Achieving sufficient primary implant stability in poor-quality bone is difficult. Other than for conventional osteotomes, little is known about the effectiveness of screw-shaped spreaders in condensing bone and increasing primary stability. Therefore, implant stability quotient (ISQ) measurements of implants placed in bone surrogate models were conducted. Whereas bony microarchitecture had no effect on implant stability, initial bone density, presence of a cortical layer, and the use of screw-shaped spreaders significantly increased ISQ levels.

**Key Words: bone condensing, primary implant stability, rotating osteotomes, resonance frequency measurements**

**INTRODUCTION**

Initial implant stability has been described as a key factor for future osseointegration and may be used as a prognostic determinant of whether an immediate or early loading protocol can be applied.\(^1,2\) In contrast to secondary implant stability, which is attributable to bone formation and remodeling at the implant-bone interface, primary implant stability at placement is a mechanical phenomenon that is related to the local bone quality and quantity, as well as the type of implant and placement technique used.\(^3,4\)

In areas of poor-quality bone,\(^5\) achieving sufficient primary implant stability is difficult.\(^6\) Various techniques, such as undersized drilling,\(^7\) the use of tapered implants,\(^8\) and the use of osteotomes,\(^8-10\) have been introduced to increase local bone density and hence primary implant stability. It has been claimed that, besides expanding atrophic ridges,\(^11\) osteotomes could also be used to conserve the bone and thus would be superior to conventional implant bed preparation using burrs.\(^12\) According to Strietzel and coworkers,\(^8\) these goals of nonablative implant bed preparation would be achieved by lateral and apical bone relocation and condensation.

Controversial results on the applicability of bone-condensing techniques to enhance primary implant stability can be found in the literature.\(^2\) In 2 human cadaver studies, bone condensing was found to affect peri-implant bone architecture, while no significant increase in implant stability was detected.\(^2,13\) Similarly, 2 animal studies showed that the use of osteotomes for implant bed preparation resulted in enhanced osseointegration of dental implants, particularly in the early healing phase.\(^14,15\) On the contrary, Gulsahi and coworkers\(^16\) reported no significant differences in bone-related parameters, such as bone mineral density, when implants were placed in patients applying conventional or bone-condensing methods. On the other hand, 2 cadaver studies showed that conventional implant placement led to higher stability than the osteotome technique.\(^17,18\) In an animal study
that investigated the influence of the osteotome technique on osseointegration and the biomechanical behavior of cylinder implants, no significant increase in primary stability could be detected in implants being placed using bone-condensing methods.\(^ {19,20}\)

In addition to the complicated use of osteotomes in the mandible, the mechanical impact from the surgical mallet is not well tolerated by patients.\(^ {11}\) Going beyond a certain level of discomfort for the patient, cases of concussions and benign paroxysmal positional vertigo have also been reported as possible side effects of using conventional osteotomes.\(^ {10,11}\) Recently, screw-shaped spreaders (rotating osteotomes) have been introduced; these can be used to laterally compress bone, thereby increasing the cancellous density adjacent to the implant site.\(^ {11,21}\)

The aim of this in vitro study was to test the effectiveness of rotating osteotomes in increasing the primary stability of implants placed in bone models differing in density and structure. The null hypothesis was that there would be no difference in primary implant stability when using drills or rotating osteotomes for implant bed preparation.

**Materials and Methods**

**Model material**

Standardized polyurethane foam models of different densities and structures comparable to cancellous bone (Sawbones Europe AB, Malmö, Sweden) were used as bone surrogate material for the investigation.\(^ {22,23}\) The materials had a solid or a cellular structure with densities of 10 or 20 pcf. In part of the models, an additional cortical layer, represented by a sheet of high-density solid polyurethane foam (40 pcf) 3 mm in thickness was simulated.
Implant system and preparation techniques

