Self-cutting blades and their influence on primary stability of tapered dental implants in a simulated low-density bone model: a laboratory study

Duck-Rae Kim, DDS, MSD,a Young-Jun Lim, DDS, MSD, PhD,b Myung-Joo Kim, DDS, MS, PhD,c Ho-Beom Kwon, DDS, MSD, PhD,c and Sung-Hun Kim, DDS, PhD,b Seoul, Korea

DEPARTMENT OF PROSTHODONTICS AND DENTAL RESEARCH INSTITUTE, SCHOOL OF DENTISTRY, SEOUL NATIONAL UNIVERSITY

Objective. This study tested the hypothesis that there would be differences in primary stability due to the presence of self-cutting blades. We investigated the effect of a self-cutting blade implant design on the primary stability of tapered dental implants in a simulated low-density bone model.

Study design. Implant fixtures with 2 different designs, one with self-cutting blades and the other without self-cutting blades, were fabricated in the same implant system. Insertion torque, resonance frequency analysis, reverse torque, and pull-out and push-in tests were evaluated in grade no. 10 solid rigid polyurethane foam.

Results. All 5 assessments of the group without self-cutting blades were significantly higher than those of the self-cutting group (P < .001).

Conclusions. The implants without self-cutting blades create a lateral compression with increased contact surface area and consequently improve the primary stability in a simulated low-density bone model. (Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2011;112:573-580)

Primary stability is an important factor for the success and longevity of dental implants, and this is known to be a prognostic marker for achieving osseointegration, especially in poor bone quality.1 The greater the primary stability, the smaller the micromotions are between implant and bone. The micromotion promotes the formation of a soft tissue capsule around the implant, and as a result implant failure may occur.2 Various methods have been introduced to evaluate primary stability for dental implants. One of the widespread methods is the insertion torque measurement. High insertion torque value reflects sufficient primary stability of implants, and low value reflects low primary stability which has a high risk of early failure.3 Thus insertion torque measurement can provide information to predict the optimum healing period and suitable point for loading.4 Resonance frequency analysis (RFA) was introduced by Meredith1 and is known to be a noninvasive method to assess implant stability at various points of time.5 Higher value indicates greater implant stability, and lower value indicates less stability and higher risk of failure. Removal torque measurement can give information about the degree of bone-implant contact.6 However, this method is too destructive and may lead to irreversible deformation. Using human cadavers, many studies to assess primary stability have been published.7,8 In those studies, removal torque was measured on the day of implant placement. A push-in test was described by Brosh et al.,9 and a push-out test was done by Cook et al.10 These methods were used to assess interfacial attachment strength between bone and implant in axial loads. In particular, pull-out tests have been a popular biomechanical assessment for anterior cervical implant in the orthopedic field.11,12 However, these studies show that all the measurement methods are sensitive to different aspects of the bone-implant interface. This explains the absence of correlation among the methods and proves that no standard procedure exists for the evaluation of primary stability.

Implants with self-cutting blades have been on the market since 1983.13 The purpose of the design is the enhancement of primary stability in poor-quality bone. As a result of bone pretapping procedure, improved primary stability has been obtained.

There were several papers to study the influence of self-cutting blades on the primary stability,14-18 however, in those studies, experiments were not performed under identical conditions. Aside the presence of self-cutting blades, other factors, such as different implant
system, design, and measurement methods, affect the results. Moreover, high variability among specimens may result in low statistical relevance. Therefore, it is necessary to isolate the other factors from affecting the results.

In the present study, the same implant design except for the presence of self-cutting blades, the same bone model, and the same drilling protocol were used to assess primary stability under identical conditions. In addition, insertion torque measurement, RFA, removal torque measurement, push-in test, and pull-out test were carried out to assess primary stability.

Primary stability is a function of local bone quality and quantity, the geometry of an implant (length, diameter, and type), and the placement technique used (the drill size in relation to implant size, whether a pretapped or self-tapping implant is used). The present study focused on modification of implant design, especially for the influence of self-cutting blades, on the primary stability in a simulated low-density bone model. In addition, the confounding factor of interspecimen bone quality variability could be removed by using an artificial bone substitute made from polyurethane foam in place of human or animal bone.

The present study tested the hypothesis that there would be differences in primary stability owing to the presence of self cutting blades, and that the tapered implant with self-cutting blades can improve primary stability in a simulated low density bone model compared with one without self-cutting blades.

The aim of this study was to investigate the effect of self-cutting blade implant design on primary stability of tapered implant systems in a simulated low-density bone model.

