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# The Correlation between Peri-implant Bone Density and the Biological Implant Stability: A Two Years Follow-up

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**Abstract** **Objective:** The aim of this study was to assess the correlation between the peri-implant bone density and the biological stability around dental implants. **Materials and Methods:** A total of 56 implants were placed in the mandibular canine area of 28 patients to retain mandibular overdentures. The assessment of bone density changes was obtained through Cone-Beam Computed Tomography (CBCT) and the assessment of implant stability was obtained through Resonance Frequency Analysis (RFA) at loading time, and after 6, 12, 24 months. **Results:** RFA measurement showed a mean of 67.5± 5.8 ISQ at loading time and a mean of 71.3±5.5 ISQ after 24 months. Bone density around the implants showed a mean of 683.48±78.63 HU at loading time, and a mean of 722.24±58.4 HU after 24 months. These increases were statistically significant ($p<0.05$). **Conclusion:** The biological implant stability as measured using the Resonance Frequency Analysis (RFA) and the peri-implant bone density as measured using Cone Beam Computed Tomography (CBCT) showed a significant moderate positive correlation.

***Keywords:*** *biological stability, bone density, resonance frequency analysis, cone beam computed tomography*

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## 1. Introduction

Dental implants are used routinely in clinical practice with great success. One of the challenges is to achieve a rapid osseointegration for loading implants with prosthetic elements. [1]

The success of implant treatment is closely related to bone quality of the implant recipient region [2]. Bone density is a concept that evaluates bone quality [3]. The mechanical competence of bone, which is referred to as bone quality in implant dentistry, comprises bone mass, structural properties, and material properties [4,5]. Consequently, greater failure of implants is likely associated with poor bone mineralization or limited bone resistance on tactile assessment while drilling [6,7].

Implant stability is a requisite characteristic of osseointegration which is also a measure of implant stability [8] which can occur at two different stages: primary stability, which mostly comes from mechanical engagement with cortical bone, and secondary stability, which offers biological stability through bone regeneration and remodeling [9]. Several studies have investigated implant stability during the healing period [10,11]. Implant stability (total stability) is not established in a linear fashion. After installation of implants, the primary mechanical stability decreases rapidly, whereas secondary biological stability increases slowly. This phenomenon has been termed a “dip” (or drop or gap) in stability [12,13].

Factors influencing primary stability are bone quantity and quality, surgical technique, including the skill of the surgeon and finally the implant (e.g.; geometry, length, diameter, and surface characteristics).Factors influencing secondary stability are primary stability, bone modeling and remodeling, and finally implant surface conditions [9].

The success of the implant treatment depends on the secondary implant stability occurred with the osseointegration. However, most of the studies assessing bone reaction around the implants are based on animal studies [14,15]. Due to ethical reasons, there is a lack of data about histological investigations of peri-implant bone in humans. Thus, secondary stability follow-ups of the implants were performed by Resonance Frequency Analysis (RFA) method. The healing process of the peri-implant bone, under different loading protocols, can also be evaluated radiologically by means of Cone-Beam Computed Tomography (CBCT) [16,17].

Quantitative methods for determining implant stability can yield valuable information regarding the success of dental implants [18]. In clinical situations, the osseointegration of implants can be assessed by non-invasive methods such as Resonance Frequency Analysis (RFA). The principle is based on analysis of the frequency transduced by implants inserted into bone [19]. Resonance frequency analysis (RFA) providing an “Implant Stability Quotient (ISQ)” has been used as a surrogate parameter to assess and monitor implant stability over time [20]. The ISQ values range from 1 to 100, where 100 signifies the highest degree of stability [21].

Radiographic analyses are commonly used in implant dentistry as an important diagnostic tool for treatment planning and follow-up [22,23]. These analyses correspond to bone quantity and quality evaluations [24,25] conducted during treatment planning, while during treatment follow-up, implant stability [18], marginal bone level and bone– implant contact could be applied [9,26]. Follow-up analysis aims to assess osseointegration and detect signs of failing integration at an early stage. Marginal bone loss and loss of bone-to-implant contact may indeed negatively influence implant success [27].

