# Assessment of the Effect of Implant Recipient Site´s Bone Density on Initial Implant Stability in the Anterior Mandibular Region.

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**Abstract: Objective:** The aim of this study was to assess the correlation between the bone density of the potential implant sites and the initial implant stability in the anterior mandibular region. **Subjects and Methods:** A total of 54 implants were placed in the anterior mandibular region of 27 patients. The preoperative bone densities of the implant recipient sites were evaluated using Cone Beam Computed Tomography [CBCT] and the initial implant stability using Resonance Frequency Analysis [RFA] measured as implant stability quotient values [Osstell, ISQ]. **Results:** The mean bone density among all implant sites was 830.4± 141.1 HU (range: 546.7 to 1265.7) and the mean ISQ values was 67.9± 6.3 (range: 55 to 79). There was a statistically significant correlation between the bone density of the recipient implant sites and the ISQ values measured immediately after implant placement **Conclusion:** The results of this study demonstrated a significant correlation between preoperative bone densities of the implant recipient sites in the anterior mandibular region as evaluated using cone beam computed tomography and the initial implant stability measured using resonance frequency analysis.

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## 1. Introduction

Quality and quantity of the bone are two important and effective factors on stabilizing the level connection of the implant and bone. In fact, enough bone volume and density are the key factors to successful implant treatment. (Naser, Etemadi et al. 2011)

A key determinant of clinical success is the evaluation of bone density around the endosteal implant. The strength of bone is directly related to bone density. Density of available bone in an edentulous site is determining factor in treatment planning, implant design, surgical approach, healing time, and initial progressive loading during prosthetic reconstruction. (Suvarna P 2010)

Several bone classification systems have been proposed for assessing bone quality. In 1985, Lekholm and Zarb (Lekholm U 1985) used radiographs to subjectively classify bone density into four types based on the amount of cortical and trabecular bone. This classification system has been utilized worldwide because it is easy to use without considerable investment. Misch, 2008 (Misch 2008) used computed tomography (CT) to objectively classify bone density into 5 types based on Hounsfield units (HU). This method allows for a precise and objective assessment of bone quality.

Computed tomography (CT) has been used for the objective quantification of direct density measurements of bone, expressed in Hounsfield Units (HU) as a parameter of bone quality. (Fuh, Huang et al. 2010)

In the last years, due to the need of less expensive image acquisition protocols or of scanners with a lower radiation dose, cone beam computed tomography (CBCT) became widely used for oral and maxillofacial imaging providing a good spatial resolution, gray density range, and contrast, as well as a good pixel/noise ratio. (Arisan, Karabuda et al. 2012; Cassetta, Stefanelli et al. 2012)

Cone-beam computed tomography (CBCT), utilizes cone-beam geometry, flat-panel detection and three dimensional (3D) reconstruction algorithms is useful for numerous indications; (Lubbers, Matthews et al. 2011). The relatively low radiation doses with high spatial resolution and accurate 3D views allow thorough information to be obtained for the bone dimensions and quality, e.g., the bone mineral density. (Kropil, Hakimi et al. 2012; Metzler P 2012)

Several studies showed the validity of CBCT for densitometric analysis and assessment of osseointegration as there was a positive correlation between total bone mineral density measured by CBCT and by dual-energy x-ray absorptiometry (DEXA) which is the most accurate technique for measuring real bone density. (Lai, Zou et al. 2010; Elhayes KA 2012; Kaya, Yavuz et al. 2012; Marquezan, Lau et al. 2012).

Dental implant stability is a measure of the anchorage quality of an implant in the alveolar bone and is considered to be the consequential parameter in implant dentistry. Implant stability can occur at two different stages: primary and secondary. (Atsumi, Park et al. 2007)

Primary stability at implant installation is achieved by the physical congruence between the surgically created bone bed and the implant, which is dependent from the macroscopic implant design, the surgical technique and the bone density (Sennerby and Meredith 2008) and it is considered to be a fundamental prerequisite for osseointegration of dental implants to obtain predictable and successful results. (Romeo, Lops et al. 2004)

Secondary implant stability represents an enhancement of the stability as a result of peri-implant bone formation through gradual bone remodeling and osteoconduction, with the possibility of new bone formation at the implant-bone interface. (Davies 1998)

