Effect of Location on Primary Stability and Healing of Dental Implants

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Primary or mechanical implant stability plays the main role in successful osseointegration.1 The implant stability is determined by the availability of bone to anchor the implants.2 Likewise, bone quality has shown to be a key factor to foresee predictability in implant therapy.3 Therefore, a quantitative measurement of bone quality is essential before implant restoration. The assessment of whether to continue with restoration is largely based on the implant stability achieved. Thereupon, implant stability could be considered as the absence of mobility; it represents an essential condition to achieve successful outcomes in implant dentistry.4,5

Many methods have been proposed to assess initial osseointegration.6–8 However, most of them are no longer available due to their invasiveness and inaccuracy.9 In 1996, resonance frequency analysis (RFA) was developed and used implant stability quotient (ISQ) as a quantitative unit to assess implant stability.9 The reading of RFA reflects on the combination of the 3 main factors: (1) stiffness of the implant fixture and its interface with the surrounding tissues, (2) design of the transducer, and (3) total effective length above the bone level.10 The current version of a RFA device uses a small L-shaped transducer to “read” the implant stability. This transducer comprises 2 piezoceramic elements: one vibrating by a sinusoidal signal (5–15 Hz), whereas the other serves as a receptor.11 The ISQ reading ranges from 0 to 100, with the higher number indicating higher stability. Although there is no definitive threshold value to differentiate a stable, integrated implant from a failing/failed implant, it has been reported that a successful implant had ISQ ranging from 57 to 82 after 1-year loading.12 Furthermore, a value less than 50 might indicate a potential risk of implant failure.11

Therefore, ISQ value at the time of implant placement reports primary or mechanical stability and is determined mostly by the availability of bone surrounding the implant and also by the drilling protocol. However, over the time, the ISQ value reflects the healing process of the bone and thus, the secondary or biological stability achieved.

Purpose: To study implant primary stability and bone healing using resonance frequency analysis in different anatomical locations 4 months after placement.

Material and Methods: Fifty-six partially edentulous patients restored by dental implants were included. Overall, 214 implants were placed without bone or soft tissue augmentation. All implants were placed with the same drilling protocol and implant insertion torque (35–40 N·cm).

Results: The mean implant stability quotient (ISQ) value at baseline for all the locations was 75.4 mm (95% confidence interval, 74.20–76.59 mm). Higher ISQ values were found in the mandible. A significant difference between ISQ values of each location (P < 0.001) was identified. The mean values obtained showed an increase (3.4%) in all the locations, being greater in the posterior lower and upper maxillae (3.8%), whereas for the anterior maxilla, it was the least (1.5%) 4 months after healing. This increase was statistically significant in the posterior upper and lower maxillae (P < 0.001).

Conclusion: Higher implant stability was found in mandible compared with maxilla in both periods, immediately after insertion and 4 months later. Therefore, according to ISQ values, restoring implants immediately after insertion or after a healing period of 4 months represents safe time points. (Implant Dentistry 2013;0:1–5)

Key Words: implant stability, resonance frequency analysis, osseointegration, implant stability quotient

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by dental implants.13 Into the bargain, implant macrodesign and microdesign have shown to have an impact on ISQ value. For instance, it has been demonstrated that increasing 0.5 mm in implant width provides 10% to 15% more implant surface and thus greater implant width provides 10% to 15% onstrated that increasing 0.5 mm in ISQ value. For instance, it has been dem-

### Table 1. Mean ISQ Values and CI Obtained at the Baseline

<table>
<thead>
<tr>
<th>Implant Location</th>
<th>Mean Value (mm)</th>
<th>SE</th>
<th>Lower Boundary</th>
<th>Upper Boundary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posterior maxilla</td>
<td>74,207</td>
<td>0.807</td>
<td>72,616</td>
<td>75,797</td>
</tr>
<tr>
<td>Anterior maxilla</td>
<td>74,528</td>
<td>1.254</td>
<td>72,055</td>
<td>77,000</td>
</tr>
<tr>
<td>Posterior mandible</td>
<td>75,423</td>
<td>0.893</td>
<td>73,662</td>
<td>77,183</td>
</tr>
<tr>
<td>Anterior mandible</td>
<td>77,450</td>
<td>1.683</td>
<td>74,133</td>
<td>80,767</td>
</tr>
</tbody>
</table>

Higher ISQ values were found in the mandible. Nonetheless, there is a significant difference between the ISQ values of each location (P < 0.05). SE indicates standard error.

