Measurement of Primary and Secondary stability of dental implants by Resonance Frequency Analysis method in mandible

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Abstract
Background: Determining the dental implant stability is critical since reflects the healing around fixture. The success of the implantation in either case depends on the sufficient primary and secondary stability. The aim of this work was to measure the stability of dental implants before loading the implants, using a Resonance Frequency Analysis (RFA) by the means of Ostells Mentor device, to determine changes in stability during early healing following implant placement.

Methods: 10 healthy and non-smoker patients over 40 years of age with at least six months of complete or partial edentulous mouth received 1-4 screw-types ITI dental implants by 1-stage procedure in mandible bone density of D2 or D3 as classified by Lekholm and Zarb index (1985). The principle behind RFA is to obtain a numerical value relating to stability. The Ostell RFA recording device measures the resonance in a magnetic field of a 1cm commercially manufactured attachment (SmartPeg) that is screwed onto the bone conduction device abutment. RFA measurements were obtained at surgery, 1, 2, 3, 4, 5, 7, and 11 weeks after implant surgery.

Results: Fifteen threaded SLA coated ITI implants evaluated. The lowest mean stability measurement was for four weeks after surgery for all bone types. At placement, the mean ISQ obtained with the magnetic device was 77.2 with 95% confidence interval (CI)=2.49, then it decreased until the 4th weeks to 72.13 (95% CI= 2.88), and at the last measurement the mean implant stability significantly (p-value<0.05) increased and were recorded higher values to 75.6 (95% CI=1.88), at 11th weeks. Changes indicated a pattern of decreased mean stability from the surgery date to 4 weeks post-placement, and significantly increased mean stability from 4 to 11 weeks after surgery and tended to increase with time. Student t test comparison of bone groups at each time point relatively significant differences between implant stability in Types 2 and 3 bone at 4 weeks after surgery (P = .006)

Conclusions: The results of the present study proved the lowest value of implant stability at 4 weeks post-surgery, which was statistically significant, and may be indicative of a period of time when loading might be disadvantageous following implant placement. There were no significant differences in stability changes pattern among two bone types after four weeks of healing; It seems that either immediate or post-early implant placement loading are suitable in terms of sufficient stability. These suggestions need to be further assessed through future studies.

Keywords: dental implants, Implant Stability Quotient, Primary Stability, Resonance Frequency Analysis, Secondary Stability

Introduction
Since more than a decade, Resonance Frequency Analysis (RFA) has been used as a noninvasive, reliable, easily predictable and objective method of quantifying implant stability. RFA has been widely used to determine the effects of immediate or early loading or assess changes in stability over
time. However, the literature on the alterations of stability during the post-placement period still lack sufficient evidence and more studies on different systems and variables are needed. The aim of this study was to investigate the primary and the secondary stability of ITI implants using a RFA device to detect changes in stability during early healing following implant placement and to determine whether the implant stability quotient (ISQ) could predict proper loading time.

Materials and Methods

Patients

Included in the present prospective cohort study were patients over 40 years of age with at least six months of complete or partial edentulous mouth. Other inclusion criteria which were dependent on further clinical and para-clinical examinations included a bone height of equal to or more than 12 mm, a crest width of equal or higher than 6 mm, and a bone density of D2 or D3 as classified by Lekholm and Zarb. Excluded were the patients with systemically compromised conditions e.g. diabetes, osteoporosis, hypertension, cardiac problems or those with psychological disorders, advanced periodontal problems, poor oral hygiene, lack of cooperation, occlusal discrepancies, insufficient density or height of residual ridge, a history of radiotherapy, smoking or par functional habits.

Ethical considerations

Our local board of research methodology and ethics peer-reviewed and approved the study protocol. The senior author informed all candidates of the study procedure and obtained signed informed consents from all the included patients in advance.

Implants

The senior author selected all the implants based on the clinical and radiological examinations and performed all the surgeries. Threaded SLA coated ITI implants were used.