Today, cone-beam computed tomography (CBCT) is increasingly replacing multislice CT (MSCT) in dentistry for evaluating mineralized tissues, because it provides adequate image quality associated with a lower exposure dose. Other advantages of CBCT are low cost, as compared with CT, fast scanning time and lower number of image artifacts [28]. Several authors have reported the use of CBCT intensity values as a measurement to assess bone density [29,30].

The aim of this study was to assess the correlation between the bone density measurements obtained by the CBCT in HU values and the biological stability measured by the RFA in ISQ values.

## 2. Materials and Methods

28 completely edentulous healthy patients (21 males &7 females) were selected with their age ranged from 46 to 64 years. Informed consents were obtained from all patients. Each patient received two implants in the mandibular canine area (Dentium Co, Korea) to retain mandibular overdenture. Under local anesthesia, conventional two-stage surgical protocol was performed after all necessary investigations. The follow up and evaluation consists of the followings:

### 2.1. Assessment of the Bone Density Changes

CBCT examination was performed as a follow up at loading time, and after 6, 12, 24 months using the Scanora® 3D machine, Sordex Co. Finland, applying the medium FOV (7.5cmx10cm).Operating parameters were 90 KV,4-12.5m A, scan time 10second ,Isotropic voxel size 0.133mm.

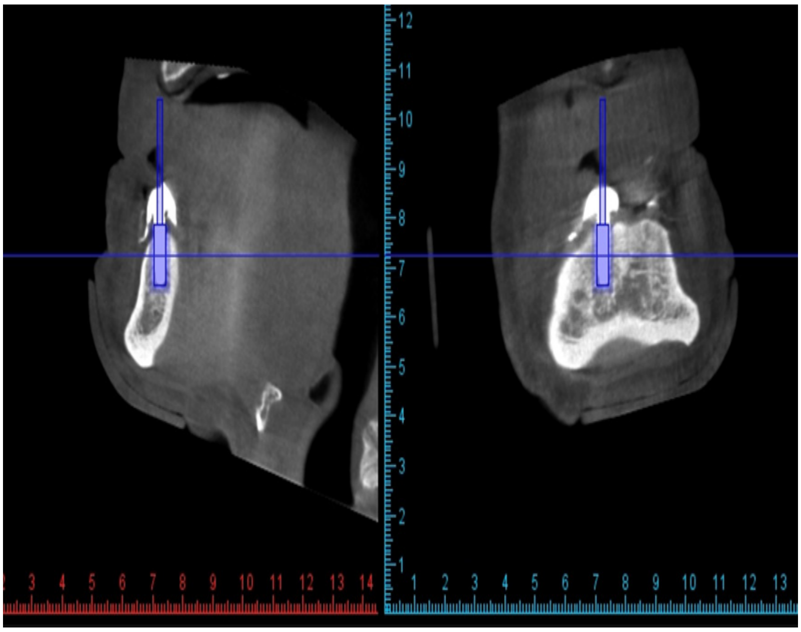

**Figure 1.** Simulating the implant and adjusting its position in the 3 dimensions

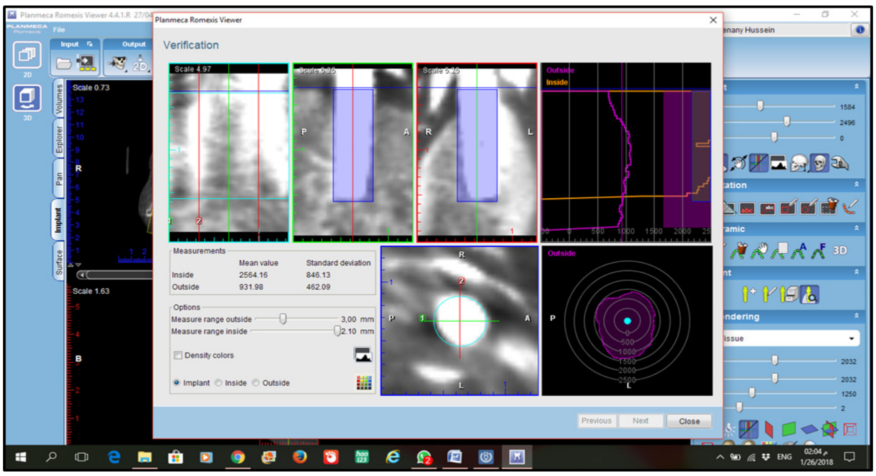


**Figure 2.** Measuring the bone density around the simulated implants using the verification tool in Romaxis software

Bone density around the implants was measured using Romaxis-1 (4.4.1.R) software by inserting a simulated implant as the inserted implant and adjusted by the same dimensions and position as shown in (Figure 1) and then measure the bone density using the verification tool in the software as shown in (Figure 2).