Objective measurement of implant stability is a valuable tool for achieving consistently good results first and foremost because implant stability plays such a significant role in achieving a successful outcome. Several studies have tested different diagnostic methods aimed to assess implant stability. These methods range from those strictly based on clinical criteria, such as the clinical perception of implant resistance to rotation or the cutting resistance of the implant during its insertion (Bischof, Nedir et al. 2004), to those that utilize more objective and quantifiable criteria, although are invasive in nature, such as reverse torque measurements or histomorphometry, and therefore, can only be used in animal experiments. (Isidor 1998) The need for a user-friendly, noninvasive, reliable, and clinically applicable technique to measure implant stability led to the development of resonance frequency analysis (RFA) by Meredith and coworkers in 1996. (Meredith, Alleyne et al. 1996)

The RFA measures the stiffness of the bone/ implant interface is calculated from a resonance frequency as a reaction to oscillations exerted onto the implant/ bone system. The method analyzes the first resonance frequency of a small transducer attached to an implant fixture or abutment. The unit of measurement in this approach is the implant stability quotient (ISQ); and a high ISQ value indicates greater stability whereas a low values implies instability. The scale ranges from 1 to 100 and the acceptable stability range lies between 55-85 ISQ. Current RFA units used clinically are Osstell® and Implomates®. (O'Sullivan, Sennerby et al. 2004)

The aim of this study was to assess the correlation between the bone density of the implant recipient sites as evaluated using Cone Beam Computed Tomography [CBCT] and the initial implant stability using Resonance Frequency Analysis [RFA] measured as implant stability quotient values [Osstell, ISQ].

## 2. Subjects and Methods

Twenty seven patients ranging from 45 to 63 years of age (with average age 56.7 years) who presented with an edentulous mandible and had implant recipient sites that exhibited bone quality of type D1, D2, D3a and D3b according to Misch's original classification and the modified sub-classification (Misch 2008) were recruited for this prospective study. None of the selected patients suffered from a systemic condition that contraindicates implant treatment modality. They were all scheduled for a two implants mandibular retained overdenture. All patients gave written informed consent after notified about the nature of the study. Every patient received a CBCT scan before implant planning. Two implants (Dentium Co, Korea) were placed in the anterior mandibular area of each patient (summing to a total of 54 implants of different lengths and diameters) with local anesthesia following a standardized surgical protocol following routine medical and dental investigations.

***a. Bone Density Assessment***

Preoperative radiographic planning of the implant sites was conducted using cone beam computed tomography (CBCT) imaging, investigating residual alveolar crest width and height as well as jaw-bone density and a replica of the patient's lower denture that was used as a radiographic stent. For visualization of the drilled sites during CBCT scanning, amalgam acrylic resin powder mix 1 to 3 by weight (Agamy ET 2009) was utilized to fill 4 mm depth channels at the center of each canine to act as radiopaque object. The orifice of each channel was sealed by a small piece of base plate wax and the radiographic examination was carried out while the patient was wearing the template. The radiographic template was thereafter transformed to a surgical stent.

Cone Beam Computed Tomography [CBCT] images were acquired using the Scanora® 3D System, Sordex Co, Finland. The patients were exposed in the sitting position and the mandibles were immobilized by positioning the head against the head rest and chin cup, with the mid-sagittal plane perpendicular to the horizontal plane using vertical and horizontal alignment beams as recommended by the manufacturer.

The X-ray field size applied in the current study (field of view for mandible only) was 10 x 7.5 height, and scanning time was 8.9 seconds (fast enough to avoid patient movement, image blurring and haziness). Operating parameters were 120 kVp, and 5 mA with slice thickness of 0.1 mm. The Romaxis 1, Planmec, Finland, was used which allows the recording of linear and density measurements of images.

For each implant site the linear measurement was performed to choose the suitable implant from the implant library provided by the Romaxis 1. After choosing the suitable implant, simulation of the implant placement was performed with the suggested angulations (fig. 1). The density measurements are performed by taking the mean of the Hounsfield units at the implant site using the implant verification tool in the software (fig. 2). The mean values of the readings were taken, tabulated and statistically analyzed.

