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# Evaluating Stability Changes of Tapered Roughened Surface Implants in Different Bone Types: A Prospective Clinical Cohort Study

Amir Reza Rokn[1] • Amir Ali Reza Rasouli Ghahroudi[2*] • Abolhasan Mesgarzadeh[3] • Seyed Asghar Miremadi[4] • Mohammad Javad Kharrazi Fard[5]

[1]Associate Professor, Department of Periodontics, Faculty of Dentistry and Dental Research Center, Tehran University of Medical Sciences, Tehran, Iran
[2]Assistant Professor, Department of Periodontics, Faculty of Dentistry, Tehran University of Medical Sciences, Tehran, Iran
[3]Associate Professor, Department of Oral & Maxillofacial Surgery, Faculty of Dentistry, Tehran University of Medical Sciences, Tehran, Iran
[4]Associate Professor, Department of Periodontics, Faculty of Dentistry, Tehran University of Medical Sciences, Tehran, Iran
[5]Statistical Consultant, Dental Research Center, Tehran University of Medical Sciences, Tehran, Iran
[*]Corresponding Author; E-mail: amirali_rasouli@yahoo.com

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## Abstract

***Background and aims.*** Implant stability of different designs have shown to be variable. The aim of this study was to evaluate the stability changes as a reflection of early healing around roughened-surface implants in human using resonance frequency analysis (RFA).

***Materials and methods.*** 153 Branemark Replace tapered Ti-unite™ implants in 68 patients were placed in the maxilla or mandible. Bone type was classified into one of 4 groups according to Lekholm and Zarb index. RFA was used for direct implant stability measurement on the day of implant placement and at 14, 30 and 60 days after placement.

***Results.*** No early failure occurred. The lowest primary stability measurement was observed in type 4 bone. Student t-test for comparison of bone groups at each time point revealed no significant difference between implant stability in all bone types ($P > 0.05$). In testing the effect of implant length and diameter with time using the mixed model ANOVA according to implant length, there was not any significant difference between groups ($P > 0.05$); however, implant diameter showed a significant effect on implant stability. There were no significant differences in implant stability between genders ($P > 0.05$).

***Conclusion.*** According to the results, pattern of stability changes are not different among different bone types.

***Key words:*** **Bone quality, resonance frequency, stability measurement, tapered implants.**

### Introduction

Endosseous implants are increasingly being used in craniofacial, dental, and orthopedic surgery. Implant failure and loss can have a number of causes, including an inherent factor related to the design of the implant system, a poor placement technique, an adverse host response, or excessive clinical loading. It has been clearly demonstrated that implant-retained prosthesis can be placed successfully and remain functional for many years.[1] On the other hand, evidence suggests excessive mechanical stresses and poor primary stability at placement as the causes of early failure of implants.[2]

Proper primary stability of the implant and postponing the loading to 3-6 months after the surgery has long been considered essential to provide the required situations for implant osseointegration. However, the necessity to wait that long before loading an implant has been based upon clinical, rather than evidence based, experience and thoughts.[3,4] Adequate stability of an implant in the bone is an essential matter for favorable repair process, bone formation, and also distribution of mastication forces. Primary stability is critical when placing the implant, as is secondary stability after osseointegration and function through time.[1,5-11] Primary stability is believed to be influenced by length, geometry, bone-to-implant contact area, cortical to trabecular bone ratio and the placement technique.[3] Secondary stability results from formation of secondary bone contact of woven and later, lamellar bone.

There is a new immense trend for immediate loading on implants, and therefore, it seems application of a simple, clinically feasible, noninvasive test to assess implant stability and osseointegration is considered to be highly desirable.[4]

Radiographic methods are probably the most widely used clinical technique in this matter. The use of x-rays is criticized for being two-dimensional and difficult to standardize. A quantitative method for evaluating the stability of an object in a solid medium is through vibration analysis. Vibration analysis of an implant is divided into two categories: transient excitation and continuous excitation. Manual percussion is the simplest form of transient vibration analysis.[12] The Periotest (NIVA, Charlette, NC, USA) is another transient excitation tool. However, when one applies the Periotest to the implant, the values obtained represent only a narrow range over the scale of the instrument, thereby indicating a lack of sensitivity in the measurement of implant stability.[13]

Dynamic vibration analysis of implant stability repeatedly uses a high-energy pulse that is applied to an implant and the resonance frequency (RF) is measured. Resonance frequency analysis (RFA) offers a clinical, noninvasive measure of stability and presumed osseointegration of implants expressed as Implant Stability Quotient (ISQ) units (0-100).[1,14] The ISQ values essentially represent the lateral stiffness of the interface between the implant and surrounding bone.[15-17] Several studies have demonstrated the ability of the device to assess changes in implant stability.[1,3,10]

The objective of this clinical study was to asses the changes in implant stability during the early phase of healing, applying the noninvasive RFA technique, and looking for the best time for loading in roughened-surface Replace Select TiUnite™ tapered implants (Nobel Biocare, Gothenburg, Sweden), with different lengths and diameters, placed in different quality types of bone through single-stage surgery.

