

The effect of implant shape and bone preparation on primary stability

Sang-Hyun Moon¹, Heung-Sik Um^{1*}, Jae-Kwan Lee¹, Beom-Seok Chang¹, Min-Ku Lee²

¹Department of Periodontology and Research Institute for Oral Sciences, Gangneung-Wonju National University College of Dentistry, Gangneung, Korea

²Department of Periodontics, Kangbuk Samsung Hospital, Seoul, Korea

Purpose: The purpose of this study was to evaluate the effects of implant shape and bone preparation on the primary stability of the implants using resonance frequency analysis.

Methods: Sixty bovine rib blocks were used for soft and hard bone models. Each rib block received two types of dental implant fixtures; a straight-screw type and tapered-screw type. Final drilling was done at three different depths for each implant type; 1 mm under-preparation, standard preparation, and 1 mm over-preparation. Immediately after fixture insertion, the implant stability quotient (ISQ) was measured for each implant.

Results: Regardless of the bone type, the ISQ values of the straight-screw type and tapered-screw type implants were not significantly different ($P > 0.05$). Depth of bone preparation had no significant effect on the ISQ value of straight-screw type implants ($P > 0.05$). For the tapered-screw type implants, under-preparation significantly increased the ISQ value ($P < 0.05$), whereas over-preparation significantly decreased the ISQ value ($P < 0.05$).

Conclusions: Within the limitations of this study, it is concluded that bone density seemed to have a prevailing effect over implant shape on primary stability. The primary stability of the tapered-screw type implants might be enhanced by delicate surgical techniques.

Keywords: Bone density, Dental implants.

INTRODUCTION

Primary stability is the mechanical coherence between bone and an dental implant fixture immediately after implantation. It is well known that primary stability plays an essential role in successful osseointegration [1,2]. Primary stability is determined by bone density, the surgical technique, and the microscopic and macroscopic morphology of the implant [3]. The success of any implant procedure requires a series of patient-related (e.g., bone volume and density) and procedure-dependent parameters (e.g., implant design, surgical procedure). While the bone density cannot be modified by the op-

erator, implant shape and surgical techniques are factors that can be controlled.

Currently, various shapes of dental implants are available, and usually present a good primary stability in cases of favorable bone density. Hence, manufacturers have recently been striving to make dental implants with a good primary stability even in poor bone quality. One of these is the tapered-screw type implant. The first tapered-screw type implants were designed for immediate implantation after extraction, and are known to increase primary stability by providing pressure on the cortical bone of regions with poor bone qualities [4]. Tapered-screw type implants distribute the occlusal force to sur-

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***Correspondence:** Heung-Sik Um

Department of Periodontology and Research Institute for Oral Sciences, Gangneung-Wonju National University College of Dentistry, 123 Jibyeon-dong, Gangneung 210-702, Korea

E-mail: hsum@gwnu.ac.kr, Tel: +82-33-640-3184, Fax: +82-33-640-3113

rounding bones more equally than straight-screw types [5], and bone perforation is less likely to occur due to characteristics of the anatomical shape [6]. However, there are only a few studies that support the theoretical basis of tapered-screw type implants.

There are various surgical techniques for improving the primary stability of implants, such as obtaining bicortical anchorage, tuberosity and pterygo-maxillary implantation, osteotome technique, self-tapping implantation, and using a thinner drill than conventional methods for implantation [3,7,8].

The purpose of this study was to evaluate the effects of implant shape and bone preparation on the primary stability of the implants using resonance frequency analysis (RFA).

MATERIALS AND METHODS

Study materials

Frozen bovine ribs were cut into 7 cm long pieces and a total of 60 bovine rib blocks were prepared. 30 of them had cortical bone removed until it was about 1 mm thick in order to make it similar to type II bone [9]. The other 30 blocks had all cortical bone removed and exposed the trabecular bone to make it similar to type IV bone. Each bovine rib block was frozen for storage. They were melted for 30 minutes in a water bath right before implantation. The group classified as type IV bone was treated with 20% glacial acetic acid for 1 hour after melting, in order to partially decalcify the trabecular bone. Two

types of straight-screw type implants and tapered-screw type implants (M, Shinhung Co., Seoul, Korea) with 4.0×10 mm (diameter×length) were installed in each of the 60 bovine rib blocks (Fig. 1).

Implantation protocol

The distance between the implants was about 3 mm. One of the three straight-screw type implants had its final bone preparation 1 mm shallower (under-preparation), while one was done according to the normal guidelines of the manufacturer (standard preparation). For the remaining implant, bone preparation was done 1 mm deeper (over-preparation). Bone preparation of the three tapered-screw type implants was performed in the same way, with one drilled 1 mm shallower, one at the usual depth, and the remaining one 1 mm deeper. Fig. 2 shows the detailed procedures of the bone preparation.