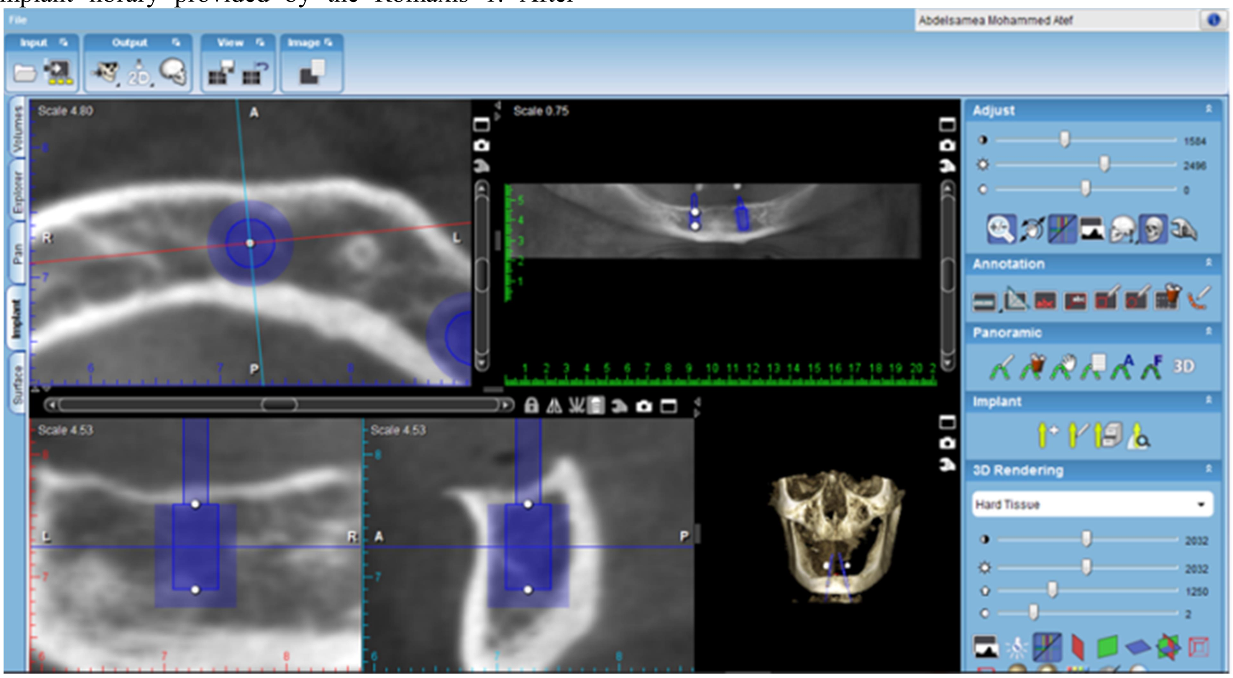


Figure 1. Placement of the simulated implant with the suggested angulations.

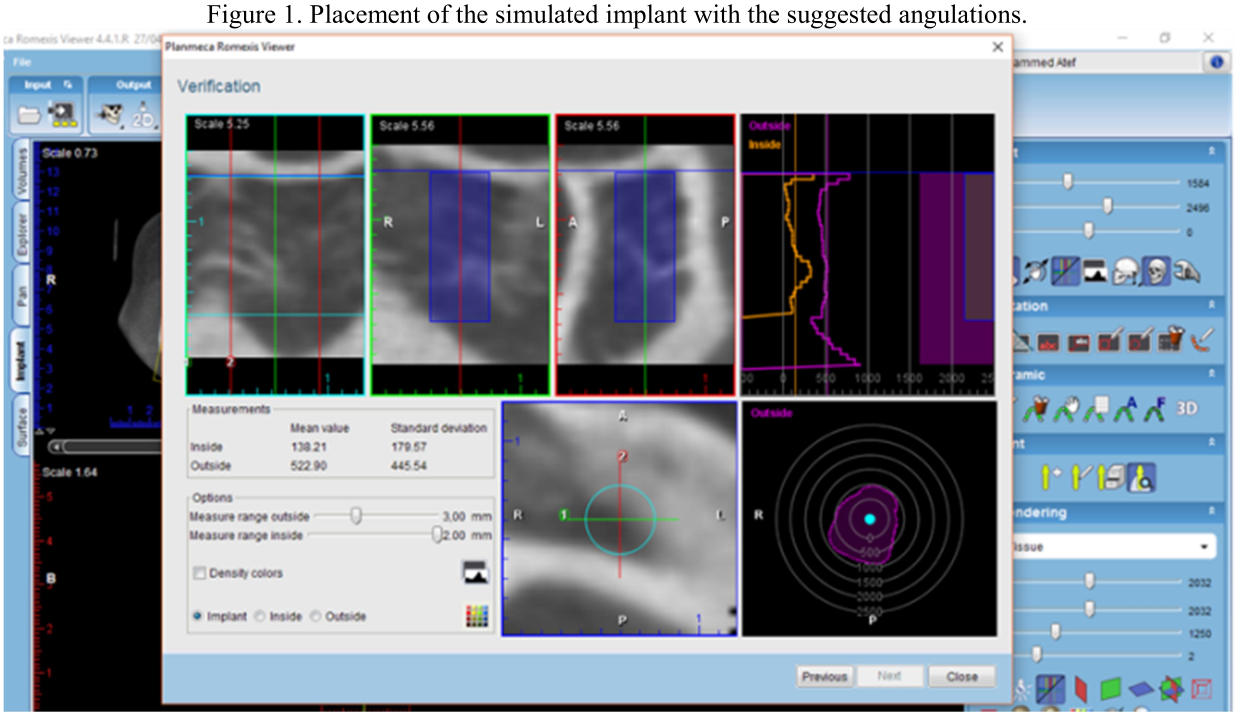


Figure 2. Hounsfield measurement using the implant verification tool.