### Table 2. Mean ISQ Values and CIs Obtained 4 Months After Implant Placement

<table>
<thead>
<tr>
<th>Implant Location</th>
<th>Mean Value (mm)</th>
<th>SE</th>
<th>Lower Boundary</th>
<th>Upper Boundary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posterior maxilla</td>
<td>77,034</td>
<td>0.645</td>
<td>75,763</td>
<td>78,306</td>
</tr>
<tr>
<td>Anterior maxilla</td>
<td>75,639</td>
<td>1.003</td>
<td>73,662</td>
<td>77,616</td>
</tr>
<tr>
<td>Posterior mandible</td>
<td>78,324</td>
<td>0.714</td>
<td>76,916</td>
<td>79,732</td>
</tr>
<tr>
<td>Anterior mandible</td>
<td>80,100</td>
<td>1.346</td>
<td>77,447</td>
<td>82,753</td>
</tr>
</tbody>
</table>

Higher values were registered in the mandible, and a significant difference between the ISQ values of each location (P < 0.001) was also identified. SE indicates standard error.

### PRIMARY STABILITY AND BONE HEALING OF IMPLANTS • MONJE ET AL

### MATERIAL AND METHODS

Fifty-six partially edentulous healthy patients requiring oral rehabilitation by dental implants were included in this study from November 2009 to September 2012. Overall, 214 implants (Nobel Biocare Groovy Implants; Nobel Biocare AB, Göteborg, Sweden) were included in the study, of which, 110 were 3.75 mm, 75 were 4.1 mm, 27 were 4.8 mm, 9 were 5.5 mm, and 3 were 6 mm. All these included implants were placed in native ridges with no necessity of bone or soft tissue augmentation. Depending of the height of the remaining bone were placed either 10 or 11.5 mm implants in length. This study was independently reviewed and approved by the local ethical committee of the University Hospital Infanta Cristina (Badajoz, Spain). Written consent from each subject was obtained before the treatment.

### Inclusion and Exclusion Criteria

All the patients recruited met the following inclusion criteria: patients had to be between 18 and 85 years of age, with no systemic diseases or conditions known to alter bone metabolism and exhibit adequate oral hygiene. Patients were selected to undergo implant therapy in native bone with proper bone quality, width, and height and thus, no necessity of bone or soft tissue augmentation. Hence, patients whom underwent either socket preservation or bone augmentation at the time of the surgery or previously were excluded. Also, patients were excluded if they were pregnant, smokers, or taking medications known to modify bone metabolism.

### Implant Placement

All implants were placed in proper bone quality, width, and height. Each patient was required to take 500 mg of amoxicillin or 300 mg of clindamycin, if allergic, 1 hour before the surgery. All operations were performed under local anesthesia or under local anesthesia + intravenous sedation. A full-thickness incision was made to release the flaps. Implants were inserted according to manufacturer’s protocol. All implants were placed with the same insertion torque (35–40 N·cm). Finally, the facial flap was released to ensure a tension-free closure, and the flaps were sutured with absorbable suture. All patients received postoperative instructions and were given antibiotics and analgesic medications. The sutures were removed after 7 to 10 days.

### Resonance Frequency Analyses

A RFA device (Ostell Mentor; Integration Diagnostics AB, Göteborg, Sweden) was used for the measurement of primary implant stability. Basically, a designated metal rod (Smartpeg; Integration Diagnostics AB) was screwed into the implant screw vent. Then, a probe was placed close to the rod at the midfacial side and the buccal side of the implant. The ISQ was generated and recorded for both sides. The 2 measurements were averaged to represent the primary stability of each implant.

### Statistical Analysis

The mean values of scores were calculated and divided into 4 groups according to their locations (anterior/posterior and upper/lower jaw). For this, a mixed model was applied to compare the ISQ values at baseline and after the healing period in all the locations.
RESULTS

Descriptive Analysis
All dental implants were successfully maintained for 4 months. The number of implants placed in the maxilla was 87 (40.65%) and 36 (16.82%) for the posterior and the anterior areas, respectively. A lesser number of implants was analyzed in the mandible, 71 (33.17%) for the posterior, and 20 (9.34%) for the anterior areas.

ISQ Values at the Baseline
The mean ISQ value at the baseline for all the locations was 75.4 mm (95% confidence interval [CI], 74.20–76.59 mm). The mean values obtained in each location are represented in Table 1. Higher ISQ values were found in the mandible. Nonetheless, there is a significant difference between the ISQ values of each location ($P < 0.001$).

