Tightening and Loosening of the Abutment Screw Negatively Affects Implant Osseointegration in the Early Healing Stage in Rat Tibiae

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Purpose: To examine the effect of tightening and loosening the dental implant screw on implant osseointegration in an elderly rat model. Materials and Methods: Titanium dental implants were inserted in the bilateral tibiae of 34 elderly Wistar rats (1 year and 3 months old). Rats were randomly divided into five groups: control (no loading); immediate loading (IL) (vertical load [3 Hz for 15 minutes/day] immediately after implantation); early loading (EL) (load started on postoperative day 7); five times abutment removal (R5) (tightening and loosening of the abutment screw once per day for 5 days each week); and two times abutment screw removal (R2) (tightening and loosening of the abutment screw once per day for 2 days each week). After 4 weeks, the rats were euthanized, and the bone structure surrounding the dental implants was evaluated using microcomputed tomography analysis. Results: Osseointegration failed more frequently in the EL, R2, and R5 groups than in the control and IL groups (P = .06). The EL, R2, and R5 groups also tended to have lower relative gray values than the control and IL groups. Conclusion: Tightening and loosening the abutment screw might negatively affect dental implant osseointegration in the early healing stage in older adults. Int J Prosthodont 2021;34:199–203. doi: 10.11607/ijp.6398

Dental implants are widely used as an established treatment method for defective prostheses. Dental implant treatment is considered successful if there is good osseointegration and stability.1–3 Furthermore, the healing period after dental implant placement must be considered, including the timing of the application of loading on the implant. In clinical practice, immediate loading and early loading have recently been widely applied to improve patient quality of life by shortening the treatment period.4–6 Although this early loading protocol has not been evaluated in many long-term clinical studies, it is considered to be a viable treatment option with a high degree of clinical evidence.7,8 However, immediate and early loading protocols are not based on biologic evidence, and immediate or early loading is not recommended in certain conditions.9,10

The mechanical loading conditions affect the osseointegration of the dental implant and the peri-implant bone structure.11–13 Previous animal studies have used various experimental loading conditions in accordance with the target loading condition and

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animal model, and so various loading devices have been used to evaluate the effect of experimental loading on the peri-implant bone response.14–17

Various load types are applied to the dental implant after implantation, including forces during chewing, awake and sleep bruxism, and loads applied by the dentist during some steps of the implant treatment process in the clinic. After the dental implant is inserted, there are several stages in which the dentist must attach and detach implant parts that are fixed with screws—for example, screw tightening and loosening is performed during placement of a healing abutment, impression coping, provisional restoration and abutment, and final superstructure. The load applied during the tightening and loosening of the abutment screw might affect the osseointegration, as the mechanical stress is directly transferred between the dental implant surface and the peri-implant bone corresponding with the screw thread. The authors’ hypothesis was that tightening and loosening the abutment screw during the treatment process after dental implant insertion would negatively affect the implant osseointegration.

To test the hypothesis, adverse conditions for osseointegration and bone healing were simulated by using a dental implant model in elderly rats. Two types of loading were applied: a mechanical vertical load, as occurs during daily functions (such as mastication), and a rotational load due to tightening and loosening of the abutment screw, as occurs during the dental implant treatment process in the clinic.

The aim of the present study was to determine the effects of the previously mentioned vertical and rotational loading conditions (simulating mastication and the treatment process, respectively) on dental implant osseointegration and peri-implant bone healing.

**MATERIALS AND METHODS**

The present study was carried out at the Institute for Animal Experimentation at Tohoku University Graduate School of Medicine under the approval of the Institutional Animal Care and Use Committee of the Tohoku University Environmental & Safety Committee (approval number 2015DnA-004-1).

Seventeen male Wistar rats were used in the present study. Elderly rats (1 year and 3 months old) were used to simulate unfavorable bone conditions. A straight-type pure titanium dental implant (SETiO Plus, GC) with a diameter of 3.0 mm and a length of 12 mm was inserted in both tibiae in each rat.

The surgery was performed under gas anesthesia (2.5% isoflurane) (Escain, Mylan) under aseptic conditions. A skin incision was made on the medial side (2.5% isoflurane) (Escain, Mylan) under aseptic conditions. A skin incision was made on the medial side, and both cortices were perforated with a surgical drill at a low rotational speed under constant saline cooling. The dental implant was inserted until the implant head was exposed by about 5 mm (Fig 1a). The implant was placed approximately 10 mm distal to the knee joint. The skin was closed with resorbable sutures, leaving the dental implant head protruding.

The experimental groups were randomly classified into the following five groups in accordance with the loading type and timing of the load application. A custom-made handheld device was used to apply a vertical load with a low frequency (3 Hz) to simulate mastication, while a rotational load was applied manually with dental instruments to simulate tightening and loosening of the abutment screw during the dental implant treatment process in the clinic.

The groups were as follows:

- Control group: No load (n = 8 implants)
- Immediate loading (IL) group: Vertical load applied immediately after implant insertion (n = 6 implants)
- Early loading (EL) group: Vertical load applied from the seventh day after implant insertion (n = 6 implants)
- Five times abutment removal (R5) group: Tightening and loosening of the abutment screw once daily for 5 days per week (n = 7 implants)
- Two times abutment removal (R2) group: Tightening and loosening of the abutment screw once daily for 2 days per week (n = 7 implants)

Under isoflurane inhalation anesthesia, the load in the IL and EL groups was applied with a custom-made loading apparatus (Fig 1b), which was used to apply a vertical load of 3 Hz with an amplitude of 5 mm for 15 minutes a day (simulating a chewing force). In the R5 and R2 groups, an abutment screw was tightened (approximately 5 N of torque) and loosened manually using dental instruments (Skill Driver Plus, Torque Wrench, GC) once daily five and two days per week, respectively. An abutment (Conical Abutment IN, height 1.3 mm, GC) was used to apply this rotational load (Fig 1c).