## 2.2. Assessment of the Implant Stability Changes

The stability was measured for each implant at loading time, after 6, 12 and 24 months using Magnetic Resonance Frequency Analyzer [Osstell ISQ, Göteborg, Sweden]. Torque of 4-6 Ncm was used to secure the SmartPeg to the implant .The measurement probe was held close to the top of the SmartPeg until an audible sound was emitted ensuring sensation of SmartPeg and achieving the ISQ value. The measurement was started in the mesiodistal then in buccolingual direction.

The measurements were made three times in each direction to ensure reproducibility. The mean of these values was used for statistical analysis.

## 2.3. Statistical Analysis

The collected data was tabulated and analyzed using the Statistical Program for Social Sciences (SPSS) for windows ver. 21.

Repeated measure ANOVA was used to compare between the bone density and RFA readings at different follow up periods at loading, 6 months, 12 months and 24 months at significance level $p<0.05$.

Linear regression analysis was performed to the data set where bone density was the dependent variable and the RFA was the independent variable in order to establish a correlation between the ISQ reading and the Bone density. Analysis of variance (ANOVA test) was used to test the statistical significance of variance for the regression model at significance level $p<0.05$.

# 3. Results

Clinical assessment of implant stability using RFA measurement showed a mean of 67.5± 5.8 ISQ at loading time, a mean of 66.8±4 ISQ after 6months, a mean of 69.9±4.4 ISQ after 12 months, and a mean of 71.3±5.5 ISQ after 24 months. The repeated measure ANOVA test showed a statistical significant difference in the different follow up periods at loading, 6 months, 12 months and 24 months at significance level $p<0.05$. (Table 1)

**Table 1. RFA measurement (ISQ values) at different follow up periods**

| | Mean | Std. Dev. | 95% Confidence Interval for Mean | | F | p |
|---|---|---|---|---|---|---|
| | | | Lower | Upper | | |
| Loading | 67.500 | 5.8216 | 65.9410 | 69.0590 | 9.54 | P<0.001* |
| 6 months | 66.893 | 4.0325 | 65.8129 | 67.9728 | | |
| 12 Months | 69.929 | 4.4553 | 68.7354 | 71.1217 | | |
| 24 Months | 71.321 | 5.5714 | 69.8294 | 72.8135 | | |

**Table 2. Bone density measurement (HU values) at different follow up periods.**

| | Mean | Std. Dev. | 95% Confidence Interval for Mean | | F | p |
|---|---|---|---|---|---|---|
| | | | Lower | Upper | | |
| Loading | 683.481 | 78.6364 | 662.4225 | 704.5404 | 12.895 | P<0.001* |
| 6 months | 654.888 | 45.9468 | 642.5832 | 667.1925 | | |
| 12 Months | 707.166 | 57.6123 | 691.7370 | 722.5944 | | |
| 24 Months | 722.249 | 58.4038 | 706.6086 | 737.8899 | | |

**Table 3. Correlation between ISQ and HU values.**

| R | R Square | Std. Error of the Estimate |
|---|---|---|
| 0.691[a] | 0477 | 48.48220 |

Bone density around the implants measured radioghrapically using (CBCT) showed a mean of 683.48±78.63 HU at loading time, a mean of 654.88±45.94 HU after 6 months, a mean of 707.16±57.61HU after 12 months, and a mean of 722.24±58.4 HU after 24 months. The repeated measure ANOVA test showed a statistical significant difference at the different follow up periods at loading, 6 months, 12 months and 24 months at significance level $p<0.05$ (Table 2).