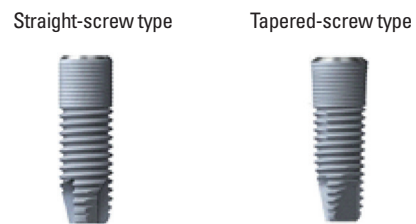


Figure 1. Types of implant fixture for this study.

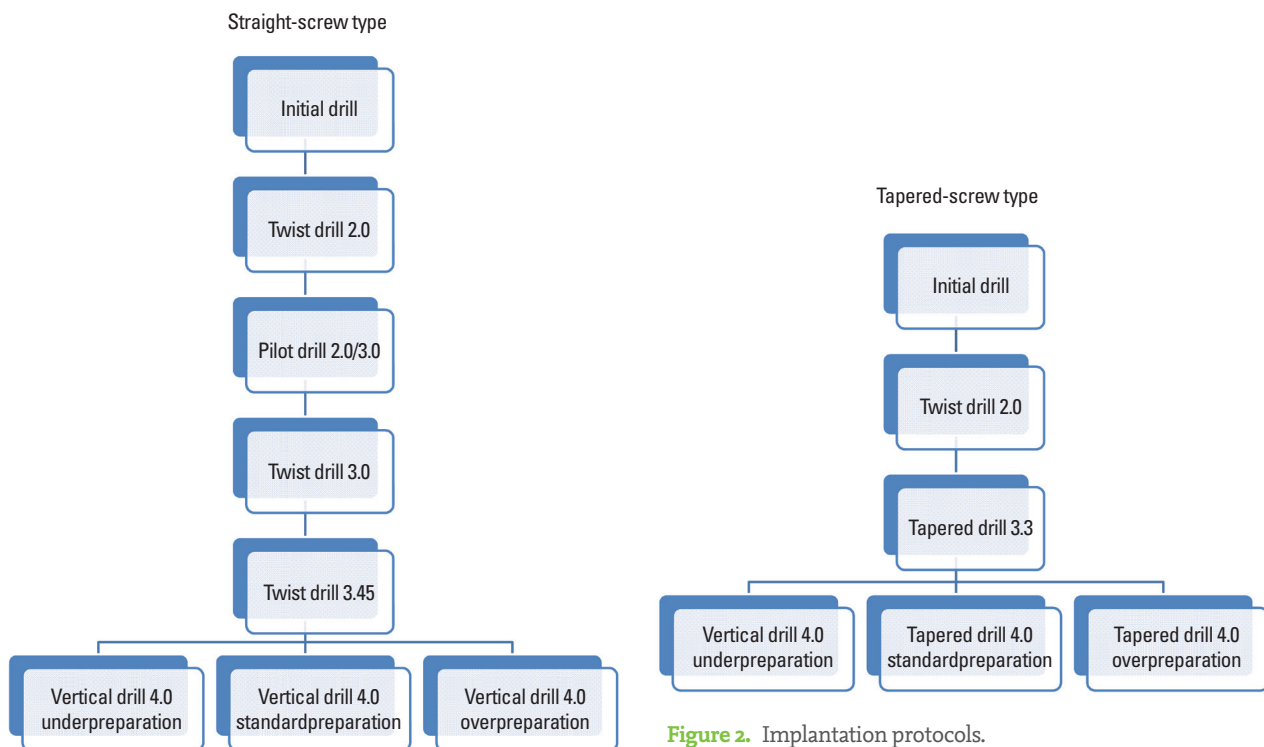


Figure 2. Implantation protocols.

ration for implantation.

Measuring the resonance frequency

After installation, the implant stability quotient (ISQ) was measured by using resonance frequency analyser (Osstell, Osstell AB, Goteborg, Sweden). For each implant, suitable-transducer was vertically connected to the longitudinal axis of the bovine rib block. Measurement was done three times repetitively and the average value was used.

Statistical analysis

Statistical software package (SPSS, SPSS Inc., Chicago, IL, USA) was used for statistical analysis. A two-way ANOVA was performed to compare the primary stability of implants depending on bone quality and the amount of bone preparation, as well as the primary stability difference of implants according to implant shape and amount of bone preparation. Also, a one-way ANOVA was done to compare the primary stability of implants depending on the amount of bone preparation. Tukey’s method was used for the post-hoc test. $P < 0.05$ was considered statistically significant.

RESULTS

Differences in ISQ values according to bone quality

For straight-screw type implants, type II bone quality (72.91 ± 7.14) had significantly higher ISQ measurements than type IV bone quality (62.56 ± 6.13 , $P < 0.05$). The tapered-screw type implants also showed significantly higher ISQ values in type II bone quality (72.57 ± 6.80) than in type IV bone quality (62.04 ± 7.13 , $P < 0.05$). Higher bone quality appeared to be related to better primary stability (Table 1).