ISQ Values 4 Months After Implant Placement
The mean ISQ value 4 months after implant placement for all the locations was 77.51 mm (95% CI, 76.82–78.72 mm). The mean values in each location are represented in Table 2. Again, higher values were registered in the mandible, and a significant difference between the ISQ values of each location ($P < 0.001$) was also identified.

Comparison Between Baseline and 4 Months ISQ Values
Figure 1 depicts the evolution of the ISQ values registered at both timelines. The mean values obtained showed an increase (3.4%) in all the locations, being greater in the posterior lower and upper maxillae (3.8%), whereas for the anterior maxilla it was slighter (1.5%). Therefore, the increase is statistically significant in the posterior upper and lower maxillae ($P < 0.001$) (Table 3). Moreover, the differences observed in the increases in all the locations are statistically significant among them ($P < 0.001$) (Fig. 2).

DISCUSSION
Assuming that implant primary stability plays the major role in early osseointegration, factors related to it must be assessed thoroughly to achieve...
successful implant therapy. Many parameters, such as implant macrodesign and microdesign or drilling protocol, have shown to affect implant primary stability.\textsuperscript{16} Nonetheless, the main parameter that determines dramatically the implant stability over the time is the bone quality. According to Misch (1989) bone quality classification, the location defines bone density. Hence, osseointegration varies according to implant position, and thus, in an attempt to not disturb the biological stability process, loading protocol relies on the location. Many studies have investigated the factors (eg, gender, diameter and length of the implants, surface coating, and other factors) that might affect implant stability.\textsuperscript{12,17} According to a recent publication, excepting implant length all the other factors, such as anatomical locations, implant surface, drilling protocol, measurement period, and implant diameter, have been shown to influence ISQ.\textsuperscript{17} Hence, the purpose of this study was to assess, under the same features and conditions, the effect of implant position upon primary stability and to understand how these implants heal up to 4 months.

RFA is a valid method to quantify initial implant stability. Primary stability is related to the percentage of bone-to-implant contact and the bone density around the implant.\textsuperscript{18} Furthermore, RFA was shown to correlate with the amount of cortical bone height.\textsuperscript{19,20} Thereupon, implant positioned in the lower maxilla should obtain higher ISQ values. Guler et al\textsuperscript{17} reported no significant difference in ISQ values between the maxilla and the mandible. However, the posterior maxilla was generally related with lower values, whereas in the mandible, higher values were obtained. On the other hand, Balleri et al\textsuperscript{12} found out that although there was significant difference between maxilla and mandible, it was not between the anterior and posterior areas. Similarly, Ersanli et al\textsuperscript{20a} showed higher primary implant stability of implants placed in the mandible.\textsuperscript{17} Accordingly, the results of this study agrees with previous studies,\textsuperscript{12,21–25} where implant primary stability was found to be higher in the mandible due to the bone quality of the healthy patients included.

Timing of assessment has been considered another important factor to consider. The ISQ values are thought to be higher during baseline due to the primary stability but tend to decrease as soon as healing process and bone remodeling starts. It reaches its peak at 4 weeks, and it increases until it reaches osseointegration at 6 months.\textsuperscript{17} Therefore, it has been stated that RFA values had a higher sensitivity and an optimal specificity at 8 weeks when compared with baseline.\textsuperscript{17} According to the results obtained in this study, ISQ values change throughout the healing period after implant placement. Four months after the insertion, mean ISQ values of the 214 implants evaluated increased to an average of 2.54 mm (from 74.97 to 77.51 mm), presenting the highest increase in the posterior mandible (2.9%), and the lowest increase in the anterior maxilla (1.11%). This is in agreement with several published reports.\textsuperscript{17,26–27} In addition, some studies showed that there is a slightly decrease of ISQ value within the first 3–4 weeks,\textsuperscript{22,26} with the lowest at 3 weeks.\textsuperscript{28}

**Conclusion**

Within the limitations of this study, it can be concluded that higher implant stability is found in mandible compared with maxilla in both periods, immediately after insertion and 4 months later. In addition, higher increase in implant stability over the study period is found in mandible. Thus, the results of this study indicated that restoring implants either immediately after insertion or after a healing period of 4 months represents safe time points due to their high stability in nonatrophied ridges.

**Disclosure**

The authors claim to have no financial interests, either directly or indirectly, in the products or information listed in the article.

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