**MATERIAL AND METHODS**

**Implant fixtures and polyurethane blocks**

Two different types of tapered implants (TS III; Osstem Implant Co., Busan, Korea), which had a diameter of 4.0 mm and a length of 10 mm, were used in this study (Fig. 1). One type was the implant with self-cutting blades. The other was customized in the same system without self-cutting blades for this study. The fixture design, including thread profiles, was the exact same between the 2 groups, the only difference being the presence of cutting blades on one-half of the apical portion of the implant body.

Solid rigid polyurethane blocks (Sawbones Pacific Research Laboratories, Washington, DC, USA) were used as an alternative for human jaw bone. To simulate low-density bone, grade no. 10 polyurethane foam (density 0.16 g/cm$^3$) was selected.

**Implant placement and insertion torque measurements**

A total of 60 implants were used for 5 different measurements: 30 with self-tapping blades and 30 without self-tapping blades. All of the implants were inserted by a specially designed CAD-CAM type machine (Osstem Implant Co.) according to the manufacturer’s instructions for soft-bone drilling. The implant site for placement was prepared perpendicular to the model surface. A vise was used to support the specimen blocks during the testing. The device was designed to insert implant fixtures with constant depth under computer control. Insertion torque was recorded automatically by a computer that was connected to the implant fixture installation device during the placement. All 5 measurements in this study were repeated 10 times for each group.

**Resonance frequency analysis and removal torque measurements**

RFA measurements were performed using the Ossstell Mentor (Integration Diagnostics, Göteborg, Sweden). Measurements were made immediately after insertion torque measurement, using the same specimen. Transducers (no. 6 Smartpeg; Integration Diagnostics) was attached to the implant fixture by hand tightening. For each implant, the 4 readings were taken at 4 orientations differing by a 90-degree angle, which were buccal, lingual, mesial, and distal sides, and implant stability quotient (ISQ) values were averaged.

After the RFA, a torque controller (MGT12; Mark-10 Co., Copiague, NY, USA) was used to unscrew the implant fixtures. The removal torque was defined as the minimum torque needed to completely unscrew the implant fixture and remove it. The torque controller enabled direct reading of the removal torque.
Push-in and pull-out tests

The push-in and pull-out tests were carried out with a Universal Testing Machine (Instron Dynamic Material Testing Machine, Instron, Bucks, UK; Fig. 2). Implants were inserted in the bone model, and a guide pin of 2-piece transfer impression coping was attached to the implant fixture by hand tightening. After alignment and mounting in the testing machine, implants were loaded vertically downward (push-in test) or upward (pull-out test) with a 2,000-N load cell at a displacement rate of 1 mm/min. The push-in and pull-out values were determined by measuring the peak of the load-displacement curve.

Statistical analyses

The PASW Statistics 17.0 software (SPSS, Chicago, IL, USA) was used for the descriptive statistical analysis. Mean values and standard deviations were calculated, and the statistical significance of the difference between 2 groups was determined by Mann-Whitney test. Spearman test was used to evaluate the correlations of the different outcome variables (ISQ value, removal torque value, push-in load value, and pull-out load value) with insertion torque value. A P value of <.05 was considered to be statistically significant.

RESULTS

Five analytical methods

The results of the all 5 measurements are summarized in Table I. Each measurement result is expressed by graphs in Figs. 3-6.

Implants without self-cutting blades showed higher median values than implants with self-cutting blades in maximum insertion torque (16.4 ± .7 N·cm vs. 11.7 ± .5 N·cm), RFA (55.1 ± .9 vs. 52.6 ± .8), and removal torque (14.0 ± 1.2 N·cm vs. 8.5 ± .5 N·cm; Figs. 3-5).

Push-in and push-out load values were measured by Instron dynamic material testing machine, and the value was recorded automatically by a computer that was connected to the machine. Among the presented values, the maximum values were determined as push-in and pull-out load values. The comparison of push-in test (188.0 ± 5.8 N vs. 150.0 ± 11.6 N) and push-out test (132.7 ± 4.4 N vs. 101.3 ± 5.6 N) between the groups also resulted in a higher median value for the implant without self-cutting blades than for the implant with self-cutting blades (Fig. 6).

All of these 5 differences were statistically significant between the 2 groups (P < .001). Thus, data from this analysis indicated that in general, implants without self-cutting blades have a higher primary stability than implants with self-cutting blades in a simulated low-density bone model.

