A Clinical Resonance Frequency Analysis of Implants Placed at Dehiscence-Type Defects with Simultaneous Guided Bone Regeneration During Early Healing

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Purpose: To investigate the implant stability quotient (ISQ) values of implants placed in bone with and without dehiscence bone defects over 12 weeks and to compare the ISQ values between the two groups. Materials and Methods: Twenty-two patients with an edentulous area at the posterior mandible were enrolled. Thirty OsseoSpeed EV Astra Tech implants (Dentsply Sirona), 4.2 mm in diameter, were placed. Twenty implants were placed without bone regeneration (no dehiscence group), while 10 presented with favorable bone defects and received simultaneous guided bone regeneration with dental implant placement (dehiscence group). At the time of implant placement, 2, 4, 8, and 12 weeks, resonance frequency analysis was utilized. The changes in ISQ values within group were analyzed with repeated-measures analysis of variance (ANOVA), and the mean ISQ values between the no dehiscence and dehiscence groups were compared using unpaired t tests. Results: All implants were successfully integrated without complication. The no dehiscence group demonstrated mean ISQ values of 74.30 ± 6.01, 69.58 ± 5.30, 71.10 ± 5.80, 75.08 ± 3.93, and 77.85 ± 3.18 at baseline, 2, 4, 8, and 12 weeks, respectively. The dehiscence group demonstrated mean ISQ values of 69.85 ± 7.00, 63.40 ± 8.47, 59.90 ± 10.23, 72.55 ± 3.10, and 76.20 ± 2.68 at baseline, 2, 4, 8, and 12 weeks, respectively. The dehiscence group showed significantly lower mean ISQ values at 2 weeks (P = .021) and at 4 weeks (P = .007) after implant placement compared with those of the no dehiscence group. Conclusion: Within the 12-week healing period, all implants demonstrated successful osseointegration and achieved stability in favorable bone defects. Nevertheless, clinicians should consider that significantly lower implant stability can occur in the first month. Int J Oral Maxillofac Implants 2019;34:772–777. doi: 10.11607/jomi.6834

Keywords: dental implant, favorable bone defect, guided bone regeneration, implant stability quotient, resonance frequency analysis

Dental implantation is currently a popular alternative treatment for restoring missing dentition. Long-term successful outcomes of osseointegrated implants are supported by several studies.1-3 Implant stability was identified as an important key in achieving osseointegration and has been proposed as one of the factors affecting implant loading and long-term success.4,5 At the time of implant placement, the primary stability is provided by mechanical retention at the junction of the implant surface and alveolar bone. Thereafter, secondary stability succeeds initial stability through osteogenesis and bone homeostasis over the implant surface.6-8

To evaluate implant stability, various methods have been developed, including the percussion test and the Periotest. Nevertheless, these methods are subjective and cannot be measured or compared prospectively.9-11 In 1996, Meredith et al introduced the noninvasive approach by analyzing the first resonance frequency through the transducer that is connected...
to the implant. The result showed as values ranging from 1 to 100 (lowest to highest stability) of “implant stability quotient (ISQ) unit.” This value was determined and displayed according to the stiffness of the bone-to-implant contact. Over the last 10 years, ISQ has become popular for the quantitative measurement of implant stability. Repeated measurements of ISQ values throughout the healing period have been performed in order to monitor the progress in implant stability during the osseointegration process in various types of implants and locations. Therefore, knowledge of the development of implant stability is important to verify the optimal healing time prior to implant loading.

Numerous studies reported the implication of quality and quantity of alveolar bone on stability of the implant. After tooth extraction, alveolar ridge resorption may occur, especially at the buccal aspect. In many cases, the placed implant with buccolingual bone insufficiency may result in a dehiscence defect on the buccal aspect. A dehiscence defect might impair the implant stability, reducing the success rate over the longer term and the esthetic outcomes of the definitive restoration. To overcome this problem, a guided bone regeneration (GBR) technique has turned out to be a predictable method of choice in order to develop new bone over the defect simultaneously with implant placement.

