# Comparison of Osteotome and Conventional Drilling Techniques for Primary Implant Stability: An In Vitro Study

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It may be difficult to achieve primary stability in the posterior maxilla because of poor quality and quantity of bone. Studies have shown that the osteotome technique immediately increases bone density thereby increasing primary stability. An in vitro study was conducted to compare the stability achieved by the osteotome and conventional drilling techniques in low density bone. Forty endosseous implant fixtures (n = 40) were inserted in a solid rigid polyurethane block simulating low density (D3) bone. The implants were divided into 4 groups to test 2 variables: (1) implant length (10 mm or 13 mm) and (2) preparation of osteotomy (conventional drilling or osteotome technique). Insertion torque (IT) and resonance frequency analysis (RFA) were measured for each implant. Statistical analysis using one-way ANOVA and Tukey post hoc test was done to study IT and RFA data of the 4 groups. Pearson Correlation test was used to determine the correlation between IT and RFA values of the implants. The IT and RFA values were statistically significant higher using the osteotome technique as compared to conventional drilling ($P < 0.0001$). Statistically significant higher values were also found for IT and RFA of 13 mm implants as compared to 10 mm implants. A significant correlation was found between insertion torque and RFA values in all 4 groups ($r = 0.86$, $P < 0.0001$). The conclusion was that the osteotome technique significantly increased primary stability.

Key Words: osteotome, dental implant, drilling, primary stability, bone density, bone quality, in vitro, resonance frequency analysis, insertion torque, soft bone

## INTRODUCTION

Dental implants are a highly predictable treatment modality. However, a number of factors, including surgical technique, bone quality and quantity, a patient's healing capacity, and implant design, can affect their survival and success.[1]

Primary stability, the initial mechanical engagement between the bone and implant, is essential for osseointegration.[1,2] It is negatively affected by inferior bone density.[2] According to a systematic review by Esposito et al,[3] implant failure is 3 times greater in the posterior maxilla than in the mandible. Therefore, modifications of the surgical protocol and dental implant design have been used to improve the primary stability of dental implants.

The osteotome technique, first developed by Summers,[4] appears to be advantageous for use in the posterior maxilla (D3 and D4 bone).[5] It improves the implant's primary stability by condensing the existing lower density bone. Additionally, it expands the maxilla, elevates the sinus floor, and minimizes intraoperative heat generation.[6,7]

To quantitatively assess the primary stability of dental implants, the implant insertion torque (IT)[8] and the resonance frequency analysis (RFA)[9–11] are clinically used. There are contradictory results regarding their correlation. Some studies have found a positive correlation between IT and RFA values.[12,13] According to others, this correlation was site specific.[14,15] Studies by Friberg et al[14] and Xing et al[15] have shown no correlation between RFA and IT in poor density bone, particularly in the posterior maxilla. Lastly, Shliephake et al[16] evaluated resonance frequency, insertion torque, and bone density using histomorphometric data and found no correlation between these measurements.

The purpose of this in vitro study was to compare the primary stability of dental implants placed in poor density bone using the condensing osteotome technique vs conventional drilling. An additional purpose was to examine the correlation between RFA and IT readings in low density bone.

## MATERIALS AND METHODS

### Experimental design

A 200 mm × 160 mm × 60 mm, 18 pcf (pcf: per cubic foot; pcf values 10–20 comparable to D3 density bone), solid, rigid polyurethane block (Sawbones, Pacific Research Laboratories, Vashon, Wash) was used to simulate D3 density bone. According to the American Society for Testing Materials,

