Two Alternative Surgical Techniques for Enhancing Primary Implant Stability in the Posterior Maxilla: A Clinical Study Including Bone Density, Insertion Torque, and Resonance Frequency Analysis Data

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ABSTRACT

Background: The primary stability of dental implants associated with resistance to micromotion during healing is affected by surgical technique and implant design, which are important especially in the soft bone, where implant failures are more likely.

Purposes: This study was designed to compare the parameters associated with implant insertion using two different methods of enhancing implant primary stability and to identify any relationship between these parameters at implant insertion.

Materials and Methods: A total of 60 implants were placed in the maxillary posterior regions of 22 patients. The bone densities at the implant sites were recorded using a computerized tomography machine in Hounsfield unit (HU). The maximum insertion torque data were recorded with the Osseocare™ (Nobel Biocare AB, Göteborg, Sweden) equipment, while resonance frequency analysis (RFA) measurements were taken using an Osstell™ (Integration Diagnostics AB, Göteborg, Sweden) machine at implant surgery. Comparisons including HU, Ncm, and implant stability quotient were made between two control groups (C1 and C2), and corresponding four test groups (T1–T4) using thinner drills to enhance primary implant stability.

Results: Two implants were lost, meaning an overall implant survival rate of 96.6% after 3 ± 1 years. When compared to control groups, significantly higher mean maximum insertion torque and RFA values were found for corresponding test groups. In addition, strong correlations were observed between the bone density and insertion torque, and implant stability values at implant placement.

Conclusion: The results of this study suggest that using thinner drills for implant placement in the maxillary posterior region where bone quality is poor may improve the primary implant stability, which helps clinicians to obtain higher implant survival rates.

KEY WORDS: bone density, computerized tomography, Hounsfield unit, implant, implant stability, insertion torque, resonance frequency analysis

Dental implants have become a milestone in dentistry, and numerous alternative oral therapies that could not be possible with conventional techniques have become possible. The penetration of dental implants in oral rehabilitation has been growing as numerous

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studies regarding dental implant treatment have showed successful results during the last two decades.[1–4] The successful outcome of any implant procedure needs a series of patient-related (ie, bone volume and quality) and procedure-dependent parameters (ie, type of implant, type of surgical procedure).[5,6]

Several classification systems and procedures were proposed for assessing the bone quality and predicting prognosis because mechanical behavior of the bone is a vital factor in the achievement of osseointegration.[7–9] The classification suggested by Lekholm and Zarb[9] in the assessment of bone density has dominated the dental literature during the last two decades. Although this method may provide valuable information about bone density, it has recently been considered as a subjective method. Schwarz and colleagues[10,11] introduced the concept of using computerized tomography (CT) scan that was more objective, for preoperative quantitative assessment of patients requiring dental implant treatment. The popularity of CT in implant dentistry has been increasing during the past few years.

It has widely been accepted that primary implant stability is a strong prerequisite for successful osseointegration.[12] Primary stability is affected by local bone quality and quantity, the geometry of an implant (ie, length, diameter), and the placement technique used (drill size–implant size, pre-tapped or self-tapped implant). Implant stability can be measured by the insertion torque technique[13] and/or the resonance frequency analysis (RFA) technique,[14] where the implant stability is recorded by using Osstell machine and the transducer including piezoceramic elements.

Clinical studies have revealed a higher survival rate for dental implants in the mandible.[15] However, a lower survival rate of the implants placed in the maxilla, particularly in the posterior region, has been reported in the literature, which can be explained by the bone around the implant having poorer volume and quality in maxilla.[7,8] A limited number of studies regarding alternative surgical protocols/implant designs to increase the primary implant stability are available in the dental literature.[16–18]

The goal of the present study was to assess bone density in implant sites, and primary stability by insertion torque and RFA measurements of implants placed according to a surgical protocol that aimed for high primary stability. Further aim was to explore possible correlations between bone density, insertion torque, and RFA measurements at implant placement.

MATERIALS AND METHODS

Twenty-two patients (10 women and 12 men, average age 49 years) have been provided from patients' pool treated with implants in two clinics (one university clinic, one private clinic), and the implants with Hounsfield unit (HU) values below 550 were selected for this study because they are most likely to detect the HU values lower than 550 HU in the posterior maxilla (premolar and molar teeth positions) for our overall patient population. Then, six groups (two controls [C1 and C2]; four tests [T1–T4]) were created according to the implant dimensions and surgical types used. It was provided that the average of HU value in each group was similar to remove the influence of bone density on the surgical types between the groups.

