application of micro-CT to dental implant research.[19-23] The micro-CT method used in the present study gave a definite advantage over single-plane histology for a detailed quantitative analysis of the entire implantation site.

To determine the influence of immediate or delayed loads on osseointegration and the height of newly formed bone around implants, an acceptable animal model was necessary. In the literature, dogs have been used as an experimental model for peri-implant bone investigation.[24-26] No significant differences in the peri-implant bony contacts at the interface of integrated healed implants in humans and dogs have been demonstrated.[27] Specifically, monkeys, dogs, rabbits, and humans present similar results for osseointegration at the bone-to-implant interface. Although animal studies can never exactly equate to studies on humans, they can yield possible answers to questions related to implant stability. If the implants are successful in dogs, then it is likely that they will also be successful in humans. However, further investigation in this field of study is needed to determine if the results are in accord with clinical findings.

To our knowledge, this is the first report to provide controlled experimental data on the influence of immediate or delayed loads on osseointegration and the height of newly formed bone around implants. Delayed loading improved both the osseointegration of the dental implants and the bone height around the implants after implantation. Our data suggest that the delayed loading of implants is more effective than immediate loading in improving implant anchorage.

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