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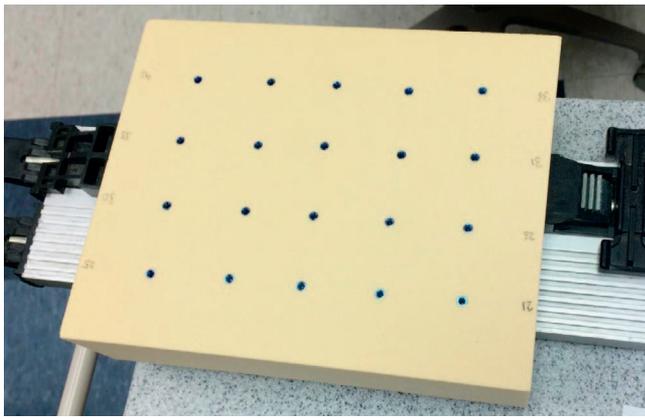
**FIGURE 1.** The block was stabilized using a clamping device in order to prevent any undesirable movements during the procedure.

polyurethane blocks have biomechanical properties simulating those of human bone. Polyurethane is often used in mechanical tests in orthopedic research.[17]

The block was stabilized using a clamping device that was fastened onto a table top. Forty implants (Prevail Certain Tapered implants, Biomet 3i, Palm Beach Gardens, Fla) were placed on the block. Of these 40 implants, 20 were 4 mm × 10

mm and the remaining 20 were 4 mm × 13 mm. These were each assigned to 2 groups depending on the technique used to prepare the implant site using a random number table. Therefore, there were 4 groups:

Group 1: Conventional drilling technique for the placement of 4 mm × 10 mm implants (10 implants)

Group 2: Conventional drilling technique for the placement of 4 mm × 13 mm implants (10 implants)

Group 3: Osteotome technique for the placement of 4 mm × 10 mm implants (10 implants)

Group 4: Osteotome technique for the placement of 4 mm × 13 mm implants (10 implants)

IT and RFA was measured for all implants.

### Preparation of site and data collection

Twenty implants were placed on either side of the block. There was a 3 mm distance between adjacent implants and the implants from the sides of the block as well (according to specifications of the manufacturer of block; Figure 1). A template was used to determine the exact implant sites. In drilling groups, a pilot drill (2.3 mm) followed by 3 mm and 4 mm quad drills were used at 1200 rpm. In the osteotome groups, 2-mm tip natural taper (NT) osteotome (Biomet 3i) was
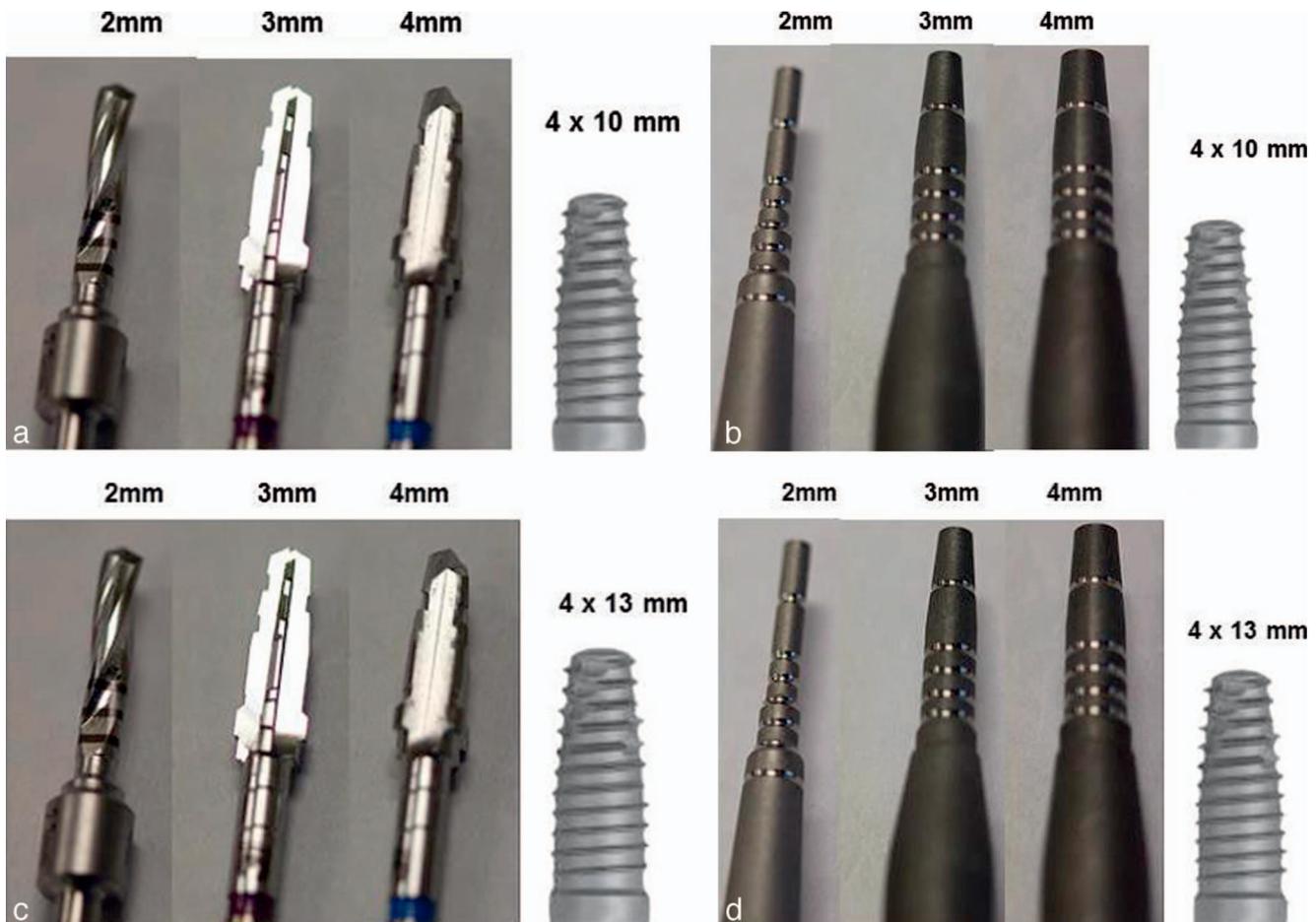