Experimental studies on cadavers have suggested a correlation between ISQ values and the occurrence of peri-implant bone defects. Nevertheless, a clinical study of stability changes, as measured by resonance frequency analysis (RFA) of the implant placed in bone presented with dehiscence-type bone defects and receiving simultaneous guided bone regeneration, has not been well-documented. Therefore, the objectives of this clinical prospective study were twofold: (1) to observe the establishment of implant stability with and without dehiscence bone defects over the first 12 weeks and (2) to investigate the comparison of measurements in implant stability obtained from RFA between two groups.

**MATERIALS AND METHODS**

**Patient Enrollment Criteria**

The study protocol was submitted to and approved by the Ethics Committee for Human Research of the Faculty of Dentistry, Chulalongkorn University (HREC-DCU 2015-061). Patients were verbally informed about the study protocol, and informed consent forms were signed prior to starting the treatment. The population consisted of patients who needed a dental implant in the posterior mandible at the Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand. Patients were assigned into two groups (no dehiscence and dehiscence) based on clinical and radiographic analyses (cone beam computed tomography with radiographic stent). Only patients who met the following inclusion criteria were accepted into the study.

**Inclusion criteria were** (1) age older than 20 years; (2) systematic health (ASA I or II); (3) healed posterior mandible ridge with more than 6 months after extraction; (4) no infection at or adjacent to the surgical sites; (5) sufficient bone volume for placement of the 4.2-mm-diameter implants in a proper prosthetic position; and (6) in the dehiscence group, patients demonstrating favorable defects for bone grafting as described by Sclar (2003) with the width of the defect being less than one-third of the mesiodistal dimension (and the height of the defect less than one-third of the implant length). Exclusion criteria were (1) heavy smoking habit (> 10 cigarettes/day), (2) history of alcoholism or drug abuse, and (3) pregnancy.

**Surgical Procedures**

All patients received an antibiotic (1,000 mg of amoxicillin) and analgesic (500 mg of mefenamic acid) prior to surgery. A one-stage surgical approach was carried out in both groups. The surgical areas were anesthetized locally, and a crestal incision with full-thickness mucoperiosteal flaps was raised to access the site. The alveolar sites were prepared following the drilling sequence recommended by the manufacturer with an external irrigation. Titanium dioxide implants with a grit-blasted and fluoride-modified surface (OsseoSpeed EV, Astra Tech Implant System, Dentsply Implants Manufacturing), 4.2 mm in diameter, were placed in the posterior mandible area in a prosthetically ideal position. A calibrated torque wrench was used to place the implant. The population consisted of patients who needed a dental implant in the posterior mandible.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Demographics of Patients and Distribution of Implants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td>No dehiscence group</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>3</td>
</tr>
<tr>
<td>Women</td>
<td>12</td>
</tr>
<tr>
<td>Age (mean ± SD) (y)</td>
<td>56.20 ± 8.29</td>
</tr>
<tr>
<td>Implant locations</td>
<td></td>
</tr>
<tr>
<td>Mandibular premolars</td>
<td>8</td>
</tr>
<tr>
<td>Mandibular molars</td>
<td>12</td>
</tr>
<tr>
<td>Implant length (mm)</td>
<td>9</td>
</tr>
<tr>
<td>11</td>
<td>3</td>
</tr>
</tbody>
</table>
used to evaluate the insertion torque of the implants when the insertion process was completed. Insertion torque in this study ranged from 15 to 45 Ncm. Healing abutments were placed. The peri-implant defects in the dehiscence group were corrected with the GBR procedure following the protocol outlined by Buser et al. Briefly, small autogenous bone chips were collected and placed to the exposed surface of the implant. Deproteinized bovine bone mineral (Bio-Oss, Geistlich Pharma) mixed with blood was then applied to form a second layer over the autogenous bone. The double-layer technique was utilized to enhance membrane stability using non–cross-linked collagen membrane (Bio-Gide, Geistlich Pharma). The membrane was cut into two strips and extended 2 to 3 mm onto the intact bony borders of the defects. The mucoperiosteal flaps were then sutured around the healing abutments. Patients were given 2 g of amoxicillin for 5 days (1,000 mg two times a day) and 500 mg of mefenamic acid for severe pain. Mouthrinse with 0.1% chlorhexidine was prescribed for 7 days to control oral hygiene.