The preoperative examination included clinical examination, a panoramic radiograph, and CT scan. The implants used in the present study consisted of 60 Brånemark TiUnite™ Mk III implants (Nobel Biocare AB, Göteborg, Sweden) with diameters of 3.75 and 4 mm, and lengths of 10 and 11.5 mm.

CT Scans

CT machine (Siemens AR-SP 40, Munich, Germany) was used for preoperative evaluation of each jawbone. Previously fabricated surgical acrylic stents including 1-mm-diameter indicator metal rods, which were located in the center of the missing teeth, were placed in the patients prior to CT scan. The same scanning conditions were used as tube voltage 130 kV, tube current 83 mA, slice thickness 1 mm, and slice intervals 1 mm. The suitable implant for each previously designated implant area was selected by using the cross-sectional images. The rectangular area of each implant placed was plotted on the cross-sectional images with a tool incorporated in the CT machine, and the mean bone density of the implant area with a surrounding 1 mm thickness was measured using a software which has already been included in the CT machine (Figure 1).[19] The bone density measurements were obtained in HU.

Surgical Procedures

All implants were placed according the manufacturer's instructions (Figure 2). The surgical procedure consisted of local anesthesia and a crestal incision, followed

Figure 1 Osstell machine connected transducer.

TABLE 1 The Dimensions of İmplants and Drills Used for Each Group

Group	Implants (mm)	Length of 2-mm-Diameter Drill Used (mm)	Length of 3-mm-Diameter Drill Used (mm)
C1	3.75 × 10	10	10
T1	4 × 10	10	10
T2	4 × 10	10	7
C2	3.75 × 11.5	11.5	11.5
T3	4 × 11.5	11.5	11.5
T4	4 × 11.5	11.5	8.5

by mucoperiosteal flap elevation. Spherical drills for marking the implant location, pilot drills from 2 to 3 mm diameter, and countersink drills were used for each implant. The lengths of 2 and 3 mm diameter cylindric drills for implant sockets differed between groups. The dimensions of implants and drills used are given in Table 1.

Insertion Torque Measurements

The local insertion torque of each implant was recorded with an Osseocare™ machine (Nobel Biocare AB). The Osseocare machine is utilized for perforation of the bone, implant placement, and abutment connection. It can only apply limited amount of torque in order to avoid mechanical overload of the equipment or bone tissue. The final insertion torque values were recorded in 20, 32, or 45 Ncm in this study.

Figure 2 The panoramic view of the patient used after the insertion of implant-supported fixed partial dentures.

Resonance Frequency Measurements

Resonance frequency measurement for each implant was performed by using the Osstell™ machine (Integration Diagnostics AB, Göteborg, Sweden) immediately after the implant placement. An 8.5 mm height transducer was screwed onto an implant. The transducer has two piezoceramic elements and is vibrated by exciting one of the elements with a sine wave, and the second element measures the response of the beam. The captured data (resonance frequency values) are represented in a quantitative unit called implant stability quotient (ISQ) on a scale from 1 to 100. ISQ values are derived from the stiffness (N/μm) of the implant/bone system and the calibration parameters of the transducer. A high ISQ value indicates high stability, whereas a low value indicates a low implant stability.

Implant Survival Examination

Implant survival was evaluated with the following criteria[20] after implant placement annually: absence of mobility and painful symptoms, absence of peri-implant radiolucency, and progressive marginal bone loss at radiographic evaluation. The follow-up period ranged from 1 to 5 years with a mean of 3 ± 1 years (Figure 3).

Statistical Analysis

SPSS 11.0 statistical program (SPSS, Inc., Chicago, IL, USA) was used for analysis. Mann–Whitney test was used for comparison of bone density, insertion torque,