Surgery

Newtome VGI (Newtome VGI, QR Verona, Italy) cone beam computed tomography imaging device was used for preoperative planning. The study followed a one-stage surgical protocol: Residual alveolar crest width as well as jawbone density were examined. Bone density was later confirmed intraoperatively by pilot drill. Before surgery, oral cavity was rinsed with Chlorhexidine 0.2% (Shahrdarou, Tehran, Iran) for a minute. Anti-inflammation therapy consisting of Novafen (400 mg Brufen + Acetaminophen 325 mg + Caffeine 40 mg) (Alhavi, Tehran, Iran) and antibiotic therapy consisting of Amoxicillin, Cefalexin or Clindamycin (Tehran Chimie, Tehran, Iran) 1-2 g half an hour before surgery were performed orally.

After the administration of sufficient local anesthesia (Lidocaine 2% with Epinephrine; Daroupakhsh, Tehran, Iran) to the surgical site, the senior author made a midcrestal incision with two vertical releasing incisions, reflected full-thickness buccal and palatal mucoperiosteal flaps, flattened the implantation bony surface. Implant sites were drilled (Straumann, Basel, Switzerland) with a speed of 400 to 600 rpm using intermittent motions without additional pressure, under copious saline irrigation. Implants were placed with an insertion torque of 35 Ncm. The healing screws were then secured to the fixtures. Primary wound closure was achieved by placing single sutures with Silk 3-0 or 4-0 (Supasil, Tehran, Iran) that were removed after 7-10 days.

Resonance Frequency Measurements

Primary stability was measured using an Ostell Mentor device (Figure-1), Integration Diagnostics, Savadale, Sweden). All measurements were performed by the junior author, immediately after implant placement and weekly until week 5, and then at 7th and 11th weeks. ISQ values were recorded into charts. A primary ISQ of 47 or less was considered a sign of questionable stability. The first two equal values were accepted as the authentic value. The authors followed the patients for 11 weeks after surgery during which they were not allowed to wear any provisional prostheses or insert any load to the fixtures (Table1).

Statistics

Patients entered the study by sequential sampling method. The authors used Microsoft Excel 2007 to organize the data and assessed the data for possible statistical significance (p < 0.05) using paired T test.

Results

Fifteen implants were examined once weekly up to five weeks and then at weeks 7 and 11 after surgery, to determine their ISQ values using Ostell Mentor device. Four males and six females, 42 to 65 years old entered the study. Table-1 summarizes the ISQ values obtained throughout the study. The mean ISQ decreases at the second measurement. Mean ISQ values continued to decrease even more significantly from the first week after placement. Starting from forth week after surgery, however, the mean implant stability values show an increasing trend but never reach the baseline values. Figure-2 aims to illustrate the alterations of implant stability values over time.

Discussion

The immediate implant placement approach has been studied extensively since being introduced. Evidence available indicates that it is a successful procedure that may benefit patients. However,
careful planning and case selection are needed to ensure implant success and final aesthetic outcomes. There is a significant biological response by the hard and soft tissues to immediate loading of dental implants. It is believed that threaded implants provide the highest mechanical stability after placement. The application of tapered implants and progressive lateral bone compression during drilling are thought to improve the implant to bone contact, implant stability and osseointegration.

Meredith et al. 6 and Sennerby et al. 7 were first to propose RFA as a highly effective qualitative method to assess implant stability. Huang et al. 8 evaluated implant behavior in different types of bone and confirmed the reliability of RFA in stability assessment. Most noticeably, authors have used RFA to trace stability alterations of implants over time. Friberg et al., 3 in a correlation analysis of the cutting torque measurements and RFA at implant placement, found satisfactory reliability of the RFA in crestal torque measurements. They also found that the stability of implants placed in softer bone seemingly raise over time with more dense bone sites no differences in stability were observed between different bones types at week 12 which is consistent to other reports. However, O’Sullivan et al., 9 compared insertion torque and bone properties in a cadaver study and obtained high values for all bone types except type IV; this was in line with the findings of Boronat et al., 10 who reported higher ISQ values for implants inserted in areas of more compact bone.