Resonance Frequency Analysis

Implant stability was measured using an Osstell device (Ostell ISQ, Integration Diagnostics) and reported as ISQ units. Immediately following implant placement, a standardized SmartPeg (SmartPeg type 49, Integration Diagnostics) was hand-tightened into the implant body. The probe of the device was held adjacent to the SmartPeg. Measurements were made in the buccal and mesial directions and served as a baseline. Thereafter, to perform the measurements at the 2-, 4-, 8-, and 12-week follow-up visits, the healing abutments were gently disconnected, and the peg was hand-tightened into the implant.

Statistical Analysis

The SPSS statistical software was employed for data analysis (SPSS 22.0; SPSS). The data were demonstrated as means and standard deviations. The normality was tested with the Shapiro-Wilk W-test. When the data distribution was normal, unpaired t tests were performed to compare the distinctions between two groups. For repeated measurements of the ISQ values, repeated-measures analysis of variance (ANOVA) was used. The significance level was set at .05 (α = .05), and statistical power analysis was performed using GPower software (GPower 3).

RESULTS

Twenty-two patients were recruited in the study between August 2015 and January 2017. Thirty implants, 4.2-mm diameter, were placed. The no dehiscence group consisted of 15 patients, 3 men and 12 women, with a mean age of 56.20 ± 8.29 years. Twenty implants were placed, 17 of which were 9 mm long, while the other 3 implants were 11 mm long (Table 1). The dehiscence group consisted of seven patients, two men and five women, with a mean age of 52.10 ± 8.21 years. Ten implants were placed; seven implants were 9 mm and three implants were 11 mm in length (Table 1). No significant differences in the mean age were found between the two groups (P = .211).

The mean values for insertion torque were 27.75 ± 8.96 and 30.5 ± 8.96 Ncm for the no dehiscence and dehiscence groups, respectively. There were no statistically significant differences in the mean insertion torque between the no dehiscence and dehiscence groups (P = .502). All implants achieved good stability and successfully integrated. Healing was uneventful in all cases with 100% survival rate of implants in the study. The range and the mean ISQ values at the baseline and in the succeeding time points of the measurement are shown in Table 2. The development of implant stability evaluated by ISQ of the no dehiscence group was as follows. At baseline, the values for ISQ ranged from 58 to 82 with a mean value of 74.30 ± 6.01. At 2 weeks, the ISQ values ranged from 55.5 to 79, with

Table 2  Range and Mean ± SD of ISQ Values for No Dehiscence and Dehiscence Groups During the Observation Period

<table>
<thead>
<tr>
<th>ISQ values</th>
<th>No dehiscence group (n = 20)</th>
<th>Dehiscence group (n = 10)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Range Mean ± SD</td>
<td>Range Mean ± SD</td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>58–82 74.30 ± 6.01</td>
<td>57–77 69.85 ± 7.00</td>
<td>.081</td>
</tr>
<tr>
<td>2 wk</td>
<td>55.5–79 69.58 ± 5.30</td>
<td>48–73.5 63.40 ± 8.47</td>
<td>.021*</td>
</tr>
<tr>
<td>4 wk</td>
<td>56–79.5 71.10 ± 5.80</td>
<td>51–71 59.90 ± 10.23</td>
<td>.007*</td>
</tr>
<tr>
<td>8 wk</td>
<td>66–81 75.08 ± 3.93</td>
<td>68–77 72.55 ± 3.10</td>
<td>.088</td>
</tr>
<tr>
<td>12 wk</td>
<td>70.5–83 77.85 ± 3.18</td>
<td>72–79.5 76.20 ± 2.68</td>
<td>.171</td>
</tr>
</tbody>
</table>

ISQ = implant stability quotient.