Correlation of the different outcome variables

Table II shows the correlations between the different outcome variables (ISQ value, removal torque value, push-in load value, and pull-out load value) with insertion torque value for the 2 types of implants. A statistically significant correlation was found between insertion torque values and push-in load values of implant without self-cutting blades (r = 0.936; P < .001). Push-in load values of implants with self-cutting blades tended to have a correlation with insertion torque values, but this was not statistically significant (r = 0.612; P = .060). In addition, removal torque values of implants without self-cutting blades tended to have a correlation with insertion torque values, but this was not statistically significant (r = 0.620; P = .056).

DISCUSSION

The present study was attempted to investigate the effect of a self-cutting blade implant design on primary stability of tapered dental implants in a simulated low-density bone model. In this study, 5 analytical methods...
Fig. 3. Mean values of maximum insertion torque grouped by implant design.

Fig. 4. Box-and-whisker plots of the of implant stability quotient (ISQ) values grouped by implant design. RFA, Resonance frequency analysis.
to assess for primary stability were evaluated for objective comparison, because there is no gold standard for evaluation of primary stability.

Based on the published validation of the American Society for Testing and Materials, polyurethane blocks are used to simulate mechanical properties of human bone. Polyurethane blocks have already been used to be the standard material for performing mechanical tests on orthopedic implants and recently have been used in dental fields.

In the study by Bardyn et al., a bone analog made from polyurethane foam was used to isolate the influences of bone density and cortical thickness in RFA. Chong et al. inserted implant fixtures in polyurethane blocks to examine the effect of self-cutting blades on primary stability in tapered implants.

Insertion torque value is considered to reflect the degree of primary stability; therefore, a proper insertion torque value can lead to success of dental implants. The present study has shown that implants without...
self-cutting blades had higher insertion torque values than implants with self-cutting blades. Too high insertion torque value is considered to inflict surgical trauma and destroy the osseointegration between bone and implant. Successfully inserted implants were associated with torque values $>32$ N cm$^{22}$ or $>35$ N cm. However, clinicians frequently face extremely low insertion torque from 5 N cm to 15 N cm during the implant installation for posterior maxilla. In the present study, insertion torque values were distributed in a lower range ($16.4 \pm 0.7$ N cm vs. $11.7 \pm 0.5$ N cm) compared with the ideal clinical criteria. It means that this experimental bone bed has a reduced bone density, such as posterior maxilla, and it would be better to use the implant without self-cutting blades in this clinical situation. On the insertion torque value curves (Fig. 3), little torque value was observed from 0 to 2 mm depth because of the gap between the tapered implant body design and the prepared hole. After 2 mm depth, the insertion torque values increased linearly.

Higher ISQ value indicates greater implant stability, and lower value indicates less stability and greater risk of failure.\textsuperscript{5} It has been shown that immediate implant loading is successful when the ISQ value is $>65$.\textsuperscript{24} There are studies in which ISQ value is reliable to assess primary stability.\textsuperscript{1,25} However, it is difficult to compare primary stability between different systems by using the ISQ value.\textsuperscript{26} Zix et al.\textsuperscript{27} demonstrated that RFA is significant only in the long-term observations with a single system and that no significant differences in ISQ values are found between implants regarding loading period or location in the jaw. According to our unpublished data, the RFA value seems to be strongly related with the total area of the implant fixture. In the present experiment, the only difference of the fixture design was the presence of cutting blades on one-half of the apical portion of the implant body. Therefore, our results showed relatively small differences in RFA. Yet this difference was statistically significant between the 2 groups ($P < .001$).

Tanaka et al.\textsuperscript{28} found that the removal torque values of the self-cutting blade group were significantly lower than those of the tapping group at 3 and 6 months. They suggested that self-cutting blades can inflict surgical trauma in denser bone, and traumatic surgery resulted in poorer osseointegration. But that study was done on dense bone, and the removal torque values are too high in clinical criteria.

Many authors have used push-in and pull-out tests for assessment of primary stability.\textsuperscript{9,10} Brosh et al.\textsuperscript{9} performed push-in tests without any apical clearance. High push-in load value were shown in that study because of no apical clearance. In the present study, there was no apical clearance and we observed higher push-in load value than the pull-out test. It could be said that the difference between the push-in load and pull-out load was caused by apical clearance. On the load curves, both load values were diminished rapidly from particular points. Those points were considered to be the points that interfacial attachment strength between bone and implant was completely destroyed by the axial load.