Other authors used RFA to determine the effects of immediate or early loading or assess changes in stability over time. Resonance frequency can also be measured at any time during the process, allowing implant failure to be diagnosed at an early stage. Very low RFA values at two months appear to indicate risk of future implant failure, while ISQ values of 57-82 at one year indicate implant success. RFA has been used at early stages of osseo-integration and reported that ISQ values of 57-70 indicate stability. Using in vitro histomorphometric analysis, it was found no correlation between bone-implant contact (BIC) and RFA. The benefits of a rough implant surface for increased RFA-measured stability are also confirmed. Authors have also compared the different locations of mandibular and maxillary ITI implants and found a significant correlation between these variables. They also observed that RFA measurements can identify unstable implants. Experimental studies using RFA to determine the stability of implants placed in irradiated bone and found that irradiation had an adverse effect on bone vascularization and hence on implant stability. It has been discussed that the objective assessment using the RFA method has made it possible to quantitatively and qualitatively analyze the stability of various types of implants and examine their behavior under different bone and loading conditions. The results of present prospective study are consistent to the fact that mandibular bone enjoys sufficient quality to render a reliable implant possible. All the implants in the present study achieved sufficient primary stability observing a one-stage surgery protocol. Systemically compromised patients were excluded from the present study to eliminate the biasing effect of conditions like osteoporosis noticed in some reports. Authors have used various measures to assess qualitatively and quantitatively the implant stability. Other methods like insertion and removal torque assessment, which determine the conditions of the implant-bone interface, cannot be used, only be used for long-term assessments. RFA is a noninvasive technique that can be used repeatedly for quantitative stability measurements both intraoperatively and postoperatively. Independently of the implant system used, ISQ values obtained via RFA can be compared. Despite numerous advantages, RFA suffers from a lack of sensitivity to the quality of surrounding bone. The more commonly used conventional bone-drilling was performed. Some authors have suggested superior outcomes following a bone-condensation technique were the bony walls of the implantation site are progressively condensed to compensate for a lower bone quality when needed. Bone micro-morphology has a prevailing effect over implant design on intraosseous initial implant stability, and it is more sensitive in terms of revealing biomechanical properties at the bone-implant interface in comparison with ISQ.

References


Table-1 The mean (± standard deviation) of the stability values measured using Resonance Frequency Analysis for 15 implants weekly until the sixth week and then at the eighth and twelfth weeks post-placement.

<table>
<thead>
<tr>
<th>Week(s)</th>
<th>Patients</th>
<th>Range</th>
<th>Mean ± SD</th>
<th>CI 95%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgery day</td>
<td>15</td>
<td>67-85</td>
<td>77.20 ± 4.92</td>
<td>2.49</td>
</tr>
<tr>
<td>1</td>
<td>15</td>
<td>72-80</td>
<td>77.00 ± 3.51</td>
<td>1.78</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>64-80</td>
<td>74.20 ± 3.82</td>
<td>1.93</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td>62-80</td>
<td>73.20 ± 5.19</td>
<td>2.62</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>62-79</td>
<td>72.13 ± 5.69</td>
<td>2.88</td>
</tr>
<tr>
<td>5</td>
<td>15</td>
<td>63-78</td>
<td>72.33 ± 4.62</td>
<td>2.34</td>
</tr>
<tr>
<td>7</td>
<td>15</td>
<td>66-79</td>
<td>73.55 ± 3.89</td>
<td>1.79</td>
</tr>
<tr>
<td>11</td>
<td>15</td>
<td>70-80</td>
<td>75.60 ± 3.72</td>
<td>1.88</td>
</tr>
</tbody>
</table>

Figure 1- Oststell Mentor Device (with permission of Oststell company)
Figure 2- Mean Implant Stability

Figure 3- Patient Number One

Note: The stability values are shown over a period of weeks, illustrating the changes in implant stability. The analysis uses resonance frequency analysis.
Figure 4- CT scan of patient number one

Figure 5- Patient number two photo and x-ray
Figure 6 - patient number two after surgery photo

Figure 7 - patient number three panoramic x-ray