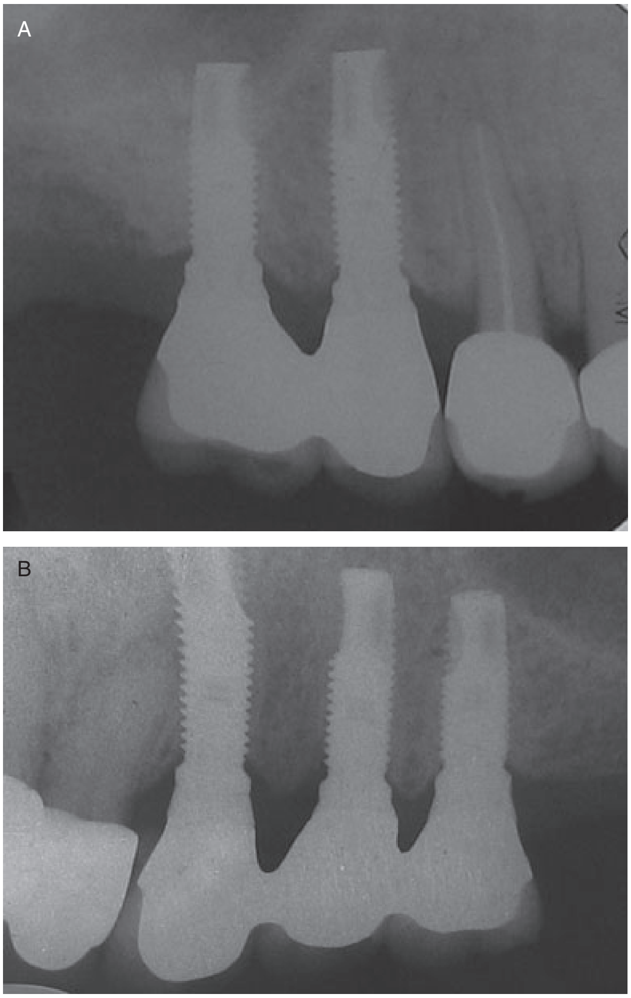

Figure 3 The right (A) and left (B) intraoral radiographs of the patient at 3-year follow-up.

and resonance frequency data between the six groups. Spearman's test was used to determine the correlations between the bone density, the insertion torque, and resonance frequency data at implant placement. A value of $p < .05$ was considered significant.

RESULTS

Of the 60 implants placed, one was lost in group C1, and one was lost in group C2 within the first month of healing, meaning an overall implant survival rate of 96.6% an average 3 years later. The recorded data for the failed implants were 387 HU, 20 Ncm, and 51 ISQ (group C1), and 401 HU, 20 Ncm, and 53 ISQ (group C2).

The mean maximum insertion torque values were 29.7 ± 8, 35.9 ± 6, and 37.2 ± 7 Ncm for groups C1, T1, and T2, respectively. The difference was statistically significant between groups C1 and T1 ($p < .05$), but not between groups T1 and T2 ($p > .05$). The corresponding values for groups C2, T3, and T4 were 30.9 ± 7, 38.5 ± 7, and 41.1 ± 6 Ncm. It was also found that the difference was statistically significant between groups C1 and T1 ($p < .05$), but not between groups T1 and T2 ($p > .05$).

The ISQ values are given in Figure 4. For 10-mm-long implants, the highest and lowest ISQ values were found in groups T2 and C1, respectively. The difference was statistically significant between groups C1 and T1 ($p < .05$). However, no significant difference was found between groups T1 and T2 ($p > .05$). The ISQ values also showed parallel results for 11.5-mm-long implants. The difference was statistically significant between groups C2 and T3 ($p < .05$). However, no significant difference was found between groups T3 and T4 ($p > .05$).

In addition, statistically significant correlations have been observed between the bone density and insertion torque, bone density and resonance frequency, and insertion torque and resonance frequency values for each group (Table 2).

DISCUSSION

Bone density assessment has always been one of the most important parameters for predicting long-term success in dental implant therapy. Although several classification systems were proposed for assessing the bone quality and predicting prognosis,[21,22] one of the most popular methods for bone quality assessment was

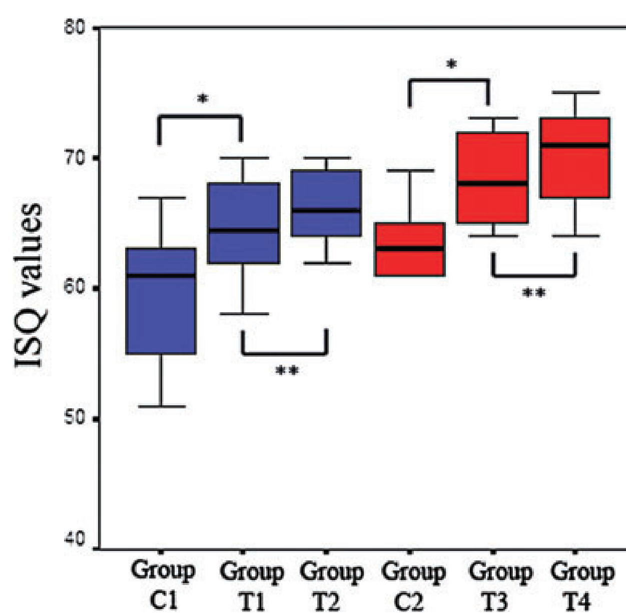

Figure 4 The average implant stability quotient (ISQ) values for all groups (*$p < .05$; **$p > .05$).

