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# Influence of Resonance Frequency Analysis (RFA) Measurements for Successful Osseointegration of Dental Implants During the Healing Period and Its Impact on Implant Assessed by Osstell Mentor Device

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**Abstract**

**AIM:** This study aimed to investigate and assess primary and secondary dental implant stability during the osseointegration period.

**METHODS:** A total of 77 implants were placed in 42 patients with 26 males and 16 females. The study was conducted by comparing the resonance frequency analysis (RFA) values of the implants inserted in the lower jaw. RFA was done immediately after implant insertion and after 12 weeks. Results were statistically evaluated using SPSS Statistics for Windows, Version 7.1. Level of significance was set at $P < 0.05$.

**RESULTS:** Significant differences were detected between the primary and secondary stability values, respectively. Maximum RFA value of 88 and the minimum value of 52 were observed. Stability values increased during the following three months, and all implants were successfully integrated without complication.

**CONCLUSION:** Our results indicate and suggest that there is a strong linear correlation between implant stability and ISQ values that can be directly estimated by the RFA, especially in the posterior edentulous mandible. Osstell implant device could represent a useful tool which can be used to identify the risk for implant failure.

## Introduction

Oral implantology is part of the dentistry that is used aggressively to improve the function of chewing, aesthetics and phonation in a partial or completely carefree jaw. The criteria to be possessed by the material for making one implant are the biocompatibility, bioadhesiveness, bioinformatics- not to alter its physical-chemical properties under the action of tissue fluids and metabolites in the body and biodegradability-the material from which the implant is made; should have a good shape or design, toughness or elasticity.

The stability of the implants is a valuable diagnostic factor for the success of implant therapy. That is a clinical measurement that can help the dentist in selecting and treating the implant loading protocol [1], [2], [3], [4].

Stability is divided into the primary and secondary-constitutional and mechanical network between bone and surface of the dental implants following a surgical protocol. The primary stability refers to the mechanical support of the implant in the bone and the absence of any micro-movement, known as mechanical stability [1], [5], [6], [7], [8], [9] while secondary stability is considered successful when there is osteointegration of the implant with the surrounding bone, known as biological stability [1], [6].

Osteointegration is the result of initial mechanical stability complemented by biological stability; the sum of these two parameters will give the value of the final stability. The primary stability depends on: the quality and quantity of the bone [10], [11], the surgical-implantation preparation technique, and the implant characteristics [1], [6], [12], [13], [14], [15]. A thicker cortical layer is better for osteointegration than the implant of a thinner cortical layer [16], [17], [18]. Size, angulation and design also affect the mechanical anchoring of the implant in the surrounding bone and contribute to its stability. Although primary stability determines the initial implantation in the alveolar bone, the secondary stability through osteointegration is required for a long-term relationship between the implant and the bone.

Certain clinical signs cause implant therapy failure. This includes bone loss around the implant, inflammation or purulent fluid of adjacent tissues and mobility (movement) of the implant. To prevent these inconveniences in treatment to patients with implants should be used useful tests such as determining the stability of the implants at the time of setting. One of the direct methods for evaluating osteointegration is the resonance frequency analysis (RFA) that provides valuable clinical objective data of implant stability. According to the evaluation of the techniques available so far and their shortcomings, it is clear that there is a need for non-invasive, quantitatively recurrent methods that can reliably determine the stability of the implants over time. Such a potential candidate for this purpose is the technique of analysis of the resonant frequency (RFA) [1], [6].

The technique of resonant frequency analysis (RFA) is noninvasive and nondestructive, essentially a test of the stability for the dental implant. It is equivalent in terms of the direction and the type of application of fixed lateral forces to the implant and the measurement of the implant displacement. This method can potentially provide clinically relevant information about the state of the interface between the implant and the bone at any stage of the treatment.

The present prospective study study aims to compare the primary and secondary dental implant stability during the osseointegration period by the ISQ quotient in the lower jaw.

## Material and Method

This study was approved by the local Ethics Committee and carried out according to the Declaration of Helsinki.

A total of 77 implants were placed in the anterior and posterior region of the mandible in 42 with partially or completely toothless/edentulism at the Private Dental Office Vita Dent, Tetovo, Republic of Macedonia.

A device called Osttell MentorTM (Osttell AB, Gothenburg, Sweden) was invented to measure the resonance frequency value of the implant fixture through the transducer or pin (Smartpeg type 32 with maintain a distance of approximately 1-3 mm, angle of 90 degrees, and 3 mm above the soft tissue) which is mounted directly to the fixture with a screw. In the period between October 2010 and October 2013, primary and secondary implant stability was measured with insertion torque, and resonance frequency analysis (ISQ values). The measurements were repeated four times in the mesial, distal, buccal and lingual directions, for each inserted dental implant in residual mandible alveolar ridges. The value of ISQ scale for analysing the results stars from 1-100.