### *Materials and Methods*

This human clinical trial was designed as a prospective study to measure implant stability with an RF analyzer (Osstell Mentor; Integration Diagnostics AB, Gothenburg, Sweden) at the time of implant placement and at 14, 30, and 60 days post-placement. The subjects consisted of 68 patients (30 male, 38 female), 18 to 70 years of age, seeking treatment at the Department of Dental Implants, Tehran University of Medical Science, Tehran, Iran, and a private dental clinic. Eligible subjects were select according to the following criteria:
Inclusion criteria:

1. One or more missing teeth in either canine or posterior region
2. Adequate bone volume
3. Adequate oral hygiene
4. Negative pregnancy test within 1 week prior to surgery for females

Exclusion criteria:

1. Extraction site healing for less than 6 months
2. Untreated periodontitis
3. Residual roots in the implant site
4. Current chemotherapy
5. History of head and/or neck surgery
6. Indication for bone or soft tissue graft in the implant site
7. Alcohol or drug abuse within the past five years
8. Systemic complications

### *Clinical protocol*

After an informed content was signed by each patient, implants (61 in the maxilla and 92 in mandible) were placed using a non-submerged technique following the manufacturer's instructions. 57 implants (37.25%) were placed in the premolar, 85 in the molar (55.55%), and 11 (7.20%) were placed in the canine site. The only implant lengths used in the study were 10 mm (n = 60) and 13 mm (n = 91) but with different diameters: 3.5 mm (n = 26), 4.3 mm (n = 89), and 5.0 mm (n = 38). Bone quality was categorized as type I, II, III or IV at the time of surgery according to the tactile sense of the surgeon (Lekholm & Zarb index):[18] 16 implants with bone type I, 76 implants with bone type II, 53 implants with bone type III, and 8 implants with bone type IV. Immediately after the implant was placed, the proper smart peg (type

12 & 13) was screwed onto the fixture and the implant stability was measured by the RF analyzer in ISQ unites. Readings were performed 3 times each and the mean was jot down. To reduce observer bias, the previous recordings on the implant were not accessed prior to RFA measurement.

### *Statistical analysis*

The data were presented with descriptive statistics and analyzed with ANOVA, regression analysis, and Student's t-test using SPSS 13.0 (SPSS, Chicago, USA) computer software.

## *Results*

None of the inserted implants failed. Implants of both 10- and 13-mm lengths showed statistically non-significant differences in ISQ values in all of the four measurements (P > 0.05). In all measurements, it was found that the greater the implant diameter, the greater the ISQ value, and thus, the greater the stability; however, this association was not significant (P > 0.05; Table 1).

The amounts of ISQ units in bone type IV were observed to be less than other bone types; however, these readings stayed constant through time (Figures 1 & 2). According to ISQ values, the pattern of stability changes in all of the four bone types were almost the same (Figures 1 & 2).

Both the bone type and the time period were not found to be significantly associated with stability of the implants assessed (P > 0.05).

**Table 1. Mean ISQ values of different implant diameters on different days of measurement**

| Implant diameter (mm) | Baseline | Day 14 | Day 30 | Day 60 |
|---|---|---|---|---|
| **3.5 (n = 26)** | 68.38 | 67.00 | 65.50 | 68.03 |
| **4.3 (n = 89)** | 72.93 | 72.32 | 72.00 | 73.29 |
| **5 (n = 38)** | 75.21 | 75.63 | 77.44 | 76.76 |

Gender and age, also, did not significantly affect the results (P > 0.05; Figure 3).

## *Discussion*

The present study led to interesting findings on the stability changes of the evaluated implant during the early stages of healing with regards to the clinical aspects. As seen in most of the previous studies,[19-23] the stability of the implant was shown to be affected by healing time (P < 0.05).