Tapered titanium dental implants (BEGO Semados RI Implantat, BEGO Implant Systems GmbH, Bremen, Germany) with a diameter of 4 mm at the implant shoulder, a diameter of 3.5 mm at the apex, and a length of 15 mm were used for the study. Conventional placement of the implants was done in strict adherence to the manufacturer’s guidelines. The implant positions were marked with a round burr followed by the use of a total of 4 twist drills and a counter sink for complete implant socket preparation. Before implant placement, threads were cut in the bone to the full length of the socket (Figure 1). For bone condensation, a set of burrs and rotating osteotomes, corresponding to the implant system (Split-Control 15 mm, Hager & Meisinger GmbH, Neuss, Germany), was used. Similar to conventional placement, the implant sites were marked and 3 twist drills (Figure 2a) were used to create an osteotomy. Preparation of the implant socket was finalized using a total of 6 osteotomes (Figure 2b). All implants were placed using a surgical motor (Surgic XT, NSK Europe GmbH, Eschborn, Germany) and the implant manufacturer’s adapter (Figure 3). A total of 10 implants were placed in each of the materials using the conventional or bone-condensing technique.

Implant stability measurements

SmartPeg abutments were attached to the implant shoulders, and resonance frequency measurements (Osstell Mentor, Osseointegration Diagnostics AB, Gothenburg, Sweden) were performed to determine primary implant stability as implant stability quotients (ISQs). Two measurements at a 90° angle corresponding to the mesial and buccal aspect were taken and used to calculate a mean ISQ value for each implant (Figure 4). The arithmetic mean of these measurements (mean ISQ value) was used for further analysis.

Statistical analysis

A three-way analysis of variance (ANOVA) was set up with initial bone density (4 categories), bone type (2 categories), and preparation technique (2 categories) as fixed factors. The design was balanced with 10 samples in each of the 16 groups. To reduce the differences in standard deviations, logarithmic transformation was applied to each of the mean ISQ values. Additionally, for the factor bone type, multiple comparisons (Tukey honestly significant difference) were performed. The level of significance was set at $\alpha = .05$.

Results

The lowest mean ISQ values were found for implants that were conventionally placed in solid 10 bone (ISQ, 49.15 ± 7.41) whereas maximum mean values were obtained for implants placed in cellular 20 bone with an additional cortical layer using the osteotome technique (ISQ, 78.5 ± 1.71). The mean values and standard deviations for ISQs resulting from different materials and preparation techniques are given in Figure 5. The ANOVA (Table 1) revealed a significant influence ($P = .000$) on primary implant stability for all three fixed factors (bone type, bone density, and preparation technique) at the main effects. With the exception of implants placed in cellular 10 bone, the use of rotating osteotomes always resulted in higher levels of primary implant stability compared with conventional implant placement. Independent from the

<table>
<thead>
<tr>
<th>Table 1</th>
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<tr>
<td>Results from analysis of variance on the effect of bone type (BT), bone density (BD), and preparation technique (PT) on primary implant stability; results are given as $P$ values, and significant differences ($P &lt; .05$) are written in bold.</td>
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<table>
<thead>
<tr>
<th>Sum of Squares</th>
<th>Degree of Freedom</th>
<th>Mean of Squares</th>
<th>F</th>
<th>P Value</th>
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</thead>
<tbody>
<tr>
<td>BT</td>
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<td>46.384</td>
</tr>
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<td>1</td>
<td>0.945</td>
<td>111.904</td>
</tr>
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<tr>
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<tr>
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</tr>
<tr>
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<tr>
<td>Error</td>
<td>1.216</td>
<td>144</td>
<td>0.008</td>
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Effect of Rotating Osteotomes

presence or absence of a cortical layer, increasing density of the bone surrogate material also led to an increase in implant stability, which explains the low $P$ values ($P = .013, P = .000$) of the respective interaction terms.

Pairwise comparisons (Table 2) between the different bone surrogate materials revealed significantly higher mean ISQ levels when an additional layer of cortical bone was present ($P = .000$). No difference between solid and cellular materials could be detected when the materials were used alone ($P = .994$) or in combination with a cortical layer ($P = .907$).