Patients were selected to meet the following inclusion criteria: collaborated patients between 37-79 years old with partial or total edentulism/toothless for at 3 least months from tooth loss, residual bone height ranging from 6 to 8 mm and sufficient bone width in the edentulous region (≥ 6 mm).

Exclusion criteria were conditions requiring the chronic routine prophylactic use of antibiotics, medical conditions requiring prolonged use of steroids, history of leukocyte dysfunction and deficiencies, neoplastic diseases, radiation and chemotherapy, renal failure, uncontrolled metabolic diseases and endocrine disorders. The definitive restorations were made in a period between 4 and 6 months after surgery. The systematic health condition of all the participants was recorded, and they fulfilled the following criteria.

The data analysis was performed in a statistical program Statistica 7.1 for Windows. Data were analysed by using repeated-measures ANOVA, Mann-Whitney U Test and Spearman Rank Order Correlations. Distribution of data (ISQ values of primary & secondary implant stability) has been tested: Kolmogorov-Smirnov test; Lilliefors test; Shapiro-Wilks test (p); The difference in the primary & secondary implant stability values was tested witht-test-dependent samples (t) or Wilcoxon Matched Pairs test, depending on the data distribution; Significance is determined for $p < 0.05$. The data are displayed tabulated and graphically.

## Results

None of the implants failed during the study period. In the remaining cases, 77 implants were placed in 42 patients (26 men and 16 women). Male: female ratio was 1.6: 1 and the mean age was 58.26 ± 4.08 years old. The largest number of implants was placed in the posterior mandible (n = 61) whereas only 16 implants were placed in the anterior mandibular region.

All dental implants were examined using Osstell mentor device on the first day of surgery (immediately) and 3 months later to determine and compare ISQ values. When we measured the value of primary stability of inserted dental implants in the mandible, no implant showed early osteointegration failure.

### Primary implant stability

Figure 1 shows descriptive statistics on the ISQ values in the primary implant stability from down to left 31 to bottom left 38.

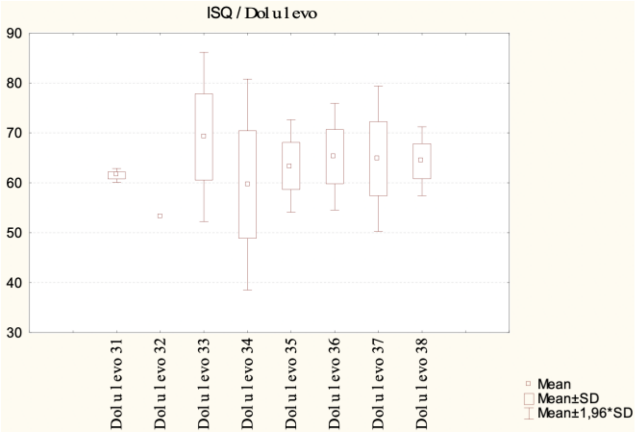


*Figure 1: Medium ISQ values are shown in primary stability*

Figure 2 shows descriptive statistics on the ISQ values in the primary implant stability are shown down from right 41 to bottom right 48.

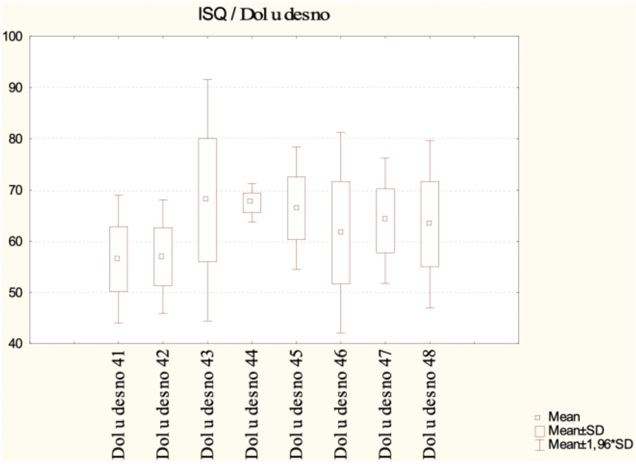


*Figure 2: The mean ISQ values for primary stability are shown*

### Secondary implant stability after 3 months

Figure 3 show escriptive statistics on the ISQ values with the secondary implant stability are displayed from down left 31 to down left 38, after 3 months of completed implants.