The present study showed that, from baseline to 60 days, stability patterns in type 1 & 2, and type 3 & 4 bone were not different. Friberg et al[22] evaluated the stability of 75 mandibular Branemark implants in 15 edentulous patients through a 15-week period, and found it to decrease rather than increase, which contradicts the results of the present study. In our study, implant stability did not decrease, but it stayed constant trough the period of the study. It is tempting to attribute this incongruity to tapered implants used in our study, which apply more lateral compression to the surrounding walls compared to parallel implants, and therefore,

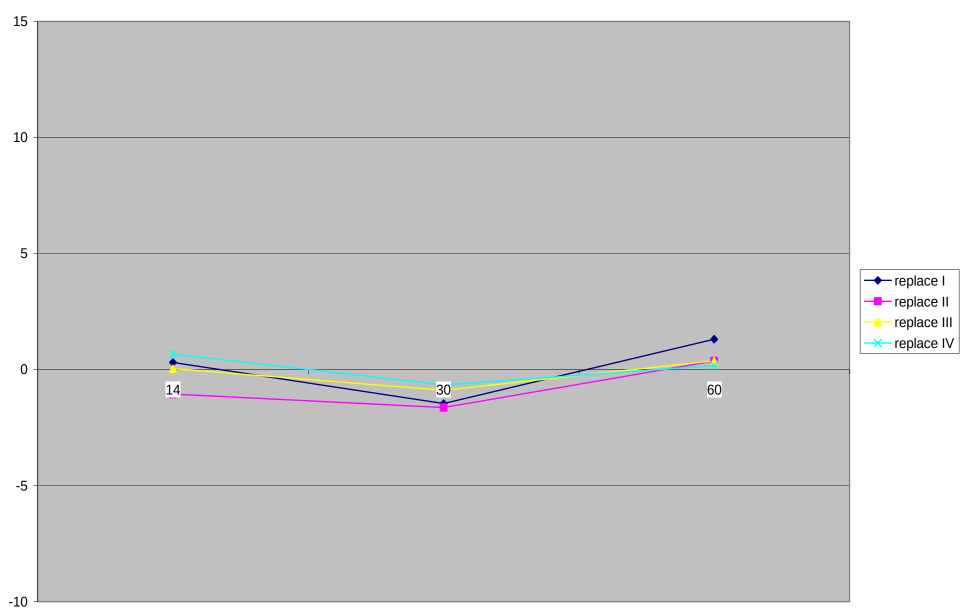


**Figure 1. Percentage changes according to mean ISQ values as compared to baseline mean ISQ values concerning bone type. Note the vertical line is ISQ difference and the horizontal line is the measurement times.**

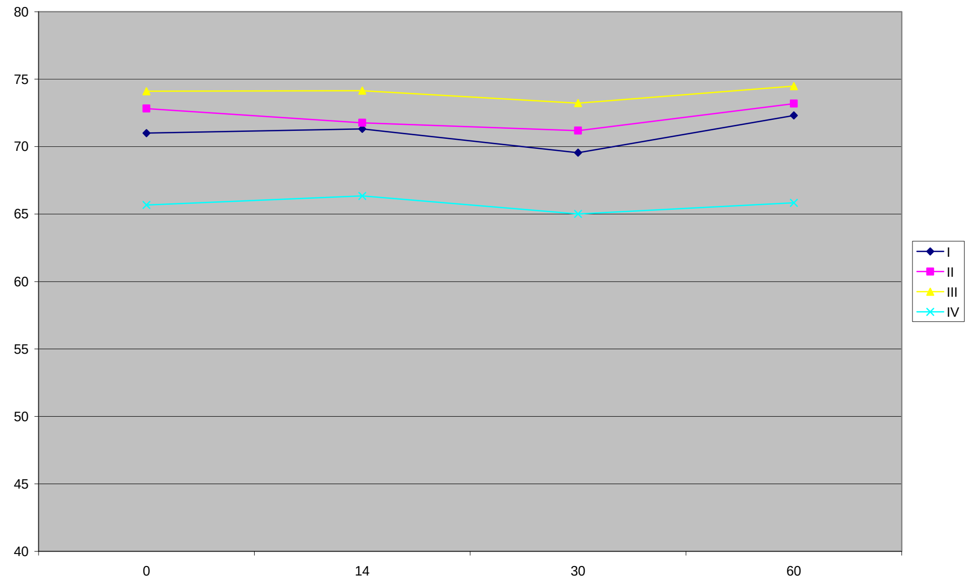


**Figure 2. ISQ levels and pattern of implant stability changes according to bone quality. Note the vertical line is the mean ISQ level and the horizontal one is the measurement times.**

create more lateral stiffness and stability.[23] The distinct properties of the implant surface (machined vs. TiUnite) and the reactions at the bone-implant interface can be another reason for the observed discrepancy between studies.

Replace Tapered™ implants seemed to show rather high ISQ values, indicating favorable primary stability at the time of placement. This can also be explained by morphology of this implant and its surface properties. Previous studies have demonstrated implants with higher ISQ values at the time of placement undergo changes in the amount of ISQ values as time goes by.[24-30] However, we found Replace Tapered™ implants to have high primary stability (mean ISQ > 65) with non-significant changes during the critical first healing time, in all bone types studied; a finding that could also prove superior design of implants used in this study.

