The concept of osseointegration was formulated by Albrektsson as “a direct functional and structural contact between living bone and the surface of a load-bearing implant.” Schroeder et al. used the term functional ankylosis to describe implant’s stiff fixation to the maxillary bone. Besides, they pointed out that the new bone was directly placed onto the implant surface, demanding atraumatic placement and implant primary stability, which is considered essential nowadays for both osseointegration and immediate loading protocols. Given that the available parameters to assess osseointegration are clinical (the presence of stable marginal bone level and absence of mobility in the fixation), osseointegration is assessed according to stability mechanic criteria. Primary stability would then be the main parameter that influences the implant loading protocol and treatment results.

Although current clinical methods do not allow getting to know the amount of bone tissue in contact with the implant, they do allow objective assessment and quantification of fixation stability and, thus, indirectly, osseointegration. These diagnostic clinical methods can be either invasive or noninvasive depending on their impact on the bone-implant interface. Among these, the Periotest system (Gulden Medizintechnik, Bensheim, Germany) and the resonance frequency analysis (RFA) (Ostell system; Ostell AB, Gothenburg, Sweden) stand out.

The latter was developed by Meredith et al in 1996 and allows objective quantification of implant stability, monitoring it through time, and help to prevent failure in implants showing reduced stability through time.

The primary stability at the time of placing a dental implant depends on the physical consistency between the surgically socket and the implant, and it will depend on factors such as bone density, the surgical technique, and implant design (macrostructure and surface). The initial mechanical stability of the implant is due to contact and friction.
between the surface and the bone, whereas its long-term maintenance is based on a biological binding between the surface and bone, which was determined primarily by the characteristics of the surface of the implant (secondary stability). Implant stability is an objective value, which is independent from time of registration, implant-surface osseointegration level, and bone-implant contact \(^{16}\); even in implants placed in bone defects, association between implant stability and bone defect size depends on defect type. In these situations, a bone defect presents less bone-implant contact at any time to register. \(^{17}\)

Several generations of Osstell products have seemed throughout the last years. Among these, the second (Osstell Mentor) and third (Osstell ISQ), both wireless, provide excellent clinical results. \(^{18,19}\) Both devices coexist in the market, so their results can be compared. The stability of 1 implant can then be measured by both technologies. This study was aimed at contributing to this comparison. It is intended to determine which device provides higher reliability in dental implant stability measurement and, whether the results obtained with both systems are comparable. The null hypothesis that we assume is that both devices Osstell Mentor II or Osstell ISQ are equally reliable for recording stability of dental implants and therefore the records obtained by the 2 devices are comparable.

**Materials and Methods**

**Study Design**

This is a cross-sectional clinical study aimed at comparing reliability of devices Osstell Mentor and Osstell ISQ regarding implant stability measurement, as well as at assessing whether their measurements are comparable. It was completed within the Master’s Degree in Periodontics and Implants at the University of Seville. The working protocol was approved by the Ethics Committee of this University, and participants signed the corresponding informed consent form.

**Patients**

Patients were selected from population of the University Teaching Clinic at the Faculty of Dentistry of the University of Seville. Stability measurements were completed on patient-placed implants from September to December 2009. Stability measurement was completed on 58 implants placed in 15 patients. Implants were placed in a population of partially or completely toothless individuals who were recovered by means of rough-surface, Klockner Essential Cone dental implants (SOADCO, Escaldes-Engordany, Andorra) obtained by means of aluminum blasting plus acid passivation (shot blasted), or rough-surface Straumann Tissue Level Standard implants (Straumann, Basel, Switzerland) obtained by means of sand blasting and acid attack. These were the inclusion criteria in patient selection:

- Patient age was equal or over 18
- Patients asked that their dental absences were treated by means of dental implants
- Collaborating patients
- The teeth to be replaced had been extracted at least 4 months before implant placement; thus, the bone ridge was fully healed
- Patients were signed the corresponding informed consent form.

**Implants**

Measurements were completed on either Klockner Essential Cone implants (SOADCO) with different diameters (3.5, 4.0, or 4.5 mm); all of them included a 4.5-mm platform, and their length was either 8, 10, or 12 mm, or Straumann Tissue level implants (Straumann) with 4.1 mm diameter, 4.8-mm platform, and 8, 10, and 12 mm length.