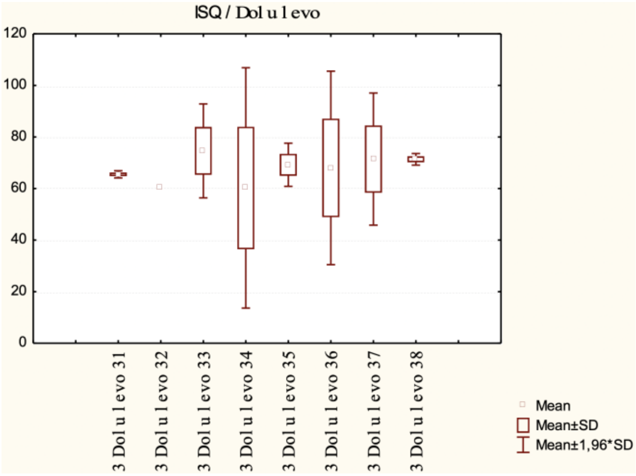


*Figure 3: The mean ISQ values for secondary stability are shown*

Figure 4 shows descriptive statistics on ISQ values with secondary implant stability are shown down from downright 41 to bottom right 48, after 3 months of performed implantations.

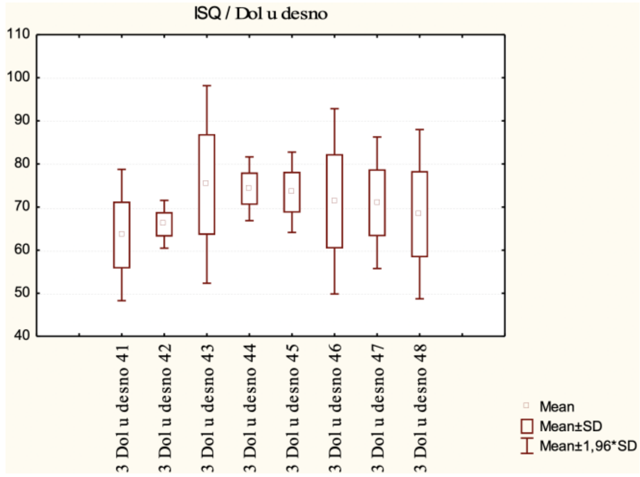


*Figure 4: The mean ISQ values for secondary stability are shown*

The ISQ values of the primary implant stability vary in the range of 63.81 ± 9.48 units, 95.00CI: 58.76-68.86; the minimum value is 52 units, and the maximum is 82 units.

**Table 5: Differences in the ISQ values of Primary Stability & Secondary Stability between segments**

| Implant stability | Valid N | Mean | Confidence -95,00% | Confidence +95,00% | Minimum | Maximum | Std. Dev. |
|---|---|---|---|---|---|---|---|
| Primary Stability | 16 | 63,81 | 58,76 | 68,86 | 52,00 | 82,00 | 9,48 |
| Secondary stability | 16 | 70,25 | 65,30 | 75,20 | 58,00 | 88,00 | 9,30 |

The ISQ values of the secondary implant stability vary in the range of 70.25 ± 9.30 units, 95.00CI: 65.30-75.20; the minimum value is 58 units, and the maximum is 88 units.

The secondary implant stability in the anterior segment of the mandible for Z = 3.52 and p < 0.001 (p

= 0.000) is significantly greater than the primary stability. Namely, after 3 months, the ISQ values of the secondary stability are significantly higher than the values of the primary stability.

The ISQ values of the primary implant stability vary in the range of 63.89 ± 6.99 units, 95.00CI: 62.10-65.68; the minimum value is 41 units, and the maximum is 77 units.

The ISQ values of the secondary implant stability vary in the interval of 69.43 ± 12.72 units, 95.00CI: 66.17-72.68; the minimum value is 0 units, and the maximum is 86 units.

The secondary implant stability in the posterior segment of the mandible for $Z = 5.51$ and $p < 0.001$ ($p = 0.000$) is significantly greater than the primary stability. Namely, after 3 months, the ISQ values of the secondary stability are significantly higher than the values of primary stability.

For $Z = -0.71$ and $p > 0.05$ ($p = 0.48$), there is no significant difference in the ISQ values of the primary stability of the implants between the front and the back segment of the mandible.

For $Z = -0.71$ and $p > 0.05$ ($p = 0.48$), there is no clear difference in the ISQ values of the secondary implant stability between the front and the back segments of the mandible.

## Discussion

The success of dental implant is affected by various factors according to the oral and general health of the patient, and it has been reported that the ISQ values vary in a range between 58 and 84, with a mean of 68 after 8-12 months [9], [15], [16], [18]. Also, various bone defects may affect the primary and secondary stability of dental implants. Besides the biological factors, primary implant stability originates from a combination of both mechanical and biological, and it’s one of the prerequisites of immediate loading. The need for a clinical diagnostic tool for evaluating the stability of dental implants is more widespread. RFA is a noninvasive intraoral method that is designed to reflect the bone and implant interface. The great number of studies have summarised that the RFA method is noninvasive anytime method.