Mean implant stability levels were rather equal on days 0, 14, and 30 and higher on day 60; this might be explained considering bone remodeling and the changes occurring at the common bone-implant interface through osseointegration process.[31-33]

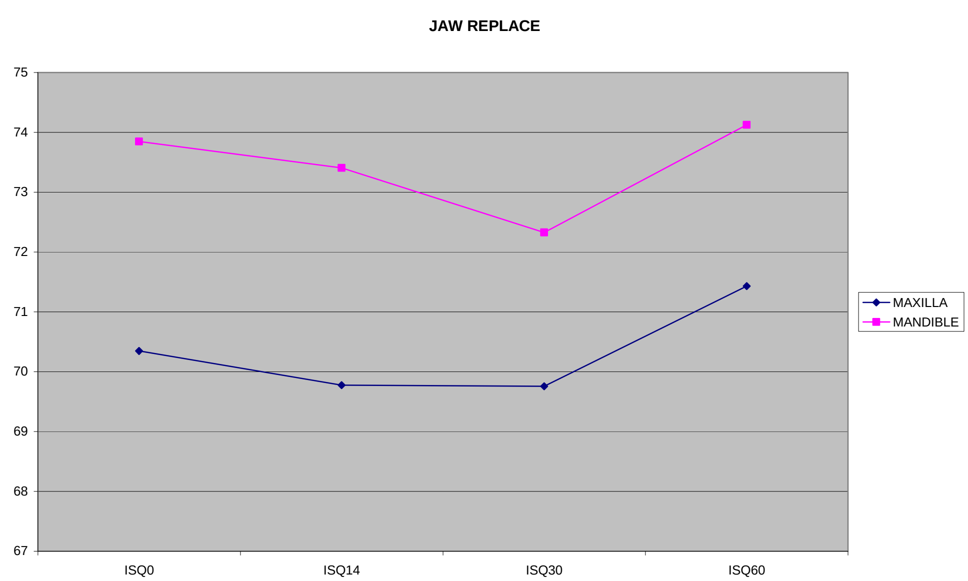


**Figure 3. Implant stability changes according to jaw position. ISQ values showed higher but not significant values in mandible compare to maxilla in all time measuring during this study. Note the vertical line is the mean ISQ level and the horizontal one is the measurement times.**

Although no occlusal forces were applied to the implants, the increase in stability after 30 days in all bone types agrees with the concept of improved bone formation around the roughened surface (e.g. TiUnite) and the likelihood of reduced clinical healing times prior to restoration.[27]

Implant length was also found not to be a significant effective factor on stability. There are other studies supporting this finding.[34-37] It can be hypothesized that once the bone-implant contact is established at the marginal level, composed mainly of dense bone, an implant with high stability is achieved and an extra 3-mm apical length in cancellous bone does not provide significant additional stability for the implant. Many previously studies have also shown success rate and/or the resorption rate of the bone does not differ when using implants with different lengths.[32,38,39] It is, therefore, likely that using the longest implant applicable is not always the best practice.

Implant diameter, however, seems to make a significant difference in implant stability. Implants with greater diameter had higher ISQ values in this study. This finding is consistent with previous reports suggesting the use of wider implants to increase primary stability due to creating a larger bone-implant contact with cortical bone.[40-44] Moreover, this can be explained by the tapered shape of the implants used, which apply more lateral compression to the surrounding walls when used in greater diameters. This results in more lateral stiffness, and thus, more ISQ values, in line with previous studies.[36,44]

It can be concluded that implants with greater diameters should be used with the immediate loading protocol, as it provides higher ISQ values, and conclusively, more primary stability.

It has been shown that bone type affects implant stability.[35,44,45] However, the effect of bone type on implant stability was not observed in our study, which may be explained by the lateral compression of tapered implants used compensating for poor bone qualities. Higher number of threads on the fixture increase bone-implant contact area and therefore can explain constant ISQ values during the two-month period of the study.

Gender and age were not found to be effective factors on the implant stability, a finding similar to previous studies.[46,32]

Studies have indicated that if stable fixation exists between the bone and the implant, even minute interfragmentary movements can be avoided and dynamic load bearing can be withstood,[47] and in those implants showing high primary stability with little change over time, an immediate loading protocol can be indicated.[13] Similarly, immediate and early loading of implants has been advocated in the literature especially with roughened-surface implants.[48,49] An implant presenting an ISQ value of above 60 with an electronic device has been recommended to be loaded directly after insertion.[50] Valderrma et al[51] demonstrated the mean ISQ value obtained using the magnetic device is 8 to12 units higher than the one obtained via the original device.

It can be concluded once adequate primary stability at the placement (mean ISQ value > 68) is gained, Replace Tapered™ implants can be immediately loaded disregarding bone type. However, with relatively less mean ISQ levels (around 65) of this implant, immediate loading should only be considered in type 4 bone where implant ISQ values stay rather constant during critical first two months of healing.

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