Differences in ISQ values between implants in type II bone according to the amount of bone preparation

Those that had standard bone preparation did not show any significant difference in the ISQ values between the tapered-screw type implants (74.27 ± 5.32) and straight-screw type implants (73.30 ± 6.21 , $P > 0.05$). When underpreparation was done by 1 mm, the tapered-screw type implant (76.83 ± 4.69) had significantly higher ISQ values than straight-screw type implants (72.23 ± 8.72 , $P < 0.05$). However, those with 1 mm over-

Table 1. Implant stability quotient in different bone quality (mean \pm SD).

	Type II bone	Type IV bone
Straight-screw type	72.91 ± 7.14^a	62.56 ± 6.13
Tapered-screw type	72.57 ± 6.80^a	62.04 ± 7.13

^aStatistically significant differences ($P < 0.05$).

preparation demonstrated significantly lower ISQ values for the tapered-screw type implants (66.60 ± 5.72) than the straight-screw type implants (73.20 ± 6.40 , $P < 0.05$) (Table 2).

Differences in ISQ values between implants in type IV bone according to the amount of bone preparation

In the group that received standard bone preparation, the ISQ values did not show a significant difference between the tapered-screw type implant (62.70 ± 5.52) and straight-screw type implant (63.37 ± 5.59 , $P > 0.05$). Of those that had an underpreparation of 1 mm, the tapered-screw type implants (66.37 ± 6.54) showed significantly higher ISQ values than the straight-screw type implants (61.40 ± 7.09 , $P < 0.05$). However, those with the 1 mm overpreparation indicated significantly lower ISQ values in the tapered-screw type implants (57.07 ± 6.10) than in straight-screw type implants (62.90 ± 5.62 , $P < 0.05$) (Table 2).

Differences in ISQ values according to bone preparation of straight-screw type implants

There was no significant difference observed in ISQ values for straight-screw type implants when an underpreparation of 1 mm and standard bone preparation were done in the type II bone and type IV bone ($P > 0.05$). Standard bone preparation and overpreparation of 1 mm also did not show any significant difference in ISQ values ($P > 0.05$). Moreover, underpreparation of 1 mm and overpreparation of 1 mm also did not show any significant difference in ISQ values ($P > 0.05$) (Fig. 3).

Differences in ISQ values according to bone preparation of tapered-screw type implants

Tapered-screw type implants had significantly higher ISQ values as bone preparation decreased in the type II bone and type IV bone (Fig. 4). The ISQ values were significantly higher when underpreparation by 1 mm was done than in standard bone preparation ($P < 0.05$). It was observed that ISQ values were significantly lower when overpreparation by 1 mm was done than in standard bone preparation ($P < 0.05$).

Table 2. Implant stability quotient in different bone quality and preparation condition (Mean \pm SD).

		Straight-screw type	Tapered-screw type
Type II bone	Underpreparation	72.23 ± 8.72^a	76.83 ± 4.69
	Standard preparation	73.30 ± 6.21	74.27 ± 5.32
	Overpreparation	73.20 ± 6.40^a	66.60 ± 5.72
Type IV bone	Underpreparation	61.40 ± 7.09	66.37 ± 6.54^a
	Standard preparation	63.37 ± 5.59	62.70 ± 5.52
	Overpreparation	62.90 ± 5.62^a	57.07 ± 6.10

^aStatistically significant differences ($P < 0.05$).

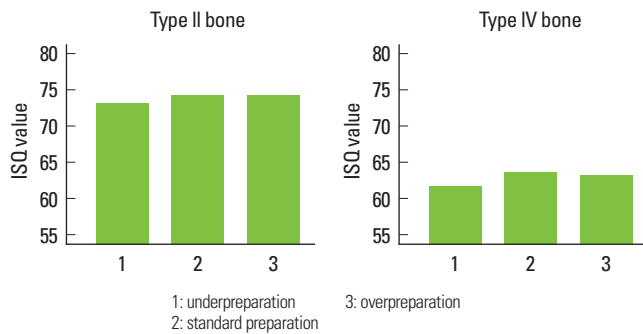


Figure 3. Implant stability quotient (ISQ) of straight-screw type fixtures in different bone preparation condition.

DISCUSSION

This study has evaluated the effects of implant shapes and bone preparation on the primary stability of implants by using RFA. In 1998, Meredith [10] introduced the method of using RFA for implant stability evaluation. Low resonance frequency values were related to low stiffness, which may indicate early failure of osseointegration. Pattijn et al. [11] reported that in RFA, the ISQ measurements could differ depending on the direction of the transducer, and that inaccurate results may occur when measurements are made without the complete fixation of the transducer. In this study, the transducer was fixed vertically to the longitudinal axis of the bovine rib block, and then measurements were done 3 times repetitively in order to reduce the possibility of these errors.