All implants were placed at the Master’s Degree in Periodontics and Implants at the Faculty of Dentistry at the University of Seville in the described period. Surgery was completed by an experienced surgeon with at least 10 years of surgical experience and deep knowledge of the Klockner and Straumann implant systems.

**Resonance Frequency Analysis**

The RFA allows objectively quantifying implant stability and monitoring it over time. The first system was marketed Osstell, a noninvasive device that measures the frequency of vibration of a transducer to an implant screwed. The result is expressed in implant stability quotient (ISQ) values on a scale of 0 to 100. It is an indirect measure of the stiffness of the implant-bone interface, that is, the higher the degree of stability of an implant, the higher its resonant frequency.

A total number of 12 ISQ-value measurements were made for each implant with 2 different transducers (SmartPeg; Gothenburg, Sweden) with the Osstell Mentor and Osstell ISQ systems. Six measurements were registered with each transducer (3 with each device) consecutively. Measurements were completed by the same dentist, who was fully experienced in the use of the Osstell Mentor and Osstell ISQ systems for RFA assessment.

Measurements in the 58 implants were taken independently from the location and time of registration. The treatment stage at which assessment was completed was not taken into account, as the study was mainly aimed at assessing the measurement system’s reliability regardless of the circumstances that provided implants’ stability levels.

**Experimental Design**

Transducers or SmartPegs directly fixed onto the implant without the interposition of the prosthesis pillar were used. The following manufacturer’s guidelines were followed:

- Use of the specific transducer or SmartPeg for direct implant assessment in both the Klockner Essential Cone implant system (platform diameter = 4.5 mm) and the Straumann Tissue Level system (platform diameter = 4.8 mm)
- No soft-tissue interposition
- Transducer tightening from 5 to 8 N·cm manually by means of a specific plastic screwdriver
- No contact between the transducer’s parts and the neighboring teeth
- Placement of a probe approximately 2 mm from the SmartPeg and with a 90 degree angle regarding the implant’s major axis. In all cases, probes were oriented vestibularly or buccally.
Stability registers were taken regardless from implant location in the mouth. After SmartPeg insertion, a register was completed with each device without removing the transducer consecutively. Afterward, the transducer was completely loosened and tightened again for a new registration with both devices. This procedure was repeated 3 times with each transducer. All registrations were completed by the same examiner.

**Statistical Analysis**

Firstly, a statistic data exploration or validation by means of numeric and graphic methods. Quantitative variables were summarized as means and SDs or, in case of asymmetric distributions, with medians and P25 and P75 percentiles. Qualitative variables were summarized by means of percentages. This description was completed with the corresponding graphic representations.

To compare the values of paired numerical variables, Student $t$ test was applied for 2 related samples (a statistical significance test for assessing the difference between, or the equality of, 2 or more population means); in case of more than 2 related samples, the Friedman test was used. The Friedman test is a non-parametric test for testing the difference between several related samples. It is an alternative for repeated measures analysis of variances, which is used when the same parameter has been measured under different conditions on the same subjects.

Data analysis was completed with software package SPSS 17.0 for MS Windows.

**RESULTS**

The 58 implants were distributed among the maxillary bone (30: 27 in posterior maxilla and 3 in the anterior maxilla) and jawbone (28: all of them in the posterior sector). Distribution according to the system used and implant length is shown in Table 1.

Mean ISQ value in measurements with Osstell ISQ and the first transducer was $72.59 \pm 7.09$ (min $= 56$, max $= 85$) in the first measurement, $72.47 \pm 7.38$ (min $= 56$, max $= 85$) in the second measurement, and $73.17 \pm 6.98$ (min $= 57$, max $= 85$) in the third measurement, whereas that obtained with the second transducer was $72.48 \pm 7.62$ (min $= 56$, max $= 85$) in the first measurement, $73.22 \pm 7.63$ (min $= 55$, max $= 87$) in the second measurement, and $73.29 \pm 7.32$ (min $= 57$, max $= 86$) in the third measurement (Table 2).

Mean value in the 3 measurements was $72.87$ (SD $= 6.87$) with Osstell ISQ and $72.04$ (SD $= 6.51$) with Osstell Mentor. The intraclass correlation coefficient was 0.98 for both Osstell Mentor and Osstell ISQ. This means an “almost perfect” degree of concordance between both measurements.

