The primary stability of dental implants is one of the crucial factors for providing long-term success of osseointegration. Vertical deficiencies, such as those due to maxillary sinus pneumatization, may cause a severe vertical limitation to residual bone height. This study aimed to examine the primary stabilization of implants without apical contacts. Materials and Methods: Eighty bone-level implants (4.1-mm diameter/10-mm length) were placed into polyurethane test blocks without apical contacts. According to coronal bone-to-implant contact, groups were set as 4, 6, 8, and 10 mm, respectively. Resonance frequency analysis (RFA) using a SmartPeg was performed separately toward the transversal and horizontal axes by two independent researchers. Data were statistically compared for interobserver and among groups. Results: Interobserver reliability varied from moderate to excellent (intraclass correlation coefficient [ICC]: 0.629 to 0.985). There were no significant differences among the 6 mm, 8 mm, and 10 mm groups, although the 4 mm group showed the significantly lowest stability (P < .001). Transversal and longitudinal measurements of the same groups did not show a parallel correlation statistically. Conclusion: RFA values may be affected by the finger torque in tightening of the SmartPeg among different researchers. Fully placed implants did not significantly show the highest stability among various apically contactless groups. Consequently, RFA should not be used alone to evaluate primary stability for implants without an apical contact. Int J Oral Maxillofac Implants 2022;37:543–548. doi: 10.11607/jomi.9480

Keywords: apically contactless, dental implant, primary stability, resonance frequency analysis
an independent statistician. Power analysis had shown that 20 samples for each group were adequate to find reliable results by taking the probability of 0.05 error and intraclass correlation coefficient (ICC) of 0.90 with 80%.\(^\text{12}\)

**Implants, Test Blocks, and Placement Procedure**

Eighty bone-level cylindrical implants (Institut Straumann), which measured 4.1 mm in diameter and 10 mm in length, had homogenously distributed threads. Their surfaces were sandblasted with large grit and acid etching. The test block had a cancellous part (0.48 g/cm\(^2\)) with a 1-mm-thick cortical layer (0.75 g/cm\(^2\)); thus, the artificial block imitated the posterior maxillary bone. The blocks were formed as a quadrangular prism imitating an alveolar bone ridge, which had transversal and longitudinal axes.

Four experiment groups were set that had 4 mm (Fig 1), 6 mm (Fig 2), 8 mm (Fig 3), and 10 mm (Fig 4) BIC coronally. First, all implant beds were prepared according to the manufacturer’s instructions: Ø 2.2-mm drill (800 rpm), Ø 2.8-mm drill (600 rpm), Ø 3.5-mm drill (500 rpm), and profile drill (500 rpm), respectively, and tapping with saline irrigation. A laser light guide was used for obtaining the correct angle while drilling (Fig 5). The experimental groups that had partial BIC were prepared by a reverse-drilling method using a Ø 4.2-mm drill to reduce RBH; then, all implants were placed with 35-Ncm torque power (10 rpm). Each implant was located at the separated blocks’ central zone and surrounded by 2-mm bone thickness.

**RFA Measurements**

Implant-placed blocks were fixed by a clamp while measuring the stability. RFA was performed using the Osstell ISQ device (Osstell). Type 54 SmartPegs (Osstell) were connected to implants with finger-tightening force. To enhance reliability, each implant was separately measured in transversal (T) and longitudinal (L) directions by the oral surgeon and the prosthodontist. Also, researchers separately tightened the SmartPegs with their own finger force before measuring. Each measurement was repeated five times, and the mode value was recorded for statistical analysis.

**Statistics**

A statistical table of data was created from the data compiled. This table was transferred to IBM SPSS V23 (IBM). The Shapiro-Wilk test was performed for testing normal distribution. The data were distributed normally (\(P < .05\)). One-way analysis of variance (ANOVA) was used for average comparison of the transversal and longitudinal groups. The Tukey honestly significant difference (HSD) test was performed for multiple comparisons. Interobserver variability was evaluated with ICC.

The study was planned in compliance with standards for reporting qualitative research (SRQR) guidelines.

**RESULTS**

In the oral surgeon’s measurements through the transversal (T) and longitudinal (L) directions (Table 1), there were statistical differences among each group (T: \(P = .001\), L: \(P = .002\)). The 8-mm RBH group was significantly higher for the transversal direction than the 4 mm and 6 mm groups, although there was no significant difference with the 10 mm group. For the longitudinal direction, the 4 mm RBH group was significantly
lower than both the 8 mm and 10 mm groups; however, there was no significant difference with the 6 mm group (Fig 6).

In the prosthodontist’s measurements through the transversal and longitudinal directions (Table 2), there were statistical differences among the values of each group (T: \( P < .001 \), L: \( P < .001 \)). The 8 mm RBH group was significantly higher for the transversal direction than the 4 mm and 6 mm groups, although there was no significant difference with the 10 mm group. For the longitudinal direction, the 4 mm RBH group was significantly lower than the 6 mm, 8 mm, and 10 mm groups. There were no significant differences among the 6 mm, 8 mm, and 10 mm groups (Fig 7).

ICC results varied from moderate to excellent (Table 3). There was excellent agreement (Figs 8a to 8d) for all transversal measurements (0.824 to 0.912). However, there was moderate agreement (Figs 9a, 9b, and 9d) for longitudinal measurements of the 4 mm (0.629), 6 mm (0.726), and 10 mm (0.635) groups. The longitudinal measurements of the 8 mm group showed the most excellent agreement (Fig 9c) among all experimental groups (0.985).