**FIGURE 2.** The sequence of procedures in each group of the study.

**TABLE 1**

Mean values, standard deviations (SD), and 1-way ANOVA for insertion torque values (Ncm)

| Group | N | Mean | SD | P-value | Tukey post-hoc* |
|---|---|---|---|---|---|
| Drilling: 4 × 10 mm fixture | 10 | 17.50 | 3.54 | < .0001 | A |
| Drilling: 4 × 13 mm fixture | 10 | 22.00 | 2.58 | | B |
| Osteotome: 4 × 10 mm fixture | 10 | 45.00 | .00 | | C |
| Osteotome: 4 × 13 mm fixture | 10 | 45.00 | .00 | | C |

*Same letter shows no statistically significant difference; A<B<C.

used followed by 3 mm and 4 mm NT osteotomes (Biomet 3i; Figure 2). The implants were placed at 20, 25, 30, 35, 40, 45 N/cm until seated at crest (IT values). If an implant measured an IT more than 45 Ncm, it was torqued to the level of the block with a hand ratchet. The implant perimeter was divided in 4 equal sections. One ISQ measurement was taken per section, ie, 4 ISQ measurements from each implant (Ostell AB, Göteborg, Sweden). The mean ISQ value for each implant was calculated for the statistical analysis. Following the instructions of the manufacturer, a new oscillating transducer was used to capture the resonance frequency of each implant.

### Statistical analysis

Insertion torque and RFA data were analyzed using 1-way ANOVA and Tukey post-hoc test to compare 2 different methods of implant site preparation as well as 2 different lengths of implant fixtures in the 4 study groups. Pearson's correlation coefficient test was also performed to determine correlation between insertion torque and RFA values in the present study. The data analysis was performed using SPSS version 21.0 (IBM, Chicago, Ill), and a P-value < .05 was selected as the level of statistical significance.