Sennerby et al. [12] conducted a study evaluating primary stability depending on whether the cortical bone exists or not, and reported that implants located in trabecular bone with cortical bone showed a higher primary stability than without cortical bone. This study showed similar results, observing a better primary stability in type II bone than type IV bone regardless of implant shapes.

O'Sullivan et al. [13] assessed primary stability depending on implant shapes. There was no significant difference in ISQ values when the bone quality was satisfactory, but they reported that the tapered-screw type implant appeared to have a significantly higher ISQ value than straight-screw type implants in type IV bone quality. Akca et al. [14] also evaluated primary stability by implant shape in cadavers, and reported that bone quality had more influence than implant shape. In this study, the tapered-screw type implant did not show any significant ISQ value difference compared to the straight-screw type implants in type IV bone quality. We believe this occurred because the bovine rib with implantation was not reproduced with the expected bone quality. The bovine rib is classified as a type II bone in other studies as well, since it contains thick compact bone and dense trabecular bone [15].

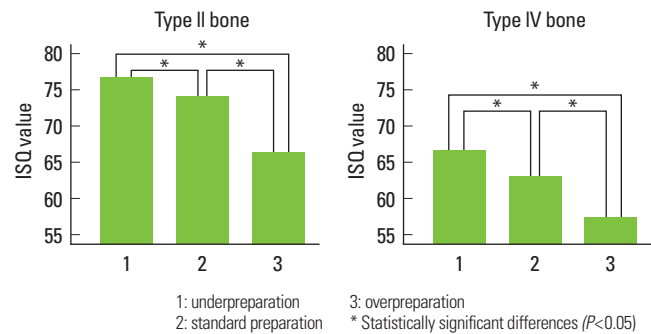


Figure 4. Implant stability quotient (ISQ) of tapered-screw type fixtures in different bone preparation condition.

The cortical bone of the bovine rib block was completely removed in order to reproduce type IV bone in this study. The trabecular bone was treated in 20% glacial acetic acid for 1 hour for partial decalcification, but this process was insufficient for obtaining the bone quality we desired.

In several previous studies, tapered-screw type implants were performed after bone preparation for straight-screw type implants [13,16,17]. In these studies, the prepared bone shape was different from the implant appearance, and in particular, the lateral compression force increased from the upper part of the alveolar bone, which improved primary stability. This may account for the difference from the results of this study. Oh et al. [18] performed straight-type bone preparation in bovine ribs with poor bone quality, followed by tapered-screw type implantation (US system of Osstem, Osstem Implant Co., Seoul, Korea), and they found that the ISQ values of the tapered-screw type implants were significantly higher. However, in implants with a bone preparation shape which corresponds to implant shape (Hexplant system of Oneplant, Warantec Co., Seoul, Korea), tapered-screw type implants and straight-screw type implants did not have significantly different ISQ values. The bone preparation shape also differed from the implant shape in this study, and no significant difference in ISQ values was observed.

Martinez et al. [3] introduced methods for obtaining adequate implant stability in poor bone qualities, such as bicortical anchorage, pterygo-maxillary implantation, wide diameter implant, the osteotome technique, and a method using a thinner drill. This study evaluated the effects of the depth of the final bone preparation on the primary stability of implants. In the case of straight-screw type implants, there were no significant changes in primary stability as a result of differences in the final bone preparation. However, tapered-screw type implants showed a significant increase of primary stability as the final bone preparation decreased. This may have been caused by the morphological characteristics of the tapered-screw type implant, in which the diameter of the cavity formed

in the bone preparation site reduces when bone preparation decreases. Meanwhile, for straight-screw type implants, lateral compression force seems to have had only a small effect on primary stability.

In this study, the cortical bone resistance was severe during the bone preparation of the type II bone. The straight-screw type implants were caught by the cortical bone before being completely implanted, so a hand wrench had to be used. This required more operation time for implantation. Meanwhile, tapered-screw type implants were rarely caught by the cortical bone when standard bone preparation was done for type II bone qualities. The bone preparation process was simple and the implantation progressed quickly.

Although the bovine rib did not achieve the desired bone qualities in this study, we were able to confirm that bone quality was a more important factor in the primary stability of implants than implant shape. Also, tapered-screw type implants showed an increase in primary stability as bone preparation decreased. Therefore, tapered-screw type implants are considered to more easily improve primary stability than straight-screw type implants, even in poor bone quality, through controlling the final bone preparation process.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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