Our experiments showed that implants without self-cutting blades had a higher primary stability than implants with self-cutting blades by all 5 measurements. It could be considered that the self-cutting blades had reduced the contact surface area and led to decrease of primary stability. Self-cutting blades had room for cutting and this space could be the reason for the difference between the 2 different implant designs.

Results of the present study corresponded well with those of the earlier studies which reported that implants without self-cutting blades had a higher primary stability.\textsuperscript{14,16,17} Originally, the self-cutting blade was developed for enhancement of primary stability in soft-quality bone.\textsuperscript{13} However, according to Rabel et al.,\textsuperscript{16} it has been shown that higher insertion torque values are reached using implants without self-cutting blades. In that study, the Ankylos implant system without self-cutting blades appeared to have greater primary stability than the Camlog implant system with self-cutting blades.

Higher ISQ values have been demonstrated for the implants without self-cutting blades in the studies by Chong et al.\textsuperscript{14} Closely similar results were obtained from our previous study.\textsuperscript{17} In that study, we also found that the Brånemark implant system without self-cutting blades have higher insertion torque value and pull-out load value than the Osstem implant system with self-cutting blades.

**Table II. Correlation of the different outcome variables**

<table>
<thead>
<tr>
<th>Method</th>
<th>Spearman correlation</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>With self-cutting blades</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insertion torque vs. ISQ</td>
<td>0.104</td>
<td>.775</td>
</tr>
<tr>
<td>Insertion torque vs. removal torque</td>
<td>0.434</td>
<td>.210</td>
</tr>
<tr>
<td>Insertion torque vs. push-in load</td>
<td>0.612</td>
<td>.060</td>
</tr>
<tr>
<td>Insertion torque vs. pull-out load</td>
<td>0.224</td>
<td>.533</td>
</tr>
<tr>
<td>Without self-cutting blades</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insertion torque vs. ISQ</td>
<td>0.202</td>
<td>.575</td>
</tr>
<tr>
<td>Insertion torque vs. removal torque</td>
<td>0.620</td>
<td>.056</td>
</tr>
<tr>
<td>Insertion torque vs. push-in load</td>
<td>0.936</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Insertion torque vs. pull-out load</td>
<td>-0.067</td>
<td>.855</td>
</tr>
</tbody>
</table>

ISQ, implant stability quotient.
These findings were in contrast to the results of Al-Nawas et al. and Toyoshima et al. Those studies showed that implants with self-cutting blades showed higher primary stability. The Bränemark implant system with self-cutting blades reveals higher insertion torque and ISQ values than the Straumann implant system without self-cutting blades. Toyoshima et al. also presented similar results that the Straumann implant system with self-cutting blades have higher insertion torque, Periotest, ISQ values, and push-out load values.

It can be considered that diversity of implant systems and measurement methods used in those studies cause such different results. The presence of other factors affecting the results leads to confusion. To compensate for the limitations of previous studies, the present study was carried out under identical conditions except for the presence of self-cutting blades. Thus, this study could evaluate the influence of the self-cutting blade itself on the primary stability in a simulated low-density bone model.

There were some limitations in this study. However, unlike previous studies, this study was carried out under identical conditions; therefore, the influence of the self-cutting blades itself on the primary stability in low-density bone could be evaluated.

Based on the findings of our biomechanical analysis, the following conclusions were obtained. The primary mechanical stability of implants without self-cutting blades is higher than those with self-cutting blades, and thus the primary stability of dental implants was affected by the self-tapping blade in a simulated low-density bone model. A positive correlation with insertion torque measurement was found only for push-in load value in implants without self-cutting blades.

What is the clinical implication of these results? When clinicians face a poor supportive capacity of bone (reduced bone density, such as posterior maxilla), compared with the implant diameter, a smaller drill diameter should be chosen. In addition, from the findings of the present study it can be assumed that implants without self-cutting blades create a lateral compression with increased contact surface area, consequently improving the primary stability. In case of low-density bone that is composed of weak trabecular bone only, the implants without self-cutting blades would not generate high insertion torque (>50 N·cm) nor overheating during the placement.

Although clinicians do not have control of bone quality available for implant placement, the remaining parameters must be carefully considered for the success of the procedure. The outcomes of the present investigations might help in clinicians’ decisions, especially when dealing with soft bone of less favorable quality.

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Reprint requests:
Young-Jun Lim, DDS, MSD, PhD
Associate Professor
Department of Prosthodontics
School of Dentistry
Seoul National University
28 Yeongeon-dong, Jongno-gu
Seoul 110-749
Korea
limdds@snu.ac.kr