TABLE 2 Three Different Data Recorded and Corresponding Correlations According to the Implant Dimensions

Dimension of Implants (mm)	Groups	Mean HU (SD)	Mean Maximum Torque (SD)	Mean ISQ (SD)	Correlations Between HU and Maximum Torque		Correlations Between HU and ISQ		Correlations Between Maximum Torque and ISQ	
					r Value	*p* Value	*r* Value	*p* Value	*r* Value	*p* Value
3.75 × 10	C1	480 ± 68	29.7 ± 8	59.5 ± 5	.87	<.001	.97	<.001	.87	<.001
4 × 10	T1	482 ± 74	35.9 ± 6	64.4 ± 3	.79	<.05	.96	<.001	.81	<.05
4 × 10	T2	484 ± 46	37.2 ± 7	66.4 ± 2	.85	<.05	.82	<.05	.78	<.05
3.75 × 11.5	C2	483 ± 53	30.9 ± 7	62.2 ± 5	.80	<.05	.98	<.001	.81	<.05
4 × 11.5	T3	481 ± 49	38.5 ± 7	68.3 ± 4	.87	<.001	.91	<.001	.84	<.05
4 × 11.5	T4	478 ± 42	41.1 ± 6	70.2 ± 3	.79	<.05	.93	<.001	.80	<.05

Control groups: C1 and C2; test groups: T1–T4.
HU = Hounsfield unit; ISQ = implant stability quotient.

proposed by Lekholm and Zarb.[9] They classified bone density radiographically into four types. With respect to their classification, a more objective and reliable bone classification method is needed to clarify the surgical sites that will receive dental implants. The use of CT, which is more objective and reliable, for the evaluation of the bone density of patients requiring implant therapy was introduced by Schwarz and colleagues,[10] and this method has been utilized in several studies.[23,24]

In the present study, the recorded bone density values are higher than those in previous studies.[8,25] The study by Norton and Gamble stated that the mean bone density was 417 HU in the posterior maxillary region including 27 implant sites. Shapurian and colleagues[25] reported that the mean bone density value in the posterior maxilla was 333 HU for 54 implant sites. These differences between the present and previous studies might result from the variations in patient-related factors (ie, age, gender). Furthermore, significant correlations were found between the bone density and insertion torque and resonance frequency values in the present study, which concur the earlier report including 158 implants.[19]

Da Cunha and colleagues[26] placed 13-mm-long 12 standard Brånemark System implants and 12 TiUnite Mk III Brånemark System implants in the maxilla. The average insertion torque and ISQ values were 37.1 and 67.9, respectively. Although the average insertion torque and ISQ values recorded for the control groups in the present study were lower than those in the study by Da Cunha and colleagues, similar values were observed for our test groups.

In the present study, strong correlations were observed between the insertion torque and ISQ for Brånemark System TiUnite Mk III implants. This finding is partially in agreement with previous reports,[26,27] although a direct comparison among the three studies was not possible, because they used different types of implant or different recipient sites. Friberg and colleagues[27] compared cutting torque and resonance frequency measurements of TiUnite Mk II implants placed in the maxilla. A significant relationship was observed, only in crestal third of the implants with no overall correlation, between placement torque and resonance frequency at implant placement. However, the strong correlations between the insertion torque values and resonance frequency values in the present study are in agreement with the previous report including 60 Brånemark System TiUnite Mk III implants placed in the anterior mandible.[28]

The fact that the primary stability at implant placement has important influence on the successful outcome of implant treatment is commonly accepted. Therefore, many attempts have been performed to achieve good primary implant stability.[18,29] The aim of the study by O'Sullivan and colleagues[18] was to analyze the mechanical performance and the primary and secondary stability characteristics of dental implants with 1° and 2° of taper when compared with the standard Brånemark design. They placed a total of 36 implants into tibia/femur of nine rabbits, and their results showed that an implant designed with 1° of taper results in a better primary stability compared with the standard Brånemark design. Another human cadaver study by

O'Sullivan and colleagues[29] compared the primary stability of five types of dental implants of varying geometry and surface topography. They concluded that the Mark IV tapered self-tapping implant revealed higher insertion torque and resonance frequency. The present study used only one type of implant (Mk III, TiUnite) and included two alternative preparation methods using thinner drills for implant sockets to enhance primary stability in the soft bone.

Under the guidelines of this study, the results suggest that using thinner drills for implant placement in the maxillary posterior region where bone density is relatively low may be a viable option to increase primary implant stability, which may result in better implant survival rates.

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