The correlation between RFA and bone density measurements showed a statistically significant moderate positive correlation between ISQ and HU values. The Pearson's correlation coefficient $r = 0.691$, ($p < 0.001$), where density was the dependent variable and RFA was the independent variable. The coefficient of determination (R2) = 47.7 %, which is the proportion of the variation in density that can be accounted for variation in ISQ values, suggesting relatively moderate prediction accuracy. The square root of mean square error was about 48.5 HU. (Table 3).

# 4. Discussion

Misch et al; 2004 A, reported that a predictable long-term osseointergation had been reported after the two-stage surgical protocol established by Branemark for placement of implants in both completely and partially edentulous patients [31].

Salvi and Lang, 2004, stated that; the parameters routinely used to monitor oral implants during maintenance care should be of high sensitivity and/or specificity, easy to measure and should yield reproducible data [32]. Accordingly, the patients were scheduled for follow up after 6, 12, and 24 month of implants' placement and loading time to correlate between bone density measured radioghraphically and biological stability measured by RFA around the implants.

Ito et al, 2008, emphasized the importance of evaluating implant stability in clinical situations [33]. In this study, RFA was used as a quantitative method for measurement of implant stability and osseointegration [34] as it has reported to be evidence based [35] and then believed to be potential useful clinical tool for prevention, diagnosis, and prediction of implant failure and is helpful in the maintenance of viable implants [36]. Several clinical studies have demonstrated the reliability of this method to determine the time point to initiate loading [11]. Osstell® ISQ devices had been shown to be effective in detecting implant stability, distinguishing implants placed in different qualities of bone [33].

Molly, 2006, stated that the bone density seems to be of great importance not only in primary implant stability but also in the predictability of oral implant outcome [2]. Bone density measurements evaluated the percentages of mineralized bone in relation to the percentages of marrow cavities [37]. To obtain this knowledge, adequate radiographic examination is required [38]. In this study, CBCT was used to assess the bone density around the implants at loading time, after 6, 12and 24 months. The validity of CBCT in bone quality assessment has been studied broadly. The majority of these studies has focused on the bone density measurement and found CBCT a reliable modality for bone density measurement. Also a study of Paras, et al, 2015, demonstrated the reliability and validity of CBCT in bone quality assessment [39].

In this study the RFA measurements showed a mean of 67.5±5.8 ISQ at loading time reaching a mean of 69.9±4.4 ISQ after 12 months, then increasing to a mean of 71.3±5.5 ISQ after 24 months. This significant increase in stability is most likely due to bone formation/remodeling and an increased stiffness of the bone. This results is in agreement with Ersanli et al, 2005, who stated that ISQ values for successfully osseointegrated implants have been reported to vary from 57 to 82 ISQ, with a mean of 69 ISQ after 1 year of loading [40].

In this study the bone density measurements around the implants showed a value of 683.48±78.63 HU at loading time reaching a value of 722.24±58.4 HU after 24 months. This significant increase in bone density around the implants was in agreement with Gotfredsen et al, 2001, who reported that continuous loads on implants resulted in increased bone density [41].

The result of this study showed a significant moderate positive correlation between RFA measurements and bone density measurements from loading time up to 24 months as the loading of dental implants increases the stability of implants and mineralization of peri-implant bone. This result is in agreement with other studies which reported that RFA was a reliable tool for the assessment of implant stability and ISQ value significantly correlated with other implant stability parameters such as bone density [42,43].

Some factors can affect implant stability and ISQ recordings such as bone shape of the implant, thread design, surface treatment, surgical technique and the experience of the surgeon [44]. In this study, all of the factors that have the possibility to affect ISQ recordings were standardized by using the same region (mandibular canine area), standard surgical technique and by correlating the RFA reading with bone density measurements around the same implants in the same patient through the 24 months evaluation period. Thus, ISQ values were a valuable and reliable tool to indicate the degree of implant stability objectively.

## 5. Conclusion

Within the limitation of this study, the biological implant stability as measured using the Resonance Frequency Analysis (RFA) and the peri-implant bone density as measured using Cone Beam Computed Tomography (CBCT) showed a significant moderate positive correlation.

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