### RESULTS

The mean insertion torque for each group is presented in table 1. Osteotome technique groups had statistically significant higher insertion torques (45 Ncm) than conventional drilling groups (P < .0001). Tukey post-hoc test revealed that the length of the fixtures also had a statistically significant effect on insertion torque values between groups 1 (17.50 ± 3.54 Ncm) and 2 (22.00 ± 2.58 Ncm).

Table 2 demonstrates the mean values and standard deviations of RFA values (ISQ) in 4 groups. A higher RFA value was obtained with osteotome technique and 4 × 13 mm fixtures (67.30 ± 1.25 ISQ) compared with other groups. Group 1 (conventional drilling with 4 × 10 mm fixtures) showed lower

RFA values (56.70 ± 2.79 ISQ). The mean between-group differences reached statistical significance (P < .0001).

Pearson's correlation coefficient revealed significant correlation between insertion torque and RFA values in all groups (r = 0.86, P < .0001; Figure 3).

### DISCUSSION

The present in vitro study showed that both variables—implant length and osteotomy preparation technique—affect initial stability.

### Comparing drilling to osteotome

Some studies[7,15,18–22] found a positive association between the osteotome technique and the primary implant stability, others found a negative association,[6,12,23,24] and some[25] no association. This controversy may be due to the variety of osteotomes design, level of site under-preparation, and study designs. Exceeding the strain range of 50–1500 microstrains,[26] within which bone is believed to function, might have led to impaired healing. According to the only prospective randomized controlled clinical study,[22] the application of the osteotome technique in the anterior maxilla leads to a statistically significant higher primary stability than conventional drilling as measured by RFA. According to Büchter et al,[23] 7 days after implant insertion in minipigs' tibia, fractured spongiosal trabeculae were present adjunct to the implant surface when using the osteotome technique. However, minipigs have a denser trabecular network than humans[27] and the insertion torque was not reported. Even more importantly, fractured trabeculae demonstrated no signs of tissue necrosis and implants in both groups were in direct contact with bone. There were no differences between drilling and osteotome sites three weeks later.[23] Shalabi et al,[28] Martinez et al,[29] and Nkenke et al[21] reported that a greater implant-to-bone contact can be achieved with the osteotome technique. It has also been claimed that the induced mechanical stimuli would accelerate

**TABLE 2**

Mean values, SDs, and 1-way ANOVA for RFA values (ISQ)

| Group | N | Mean | SD | P-value | Tukey post-hoc* |
|---|---|---|---|---|---|
| Drilling: 4 × 10 mm fixture | 10 | 56.70 | 2.79 | < .0001 | A |
| Drilling: 4 × 13 mm fixture | 10 | 60.70 | 1.77 | | B |
| Osteotome: 4 × 10 mm fixture | 10 | 64.50 | 1.08 | | C |
| Osteotome: 4 × 13 mm fixture | 10 | 67.30 | 1.25 | | D |

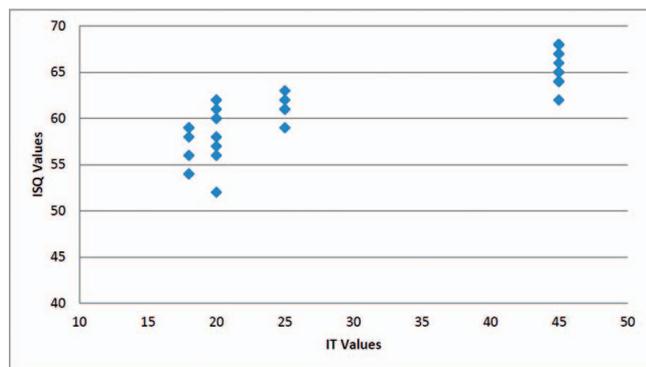*Same letter shows no statistically significant difference; A<B<C<D.