With this study, we aimed to compare the primary and secondary dental implant stability results during the osseointegration period in the lower jaw, and the reliability is measured using repeatability. In our study, several attempts with the same transducer lead to similar results. Many authors have described changes in implant stability over time. The ISQ indexes increased from the first visit showing higher implant stability after 3 months. The increase was gradual, being lower from the first time visit to the 3$^{rd}$ month postoperatively. This fact could be explained by the micro-threats in the part of the implant body, which achieved the lowest 52 units at the time of measurement.

This fact is by the publication done by Al Juboori et al., [19] who assure that two months after implant placement, the mean ISQ value for implants was 75, and 79 after six months, respectively.

Aragoneses JM [20] and colleagues also published clinical trial and found that average implant stability quotient (ISQ) values were 69.62 for 3.7 mm implants, 72.02 for 4.0 mm implants, and 69.67 for 4.3 mm implants.

Andersson et al., [21] investigate the influence of patient- and implant-related factors on implant stability, and they showed a significantly higher risk for implant failure especially in patients with an ISQ value below 70.

Janyaphadungpong et al., [22] evaluated and investigate the implant stability quotient implants placed in bone with and without dehiscence bone defects and demonstrated successful osseointegration and achieved stability.

For example, in a study by Sargolzaie et al., [23], there was no statistically significant relationship between bone density on implant stability.

In another study, Farré-Pagés et al., [24] show a significant relationship between bone and location with ISQ values. In their study, they demonstrated a strong relationship between the bone density values from computerised tomography and location of dental implants according to the Lekholm & Zarb classification.

Furthermore, Kahraman et al., [25] concluded that the correlation between insertion torque and RF values were indicated to be statistically significant for 42 implants, respectively.

According to this study, RFA score for implant stability according to the region of implant placement was obtained to be higher (at the end of 3 months) in the anterior segment of the mandible. Our study also correlates with the study of Lekholm and Zarb (1985), which also reveal higher stability values for the mandibular implants in comparison with the maxillary ones because of the quality of lower jaw bone.

Based on a study by Sadeghi et al., [26] was proposed as reliable implant stability with implant primary stability quotient (ISQ) of 71 for the osteotome group and 67.4 ± 10 for the control group. They found that the osteotome technique does not lead to higher implant stability.

During the osseointegration phase, the ISQ values in our study showed slight variations. From the first time of date, the mean ISQ values did not show significant changes in any groups, and primary stability varies in the range of 63.89 ± 6.99 units, but from the first month to the third, values increased significantly in the range of 70.25 ± 9.30 units. This may be explained by the good bone quality observed in the mandible. Implant length had no influence on the stability in the present study. In fact, significant differences were only seen for the 66 and 74 ISQ threshold levels.

These results are in line with several other clinical studies that have shown an increase in implant stability [26], [27], [28], [29].

A study conducted by Sarfaraz et al*.* [30] with two different types of implant showed that there is a significant decrease in the 3rd week of ISQ values, after which there was a progressive increase in the values till the 15th week. The findings of their study suggest no correlation was found between the implant length and the insertion torque value.

The Osstell® Mentor (Integration Diagnostics AB, Göteborg, Sweden) is a commercially available device that converts resonant frequencies of 3,500 – 8,500 Hz into an implant stability quotient (ISQ) graded from 0 to 100.

Some studies have shown in the past that there is still no any clear standard for the normal range of ISQ values for successfully osseointegrated implants when used as a single method, but higher ISQ values generally represent higher implant stability during the healing period. It has further been demonstrated that considerable debate still exists [31], [32], [33], [34], [35].

Kokovic et al., [36] indicate that primary implant stability is only a mechanical phenomenon and depends on the contact between the implant and the bony bed.

Koshy et al., [37] concluded that the mean ISQ values at placement were 74 and 75.2, respectively. Also, he indicates that RFA has proven to be a reliable indicator to assess implant stability during the various stages of healing following implant placement. This is in accordance with much more published studies in literature where the relevance of this application is widely accepted [38], [39], [40], [41], [42], [43], [44].

In our study, all patients completed the 3-month follow-up examination. Our data corroborate with the outcomes of other studies showing an increased risk for implant failure with decreased stability. Postsurgical wound healing was uneventful in all cases, and none of the cases was complicated by continuous pain, limited mobility, radiographic radiolucency or infection. The cumulative success rate was 100%.

In conclusion, implant stability can be affected by several factors (bone quality, surgical technique, and implant design). The RFA does appear suitable for the evaluation of implant stability with no graft materials when used as a single method. They are good indicators of implant stability and may predict the appropriate timing of loading and implant failure. There was a strong correlation between the primary and secondary magnetic RF values of mandible implant used, and repeated RFA measurement appears to facilitate diagnosis of implants with limited stability.

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