***b. Implant Stability Measurement:***

The stability of each fixture was measured as ISQ values [implant stability quotient] with Magnetic Resonance Frequency Analyzer, Osstell ISQ immediately after implant placement.

A special smart peg was connected to the implant body at 4 - 5 N/cm torque, and measurements were made at 2 - 3 mm away so that the probe tip of the analyzer would point to the small magnet above the smart peg. Measurements were made at two directions, buccolingual and mesiodistal directions. The measurements were made three times for each direction to ensure reproducibility. The mean of these values was used for statistical analysis.

***c. Statistical Analysis***

The collected data were tabulated and analyzed using SPSS 20.0 (Statistical Package for Scientific Studies) for Windows.

Implant stability measurements were plotted according to the bone densities. The intensity of the correlation or the absence of correlation was calculated using the Pearson correlation test. The gender relation with the bone density and implant stability was also tested using student´s -t test.

**3. Results**

According to the bone quality classification (Misch 2008) of the recipient implant sites (Table 1); 2 implants were placed in D1 bone (3.7%), 15 implants were placed in D2 bone (27.8%), 32 implants were placed in D3a bone (59.2%) and 5 implants were placed in D3b bone (9.3%).

Table 1. Distribution of the implant recipient sites according to bone type

| **Bone Type** (HU) | **D1** >1,250 | **D2** 850-1250 | **D3a** 600-850 | **D3b** 350-600 | **Total** |
|---|---|---|---|---|---|
| **No.** | 2 | 15 | 32 | 5 | 54 |
| **%** | 3.7% | 27.80% | 59.2% | 9.3% | 100% |

The mean bone density among all implant sites (54 implants) was 830.4± 141.1 HU (range: 546.7 to 1265.7) and the mean ISQ values was 67.9± 6.3 (range: 55 to 79).

Table 2. Statistics corresponding to bone density and ISQ values in relation to gender

| **Gender** | **Bone Density (HU)** | | **Implant Stability (ISQ)** | |
|---|---|---|---|---|
| | Mean±SD | Min. – Max. | Mean±SD | Min. – Max. |
| **Male** | 843.3±148.4 | 584.3-1265.7 | 67.6±6.3 | 55-79 |
| **Female** | 793.5-114.6 | 546.7-947 | 68.6±6.7 | 55-78 |
| **t (p) *** | 0.260 | | 0.601 | |
| p: for Student's t-test *: significant at p<0.05 | | | | |

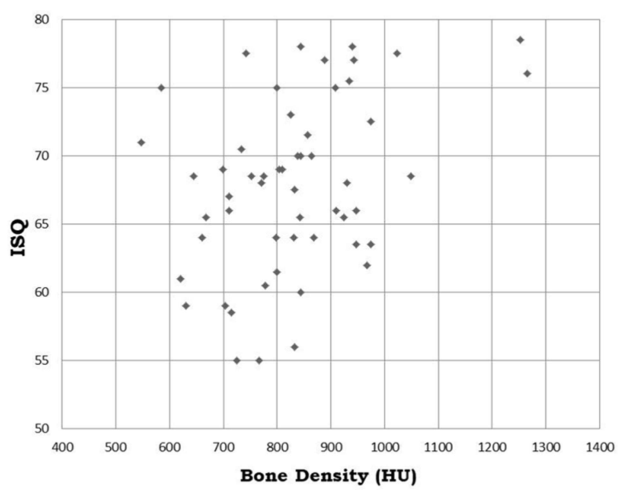


Figure 3. ISQ values according to bone density (HU). Pearson correlation test, r = 0.369, p = 0.006, significant at: p <0.05.

Regarding the gender distribution among the 27 patients recruited for this study; 20 patients were male and received 40 implants (74%) and 7 patients were female and received 14 implants (26%). The statistical analysis corresponds to bone density (HU) and primary implant stability (ISQ) measurements among both genders (table 2) using student´s t-test showing no statistical significant difference between male and female patients neither in preoperative bone density nor in primary implant stability.