Four weeks after dental implant insertion, the rats were euthanized and the bone structure of the cortical bone surrounding the implant was evaluated with microcomputed tomography (microCT) (200 kV and 100 μA, Scan Xmate-D225, Comscan Tecnoc) (Fig 1d). After three-dimensional reconstruction, a sagittal slice along the axis of the tibia and dental implant was selected for analysis (Fig 2). The region of interest was set as a 0.4 × 0.4-mm square in the peri-implant cortical bone. A relative gray (RG) value (where water = 0 and dental implant = 100) was calculated for the evaluation.15 Cases in which there was no bone around the dental implant and the implant was covered with soft tissue were defined as osseointegration failure.
Statistical analyses were conducted using SPSS 21.0 (IBM). Chi-square test was used to analyze the success or failure of dental implant osseointegration in each group. In addition, Kruskal-Wallis test and Dunn test were used to compare the RG values among groups in microCT image analysis. The significance level was set at $P < .05$.

**RESULTS**

Failure to osseointegrate occurred in 14 of 34 implantations. There was a marginally significant difference in the success/failure ratio of osseointegration between groups (chi-square test, $P = .06$) (Table 1).
The present results indicate that tightening and loosening of the abutment screw (with force acting in the opposite direction to the dental implant thread) might adversely affect the success of osseointegration. The RG value of the R2 group was significantly lower than that of the control group, and the success/failure ratio of osseointegration in the R2 group was the lowest among all groups. These results suggest that the loading condition applied in the R2 group had a greater adverse effect on dental implant osseointegration than the loading conditions in the other groups. In daily clinical practice, the loading situation in the R2 group often occurs during the dental implant treatment process, such as during replacement of the cover screw with the healing screw, during impression of the provisional superstructure using impression coping, and during replacement of the provisional superstructure with the final superstructure.22,23 Although the present study used an adverse elderly rat model, care should be taken to minimize these loading conditions during the dental implant treatment process, especially in the early healing stage.10,11 Furthermore, extra care should be taken in patients with compromised bone, such as in older adult patients with osteoporosis. Since the RG value results assessed with microCT might be related to the bone remodeling response under a specific loading condition,10,14–17 further detailed investigation into the timing and frequency of the unfavorable loading is needed.

Although there was no significant difference between the EL and IL groups in the present study, both the success rate of dental implant osseointegration and the RG value of the EL group were relatively low compared to the IL group. This suggests that the timing of the loading may affect dental implant osseointegration.10 This seems to be related to the change in the stability of the dental implant during the time from the initial fixation immediately after implantation to the establishment of secondary fixation from the dip; that is, there may be a risk of overloading near the dip. If the stability decreases below a critical level during the healing process, a functionally loaded dental implant becomes unstable and fails.2

**CONCLUSIONS**

To preserve the osseointegration and stability of the dental implant, dentists should pay attention to the load being applied during the attachment and detachment of the abutment screw in the early stage of peri-implant bone healing, as it might adversely affect the implant osseointegration, particularly in older adults.
ACKNOWLEDGMENTS

The authors thank Kelly Zammit, BVSc, from Edanz Group (www.edanzediting.com/ac) for editing a draft of this manuscript. This study was partially supported by a Grant-in-Aid for Scientific Research (C) from the Ministry of Education, Culture, Sports, Science and Technology, Japan (grant numbers 15K11148 and 16K11581). The authors have no conflicts of interest related to this study.

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In Vitro Cytotoxicity of Different Dental Resin-Cements on Human Cell Lines

Adhesive resin cements are increasingly used in modern dentistry. Nevertheless, substances released from resin materials have been shown to cause cellular toxic effects. Disc-shaped specimens from 12 different resin cements and one conventional zinc phosphate cement were prepared and used for direct stimulation of five different human cell lines via a transwell cell culture system or in an indirect way using conditioned cell culture media. Cytotoxicity was determined using LDH and BCA assays. All tested cements led to a decrease of cell viability, but to a distinct extent depending on cell type, luting material, and cytotoxicity assay. In general, cements exhibited a more pronounced cytotoxicity in direct stimulation experiments compared to stimulations using conditioned media. Interestingly, the conventional zinc phosphate cement showed the lowest impact on cell viability. At the cellular level, the highest cytotoxic effects were detected in osteoblastic cell lines. All resin cements reduced the cell viability of human cells, with significant differences depending on cell type and cement material. Osteoblastic cells especially demonstrated a tremendous increase of cytotoxicity after cement exposure. Although the results of this in vitro study cannot be transferred directly to a clinical setting, they show that eluted substances from resin cements may disturb osteoblastic homeostasis that in turn could lead to conditions favoring peri-implant bone destruction. Thus, the wide use of resin cements in every clinical situation should be scrutinized. Correct use with complete removal of all cement residues and sufficient polymerization should be given the utmost attention in clinical usage.