In the case of the Osstell Mentor device, the obtained repeatability, assessed by means of the intraclass correlation coefficient (ICC), for each transducer was 0.96 and reproducibility, assessed by the method itself, was 0.97. For the Osstell ISQ device, repeatability was 0.97 (slightly better) for each transducer, whereas reproducibility was kept at 0.97.

The existing correlation between both measurement systems is shown in Fig. 1, which shows a positive, nonzero correlation. The distribution of differences can also be assessed by means of their histogram (Fig. 2). This figure shows a Bland-Altman graph aimed at assessing concordance between both measurement systems. This procedure consists on the graphic representation of the differences between 2 measurements relative to their mean. Thus, the interval between 2 SDs relative to the mean of the differences includes 95% of the observed differences. These values must be compared with the concordance limits settled before study onset so as to conclude whether the observed differences are clinically relevant or not. As shown in this graph, most of the stability values obtained are grouped around the mean value; indeed, almost all of them are within the limits

**Table 1. Distribution of Implants According to Implant Length and Implementation System**

<table>
<thead>
<tr>
<th>Implants</th>
<th>8 (mm)</th>
<th>10 (mm)</th>
<th>12 (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straumann</td>
<td>14</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Tissue Level Standard</td>
<td>14</td>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td>Klockner Essential Cone</td>
<td>14</td>
<td>7</td>
<td>6</td>
</tr>
</tbody>
</table>

*All implants had a length of between 8 and 12 mm.*

**Table 2. Mean ISQ Value in Osstell Mentor and Osstell ISQ Groups**

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osstell ISQ SP 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st</td>
<td>72.59</td>
<td>7.09</td>
<td>56</td>
<td>85</td>
</tr>
<tr>
<td>2nd</td>
<td>72.47</td>
<td>7.38</td>
<td>56</td>
<td>86</td>
</tr>
<tr>
<td>3rd</td>
<td>73.17</td>
<td>6.98</td>
<td>57</td>
<td>85</td>
</tr>
<tr>
<td>Osstell ISQ SP 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st</td>
<td>72.48</td>
<td>7.62</td>
<td>56</td>
<td>85</td>
</tr>
<tr>
<td>2nd</td>
<td>73.22</td>
<td>7.63</td>
<td>55</td>
<td>87</td>
</tr>
<tr>
<td>3rd</td>
<td>73.29</td>
<td>7.32</td>
<td>57</td>
<td>86</td>
</tr>
<tr>
<td>Osstell Mentor 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st</td>
<td>72.43</td>
<td>7.19</td>
<td>56</td>
<td>86</td>
</tr>
<tr>
<td>2nd</td>
<td>72.60</td>
<td>6.52</td>
<td>55</td>
<td>86</td>
</tr>
<tr>
<td>3rd</td>
<td>73.26</td>
<td>6.80</td>
<td>57</td>
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<tr>
<td>Osstell Mentor 2</td>
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<tr>
<td>1st</td>
<td>72.98</td>
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<td>58</td>
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<td>2nd</td>
<td>73.26</td>
<td>7.05</td>
<td>57</td>
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<tr>
<td>3rd</td>
<td>73.74</td>
<td>7.14</td>
<td>56</td>
<td>86</td>
</tr>
</tbody>
</table>

Mean value in the 3 measurements was $72.87$ (SD $= 6.87$) with Osstell ISQ and $72.04$ (SD $= 6.51$) with Osstell Mentor.
set by SDs. Therefore, correlation is thus observed with the value obtained by the ICC (0.98) with an almost perfect degree of concordance.

**DISCUSSION**

Numerous works prove the usefulness of the system for RFA to obtain an objective assessment of implant stability due to its reliability and high reproducibility.14,20–23 This study is focused on the comparison of 2 RFA devices currently available in market, Osstell ISQ and Osstell Mentor, with the aim of determining which offers greater reliability and whether their results are comparable.

The results of this study prove that the RFA system, Osstell system, is a reliable system to measure implant stability, thus in agreement with the results of the work by Zix et al,24 who compared reliability in Osstell and Periotest systems on Straumann Tissue Level implants. Periotest measurements showed a group of atypical or extreme measures that did not appear in Osstell measurements on 213 implants in 65 patients; registers were completed in triplicate with each device. The obtained mean ISQ value was 57.66 (from 23 to 73). These authors conclude that both systems are applicable to implant stability measurement, yet the Osstell system is highlighted as more precise.