Repeated-measures analysis of variance (ANOVA) and unpaired t tests were used to analyze the data.

*Refers to the corresponding statistically significant groups.
the mean ISQ value decreasing to 69.58 ± 5.30. Thereafter, the mean ISQ value continuously increased to 71.10 ± 5.80 at 4 weeks (ranging from 56 to 79.5) and 75.08 ± 3.93 at 8 weeks (ranging from 66 to 81). At the end of observation, the mean ISQ value increased to 77.85 ± 3.18 within a range of 70.5 to 83 (Table 2). Statistically significant differences were found between the mean ISQ values at 2 weeks and 8 weeks (P = .000), at 2 weeks and 12 weeks (P = .000), and at 4 weeks and 12 weeks (P = .001), as depicted in Fig 1.

Regarding the dehiscence group, at initial post-placement, the values for ISQ ranged from 57 to 77 with a mean value of 69.85 ± 7.00. Subsequently, the mean ISQ value decreased to 63.40 ± 8.47 at 2 weeks (ranging from 48 to 73.5). The lowest mean ISQ value of 59.90 ± 10.23 was reached at 4 weeks (ranging from 51 to 71). Subsequently, the mean ISQ value increased to 72.55 ± 3.10 at 8 weeks (ranging from 68 to 77) and 76.20 ± 2.68 at 12 weeks (ranging from 72 to 79.5) (Table 2). The longitudinal development of the ISQ value of the dehiscence group is shown in Fig 1. Statistically significant differences were found between the mean ISQ values at 2 weeks and 12 weeks (P = .019) and at 4 weeks and 12 weeks (P = .011).

It was evident that the changes in the implant stability over the 12-week healing period, when compared between the two groups, displayed a different pattern, as shown in Fig 1. Higher mean ISQ values in the no dehiscence group compared with the dehiscence group were observed at all time points. Furthermore, statistically significant differences in the mean ISQ values between the no dehiscence and dehiscence groups were found at 2 weeks (P = .021) and 4 weeks (P = .007). The analysis from GPower indicated that the power of the study was 0.95, when the alpha level probability was set at 0.05.

**DISCUSSION**

Resonance frequency analysis has been suggested as a reliable and repeatable method for measuring implant stability over the healing period. The RFA system can be influenced by the SmartPeg design, the effective implant length over the crestal bone, the implant characteristics, and the bone type. To control the confounding factors for implant stability, a single-implant system was employed in the posterior mandible with bone in types 2 and 3. This resulted in favorable bone defects grafted with the GBR technique being one of the major variables in the present study.

This investigation aimed to evaluate the establishment of implant stability placed in bone with and without dehiscence bone defects over a 12-week healing period. The implants in the no dehiscence group were inserted in the posterior mandible with adequate surrounding bone thickness. The results of the present study demonstrated the mean ISQ value to be 74.30 ± 6.01 at baseline. The lowest ISQ value was found at 2 weeks, and then, the mean ISQ values continuously increased at subsequent time points. The development in ISQ values as presented in the study agreed with results of earlier studies. The studies of Geckili et al and Schliephake et al placed the Astra Tech implant in the region of the mandible and reported mean ISQ values of 75.5 ± 8.9 and 73.3 ± 6.8 immediately after placement. They also found the lowest stability at 2 weeks, similar to the results of the present study. The reason for the decrease in ISQ values at 2 weeks was described as the result of the resorption in the pitch regions, providing retention of the mechanical stability, and the newly formed woven bone with low mineral density appeared to be less intense.