Regarding the statistical correlation analysis between the preoperative bone density (HU) and the initial implant stability (ISQ) using Pearson's correlation test; there was a statistically significant correlation between the preoperative bone density of the potential implant sites and the ISQ values immediately after implant placement. (Fig. 3)

**4. Discussion**

Primary implant stability has been identified in several reports as a major determinant of implant integration. (Morris, Ochi et al. 2004; Ostman, Hellman et al. 2005). It is conditioned by the amount and type of immediate direct contact between the implant and the prepared bone bed. For this reason, primary stability is related to the surgical implant site preparation and the recipient bone density, as well as the implant geometry. (Trisi, Berardini et al. 2015)

Ilser Turkyilmaz et al. in a study mentioned that the factors affecting the primary implant stability can be divided into: patient-related (ie, bone volume and quality) and procedure-dependent parameters type of implant and type of surgical procedure. (Turkyilmaz, Aksoy et al. 2008)

Merheb et al 2016, concluded that; Implant stability seem to be influenced by both local and general bone densities. (Merheb, Temmerman et al. 2016)

The computed tomography (CT) can determine the bone anatomy and density more precisely. Each voxel within a scan of a bone specimen generates a CT value (in Hounsfield units: HU) that is related to the density of the tissue represented by the voxel bone density classification, which is categorized as follows: D1, >1,250 HU; D2, 850–1,250 HU; D3, 350–850 HU; D4, 150–350 HU. D5, 0–150 HU. (Sogo, Ikebe et al. 2012)

Regarding the CBCT, Naitoh et al 2010 suggested that voxel values of mandibular cancellous bone in CBCT could be used to estimate bone density (Naitoh, Aimiya et al. 2010). This bone density assessment was performed by measurement of Hounsfield Units (HU) as in the CT classification. (Aranyarachkul, Caruso et al. 2005)

Metzler et al 2012 stated that; Owing to the low-dose high-spatial-resolution visualization of high-contrast structures and accurate 3D views, CBCT imaging permits quantitative and qualitative evaluations of osseous structures. For these reasons, as well as socioeconomic costs, especially under the premise of prospective regular follow-ups, the CBCT technology was chosen for Bone Mineral Density evaluations. (Metzler P 2012)

CBCT was used in this study to assess the bone density of the potential implant sites this was based on several studies that support the use of CBCT to evaluate the bone density. (Lagravere, Carey et al. 2008; Hsu, Chang et al. 2011; Gonzalez-Martin, Lee et al. 2012; Marquezan, Lau et al. 2012)

Tatli et al, 2014 concluded that: bone density values from CBCT are significantly correlated with primary and also secondary stability parameters derived from RFA in immediately loaded implants and it is possible to predict initial implant stability and also stability changes of immediately loaded implants by using preoperative CBCT scan. (Tatli, Salimov et al. 2014)

In another study conducted by Merheb et al 2010, it was stated that; Primary implant stability seems to be influenced by mainly bone-related factors, namely bone density of the spongious part of the osteotomy site and the cortical plate's thickness. Other factors such as implant length or diameter, even though not influential on implant stability when considered individually, seem to significantly affect stability when considered in a wider multi-variable model. (Merheb, Van Assche et al. 2010)

The results of our study showing that; there was no statistically significant association between the Hounsfield values of bone density measurement with gender difference of the studied sample which in line a study conducted by Shapurian et al 2006, who stated that; there was no statistically significant association between the Hounsfield values of bone density measurement with certain demographic parameters of the population studied including gender and age. (Shapurian, Damoulis et al. 2006)

Huber et al. 2012, (Huber, Rentsch-Kollar et al. 2012) identified significantly lower ISQ values for implants in the edentulous maxilla of female patients than male patients at various time points while this gender difference disappeared when RFA measurements were compared in the edentulous mandible which is in line with our study as no statistical difference was found between male and female patients regarding the ISQ values in the anterior mandibular region.

In our study a statistically significant correlation was found between mean bone density and implant stability measurements in ISQ units, which corroborates with the results from several previous studies that identified the bone density as one of the major factors affecting the primary stability of an implant. (Tricio, van Steenberghe et al. 1995; Huang, Lee et al. 2002; Beer, Gahleitner et al. 2003; Merheb, Van Assche et al. 2010; Tatli, Salimov et al. 2014)

**Conclusion**

Within the limitations of this study, It can be concluded that; there is a significant correlation between the bone densities of the implant recipient sites in the anterior mandibular region as evaluated using cone beam computed tomography and the initial implant stability measured using resonance frequency analysis.

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