FIGURE 3. The Pearson correlation coefficient test showed significant correlation between IT (Ncm) and RFA (ISQ) values.

the formation of trabecular bone[26] through a regional acceleratory phenomenon.[7] Lastly, the preparation of implant bed through the protocol of the expansion-condensing osteotomes ensures the maximum preservation of the remaining bone. Contradictory results have been reported regarding implant stability at 3 months postoperatively.[6,7,18]

In the present study, the initial stability of the implants placed by the osteotome technique as gauged by the insertion torque was 45 Ncm, as compared with 17 Ncm in the 10-mm implant drilling group and 20 Ncm in the 13-mm implant drilling group. According to Xing et al,[15] an intelligent preparation of the implant bed by using expanding-condensing osteotomes in D3–D4 bone class minimizes microdeformations.

It should also be emphasized that the term bone density is often discussed rather than bone quality. Many papers in the literature define bone quality as equivalent to bone density. In addition to bone density, however, bone quality is affected by bone metabolism, cell turnover, mineralization, maturation, intercellular matrix, and vascularity. The extent to which every single factor of bone quality influences the outcome of the implant treatment has not yet been defined.[2]

To overcome postoperative complications that have been reported in the literature, like osteonecrosis and paroxysmal positional vertigo, divergent shaped osteotomes have been proposed.[15,30] Divergent osteotomes were used in the present study.

### Implant geometry

It has been shown that implant length is of great value in achieving primary stability. In the present study, it was observed that greater implant length attributed to an increase in primary stability. IT as well as RFA values were significantly higher in 13-mm groups than in the 10-mm groups. These findings suggest that implant length affects the initial stability particularly in low density bone.

Tapered implants have been used in the present study due to the fact that they distribute forces into the surrounding bone leading to a lateral compression of the bone, compared with parallel-walled implants.[31,32] However, Chong et al[32] reported that bone density has a stronger association with initial stability than implant design.

### Insertion torque and RFA

The present study revealed significant correlation between insertion torque and RFA values. Magno et al[33] indicated that there is a correlation between IT and RFA for different bone densities as assessed by the Lekholm and Zarb index.[5] Ahn et al[12] also showed a positive correlation between IT and RFA. On the contrary, Schliephake et al[16] evaluated resonance frequency, insertional torque, and bone density using histomorphometric data and found no correlation between these measurements. Friberg et al[14] and Xing et al[15] have shown that there is no correlation between RFA and IT in poor density bone, particularly in the posterior maxilla. Further, it has been shown that RFA is a variable measure, which fluctuates due to micro-movements at the implant-bone interface.[34] Studies by Degidi et al[35] suggested that IT and RFA may be independent factors of primary stability. In their study, it was shown that there was a strong dependency between IT and bone quality and that a very weak dependency existed between RFA and bone quality. RFA has also been observed to be more reliable in detecting the coronal implant-stability changes rather than in the apical thirds of the implant-bone system, whereas insertional torque is found to be related to the circumferential mean bone density.[36] Based on their findings in a clinical study, Xing et al[15] hypothesized that RFA and insertional torque were sensitive to different phases of implant-bone interface. Studies by Bayarchimeg et al[37] have reported similar findings. However, in the present in vitro study, there was a strong correlation between RFA and IT values across all groups.

Interestingly, in the drilling groups, while the insertion torque values were low, with a mean of 17. 5 Ncm for the 10-mm implants and 22 Ncm for the 13-mm implants, the mean RFA values were high at 56.7 and 60.7, respectively. The authors speculate that if similar observations were made in clinical practice, the clinician may consider an immediate loading protocol based on RFA values; osteotome site preparation may be preferred in type IV bone. Whereas, the revealed low IT value at the same sights might have been a concern for immediate loading. Therefore, the insertion torque should be considered as a more reliable measure of primary stability in low density bone when considering immediate loading. Please note that both the insertion torque and RFA measure mechanical implant stability achieved after bone condensation. They do not measure the applied pressure to induce bone compression. The osteocytes of the trabecular bone, however, seem to remain intact when the force of compression does not exceed 10–20MPa.[38,39] Further studies should be performed regarding the use of osteotomes and immediate implant function.

### ABBREVIATIONS

IT: insertion torque
NT: natural taper
RFA: resonance frequency analysis

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