The expiration of the transducers makes using different devices when it comes to register stability throughout implant lifetime. It is important to check calibration or reliability in the behavior of the assessment system. Literature includes no work proving the clinical behavior of the different RFA generations. In this sense, Meredith et al11 completed a study on the first Osstell generation and found high repeatability, yet the transducer’s tightening strength was referred as the only one with a variable that might distort registers. In this study, high repeatability was observed with both devices, yet slightly higher with Osstell ISQ (0.97 vs 0.96), similar to Meredith’s study.

In this study, to measure concordance between 2 quantitative variables was obtained with the same or different
transducers, the ICC (mathematically equivalent to Cohen’s kappa), recommended to quantify reliability in clinical measurements by either repeating measurements with the same instrument under identical conditions or determining concordance in the assessment of different instruments or observers under identical circumstances. Given that value 1 matches perfect concordance and that the results of this study reach 0.97, Ossstell ISQ repeatability and reproducibility can thus be inferred to be almost perfect. Thus, no extra measurements were necessary to assess Ossstell ISQ reliability. In a study on 32 implants (16 cone-shaped and 16 cylinder-shaped implants) placed in desiccated human jaws, Brouwers et al\textsuperscript{25} aimed at determining RFA system’s intraobserver and interobserver reliability. The result of this study shows medium to good results according to the ICC for both intraobserver and interobserver reliability. Applying an implant removal torque after implant measurement, no correlation was found between RFV and removal torque values. However, in this work intraobserver and interobserver reliability in both devices would be in a higher range in which almost perfect is equivalent to “good.” Ossstell Mentor II and Ossstell ISQ showed 0.96 and 0.97, respectively, for both transducers, and both showed 0.97 in the intertransducer ICC assessment. Lachmann et al\textsuperscript{12} compared reliability of FRA systems and Periotest on 8 implants placed on cow ribs. Three measurements were registered without withdrawing the transducer, 3 after transducer withdrawal and manual retightening, and another 3 after transducer withdrawal and mechanized retightening with a 10-N control torque rotary unit. Data were analyzed with ICC with a 95% confidence interval, obtaining a 0.99 value for the RFA, Ossstell system, categorized as almost perfect. RFA repeatability was below 1% (1 ISQ), so error range in both the Ossstell and Periotest systems was concluded to have no clinical relevance. These results are similar to those contributed by Meredith et al\textsuperscript{11} and this article.

Valderrama et al\textsuperscript{26} compared Ossstell initial system (electronic technology) with Ossstell (magnetic technology) on 34 SLA-surface and SLActive Straumann Tissue Level implants on 17 patients. Three measurements were taken with each system on implant placement, as well as 2, 3, 4, 5, 6, and 12 weeks afterward. It was concluded that changes in implant stability are detected by both systems and show similar correlation. Atypical values were obtained with Ossstell Mentor in 15% of the registers, yet not with the Ossstell system. Likewise, repeatability was also studied by means of sets of 3 measurements with each device, loosening and tightening transducers fully after every measurement. Differences between the registered measurements were greater in 58.2% of the cases for the magnetic device, in 26.4% of the cases for the electronic registers, and the remainder was equal. The authors observed that the values obtained with the magnetic system were from 8 to 12 points higher than those obtained with the electronic system, thus suggesting that it may well be due to either the necessary strength for transducer fixing, or the electronic design of the registration system, which would be different, or the fact of tightening the transducer to the implants’ crown (electronic system) or to the implants’ interior (magnetic system). They concluded that the data rendered by both systems cannot be compared directly. This is unlike the way it occurs in this study between the new generation, Ossstell ISQ, whose results are, apart from reliable, also fully comparable with those by Ossstell Mentor.

**Conclusions**

It can be inferred from the results of this study that the RFA system Ossstell Mentor and the RFA system Ossstell ISQ show almost perfect reproducibility and repeatability after statistical analysis with ICC with a 95% confidence level. Likewise, the stability registers obtained with both systems are comparable, as there is no significant device-related variation.

**Disclosure**

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

**References**