**DISCUSSION**

Rejecting the null hypothesis, greater and more consistent ISQ values were obtained for implants placed with the osteotome technique compared with conventionally placed implants. Hence, it may be argued that the use of rotating osteotomes increases the primary stability of dental implants. This is consistent with previous studies applying the osteotome technique in human cadavers$^{2,13}$ and animal models,$^{14,15}$ respectively. However, contradictory reports that did not find a significant influence of osteotomes on primary implant stability and bone quality$^{16,19,20}$ or that found conventionally placed implants to be more stable$^{17,18}$ can be found.

Clinically, osteotomes are predominantly used in areas of compromised bone quality. For that reason, only bone surrogate materials with low levels of density have been used in this study. Although it was found that primary bone density affected implant stability with and without the use of rotating osteotomes, it cannot be inferred based on the results presented that osteotomes would be equally effective in bone showing higher levels of density. Similarly, in previous reports, individualized drilling sequences depending on bone density have been recommended.$^7$

Whereas no influence of microarchitecture of bone, that is, solid versus cellular materials, on primary implant stability has been found, the presence of an additional layer of cortical bone led to a significant increase in ISQ levels for both preparation techniques. This appears to be consistent with the results of a human cadaver study demonstrating a correlation of cortical bone thickness and primary implant stability.$^{27}$

Besides primary implant stability, the subsequent healing phase is also of great importance for implant success. Based on reports from different animal studies, it appears that the use of osteotomes influences the architecture of bone surrounding the implants and the bone-implant interface. In the initial healing phase, favorable values in terms of bone density and bone implant contact have been shown,$^{13–15}$ which then gradually converged with values from conventionally placed implants.$^{14,15}$ It has also been reported that increased numbers of fractured trabeculae$^{19}$ and higher levels of turnover$^{14}$ can be found in bone surrounding implants placed using bone-condensing methods. It can therefore be concluded that the application of osteotomes leads to greater damage of bone, resulting in lateral and apical bone relocation and condensation,$^8$ which in turn leads to an increased remodeling rate. Decreased implant stability after the initial healing phase,$^{19}$ as well as a potentially decreased success rate of implants placed using the osteotome technique,$^{16}$ may be considered as disadvantages of this technique.

**Limitations of the study**

Although no significant differences in standard deviation of ISQ values could be detected between experimental groups for implants placed with the osteotome technique (Levene’s test of equality of error variances; $P = .208$), standard deviations in conventionally placed implants differed significantly (Levene’s test of equality of error variances; $P = .028$). This has to be taken into account when interpreting the statistical results presented, as equal variances are a prerequisite for the use of ANOVA. Because this test is robust against unequal

<table>
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<th>Table 2</th>
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<tr>
<td>Results from Tukey honestly significant difference tests comparing different bone types; results are given as $P$ values, and significant differences ($P &lt; .05$) are written in bold.</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Cellular</td>
</tr>
<tr>
<td>Solid</td>
</tr>
<tr>
<td>Cellular plus cortical</td>
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<td>Solid plus cortical</td>
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</tbody>
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error variances in the case of balanced designs, however, the results can—in view of the very low \( P \) values—be assumed to be valid.

Although it has been argued that cancellous bone has a cellular structure consisting of a connected network of rods and plates with mechanical properties similar to that of other cellular materials, such as polymeric foams, the use of polyurethane foam models as bone surrogate material might be seen as a limitation of this investigation. On the other hand, the use of materials with well-defined properties has advantages in terms of handling and consistency of the results. Nevertheless, controlled clinical studies are needed for an ultimate evaluation of rotating osteotomes where factors related to handling characteristics, such as time expenditure and patient discomfort, should also be taken into account.

**ABBREVIATIONS**

BD: bone density  
BT: bone type  
ISQ: implant stability quotient  
PT: preparation technique

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**REFERENCES**