The influence of bone defects on the initial ISQ value has been previously reported in many experimental studies. Nevertheless, in the present study, the differences in the mean ISQ values when comparing at baseline between the no dehiscence group and the group with bone defects were not statistically significant. The disagreement among these results could possibly be due to the difference in implant design, implant diameter, the defect characteristics, and the bone type that was used in the studies. The results of the present study were in accordance with the study of Chan et al that reported no correlation between the narrow dehiscence defect type and the primary ISQ value. Furthermore, Merheb et al demonstrated that a significant difference in the initial ISQ values was found in a constant 3-mm dehiscence defect after removal of bone more than 10 mm deep. The narrow dehiscence defect and the constant 3-mm dehiscence defect with a height less than 10 mm could be similar to the favorable defect of the present study.
The development in the ISQ values over the 12-week healing interval of the no dehiscence and dehiscence groups demonstrated the variously decreasing and increasing patterns. The lowest mean ISQ values in the no dehiscence group were observed at 2 weeks and then started to escalate at 4 weeks, whereas the mean ISQ values of the dehiscence group dropped down until 4 weeks and then started to escalate at 8 weeks. It may be indicated that the decreasing and increasing of the ISQ values represent the bone resorption and formation of a biologic bonding. The difference in the pattern of the ISQ values between the two groups could possibly be explained by the different bone formation patterns. Histologic studies demonstrated that organized parallel-fibered bone and lamellar bone were prevalent at 4 weeks in the implants placed in pristine bone. By contrast, these two types of bone appeared to occur slowly in the implant presented with dehiscence-type defects that received GBR. In the GBR group, the parallel-fibered bone and nearly complete bone fill into the defect area were found at 6 weeks. The parallel-fibered and the lamellar bone were more mature bone of the initially formed woven bone, resulting in improvement in bone quality. Therefore, the development in ISQ values may reflect the progress in the stiffness of the implant-bone junction during the osseointegration process. Thus, it is possible that the delay in increasing ISQ values of the dehiscence group may be caused by the delay in forming of the parallel-fibered and lamellar bone.

ISQ has been used to evaluate implant stability in several studies. The results of previous studies and the manufacturer’s guidelines suggested that an ISQ value more than 70 is a safe level of stability and may serve as a threshold. Throughout the 12-week period, the mean ISQ values of the no dehiscence group appeared to be unaltered at each observation point. The ISQ values in the no dehiscence group reached a threshold level of 70 at every time point, except at 2 weeks, and a statistically significant increase was found at 8 weeks and more. By contrast, in the dehiscence group with low initial ISQ values, secondary ISQ values tended to increase after osseointegration. The mean ISQ values of the dehiscence group reached a threshold level of 70 at 8 weeks and reached a statistically significant difference at 12 weeks. Some previous studies reported similar results: the implants with high primary ISQ values more than 70 appeared not to increase with time, while implants with lower ISQ values exhibited an increase in stability.

Based on the results of the development of implant stability within the 12-week follow-up period, the implants in patients that presented with favorable bone defects and that received GBR augmentation were as stable as the implants in patients with no bone defect at the end of observation. Nevertheless, significantly lower implant stability can occur in the implants treated with the GBR technique during the first weeks of healing; therefore, loading with a definitive restoration should wait until at least 8 weeks to ensure greater stability and osseointegration.

Since only one implant system was utilized and placed in the posterior mandible, these results may not generalize to other types of implant and bone. Future studies with larger sample sizes, different implant designs, implant diameters, or bone types would be beneficial for gaining knowledge regarding clinical treatments with dental implants.

CONCLUSIONS

Within the limitations of the investigation, the mean ISQ values were obtained from the 4.2-mm-diameter implant over a 12-week healing period. The following conclusions could be extracted. The ISQ values of the implants in patients without bone defects were significantly higher than the ISQ values of the implants in patients presenting with favorable bone defects that underwent the GBR technique at 2 weeks and 4 weeks. The stability of the implants in patients presenting with favorable bone defects that underwent the GBR technique were similar to implants in patients without bone defects. Nevertheless, functional loading with a definitive restoration should wait until at least 8 weeks.

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