According to the ICC, the independent statistician advised combining both researchers’ results. Data were reanalyzed with average values (Table 4). There were statistical differences among the average values of each group (T: \( P < .001 \), L: \( P < .001 \)). The average statistical result for both the transversal and longitudinal directions showed that the 4 mm group was significantly lower than the others, and among the 6 mm, 8 mm, and 10 mm groups, there was no significant difference (Fig 10).

There was at least one ISQ result of 60 and above in all groups. Although there was no significant difference, the average of the 8 mm group was slightly higher than the average of the 10 mm group for both directions.

**DISCUSSION**

In the present study, the experimental model simulated the implant placements with sinus elevation
Fig 8  Bland-Altman plot for transversal measurements of (a) 4 mm RBH, (b) 6 mm RBH, (c) 8 mm RBH, and (d) 10 mm RBH.

Fig 9  Bland-Altman plot for longitudinal measurements of (a) 4 mm RBH, (b) 6 mm RBH, (c) 8 mm RBH, and (d) 10 mm RBH.
procedures in the posterior maxilla. A 0.48 g/cm³ density of polyurethane block with a 1 mm cortical layer was generally used in implant stability studies for optimizing standardization.13,14 Also, there are cadaver and animal studies in the literature.15,16

Implant site preparation directly affects the primary implant stability.17 The oral surgeon can modify the drilling protocol according to bone conditions. In the present study, the recommended regular drilling protocol with profile and tapping was used before implant placement. Thus, it was aimed at evaluating the primary stability neutrally. The insertion torque was in the optimal placement value according to the manufacturer’s recommendation, which is 35 Ncm.18

Implants ≥ 4 mm wide were described as conventional and recommended for posterior sites of the jaws.19 However, there is still a discussion about using implants that are shorter than 10 mm or the recommended-length (≥ 10 mm) implants combined with sinus elevation procedures.19 Guljé et al stated that 6-mm implants and 11-mm implants combined with sinus floor elevation surgery were equally successful to support a single crown after 1-year follow-up.20 A systematic review conducted by Fan et al showed no difference between the survival rates of short implants (5 to 8 mm) and long implants (> 8 mm); complications in short implants were lower than those in the long implants.21 In the present study, 10-mm implants were preferred for determining the ISQ differences among partial placements more prominently in only the mechanical aspect, and the RFA device showed an interesting result for 8 mm BIC.

Implant shape and thread distribution directly affect primary stability.22–25 Both straight and tapered-shaped implants can be used with sinus elevation procedures. In the present study, cylindrical-form implants with homogenous thread distribution were the preferred implants to compare the stability in an unbiased way.

RBH is a determiner for a one-stage or two-stage surgical procedure for the posterior maxilla. According to some authors, it is recommended that RBH should be ≥ 4 mm for simultaneous implant placement with sinus floor elevation. There are different sinus floor elevation techniques described in the literature, and the most crucial factor is RBH presence for implant placement.26,27 Primary stability is achieved via RBH; in contrast, the augmented sinus floor does not.28

Implant stability can be measured by RFA, which is the most accepted method. ISQ values ≥ 60 are the critical thresholds for primary stability. Besides, insertion torque should be 25 to 40 Ncm for good stability.26,29,31 In the present study, all groups showed different varying ISQ values under and above 60. Thus, there was no apparent correlation among groups with different BIC. Han et al tested primary implant stabilization in polyurethane models, which simulated sinus elevation procedures, and interestingly stated that the RFA result of 3 mm RBH was higher than 5 mm, 8 mm, and 12 mm.12 According to the present study, some 8 mm group measurements showed higher values than the 10 mm BIC group.

Cannizzaro et al compared long-term stability of one-stage lateral versus crestal sinus elevation of 8-mm implants with RFA analysis in the 5-year term and found no significant difference between RFA results, but no data about initial RFA values were declared.32 Shen et al reported that implant collar design affects primary stability and stress distribution.33 The micro-grooved collar design can be used for apically contactless cases to achieve good stability.34 In the present study, a plain collar design was preferred to avoid deviating the results.

Applying finger torque while fixing the transducer can affect RFA. The study conducted by Geckili et al reported that the SmartPeg tightening force of an individual’s finger torque might change the RFA values.35 In the clinical aspect, an oral surgeon and a prosthodontist can measure the implant stability separately. The present study showed that RFA results may be varied at different hands. Nevertheless, RFA is still a reliable

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**Table 4 Average of Oral Surgeon and Prosthodontist RFA Results**

<table>
<thead>
<tr>
<th>RBH</th>
<th>Transversal ISQ</th>
<th>Longitudinal ISQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 mm</td>
<td>55.8 ± 13.6 a)</td>
<td>64.4 ± 5.9 a)</td>
</tr>
<tr>
<td>6 mm</td>
<td>59.3 ± 10.5 b)</td>
<td>69.5 ± 5.6 b)</td>
</tr>
<tr>
<td>8 mm</td>
<td>72.0 ± 12.7 b)</td>
<td>72.6 ± 4.9 b)</td>
</tr>
<tr>
<td>10 mm</td>
<td>63.6 ± 11.0 b)</td>
<td>71.7 ± 6.2 b)</td>
</tr>
</tbody>
</table>

*P value* < .001 < .001

Values are presented as mean ± SD.

RFA = resonance frequency analysis; RBH = residual bone height; ISQ = implant stability quotient.

a)· b) No statistically significant difference between columns marked with the same letters.

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**Fig 10** Boxplot graphic RFA results for the averages of oral surgeon and prosthodontist.
measurement for evaluating implant stability. Although a high ISQ value in the surgical placement phase is a reliable indicator, it is not a lone determinant for long-term implant success.

CONCLUSIONS

Within the limitation of this mechanical study, the RFA can be devoted for assessing apically contactless implants and might be insufficient to determine primary stability alone.

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