Original Article

Comparative evaluation of bone density after implant placement using cone-beam CT analysis in augmented versus non-augmented

ABSTRACT

Introduction: Dental implants are the most popular alternative to rehabilitation of missing teeth and oro-facial structures. The outcome of such procedures depends on various factors and most-importantly on the osseo-integation with the surrounding bone. The evaluation needs better visualization and evaluation using CBCT anaylsis and determination of HU, using an appropriate software.

Materials and Methods: This prospective cohort study was conducted at a tertiary level teaching hospital. A total of 129 cases were considered for the study after applying the laid down inclusion and exclusion criteria. Implant placement was done by single operator for placement of the endosteal implant (AB implant system Inc). All implants were placed using a minimum insertion torque of 25 Ncm as assessed by the physio-dispenser (NSK). The HU numbers were obtained at specified areas after immediate and 24 weeks post-operative period. The cases were divided into Augmented cases (Group I) and non-augmented cases (Group II). The augmented cases utilised Novabone putty bone graft.

Results: The study showed homogenous distribution of skewness and kurtosis in both the groups. The initial increase in augmented cases was due to increased radio-opacity of the graft. The HU values reached to near normal in both groups with no significant difference. The statistical test needed to analyze equality of variances, Levene's test was considered to ascertain the level of significance. Although the variance of subjects in group I is significantly different from that of group II, the test concludes that equal variances are not assumed. This prompts us to reject the null hypothesis at hand.

Conclusion: The use of augmentation as in this case with a bone putty show no significant improvement in improved bone quality at accelerated time. The study may need to be further augmented with research.

Keywords: Augmented, cone-beam CT, HU values, implant, osseo-density

INTRODUCTION

Dental implants are the most popular alternative for rehabilitation of missing teeth. The quality greatly influences the success of dental implant placement and the quantity of available bone. The studies conducted by Herrmann *et al*.[1] have suggested a direct correlation between higher failure rates in cases where the bone was considerably poor in quantity and quality. The fact that bone quality is an important variable in success is also supported by studies conducted by Esposito *et al*.,[2,3] which suggests that better stability favors implant osseo-integration. The implant's success depends on many factors, including the surgical technique, healing time, loading period, and more importantly bone quality and quantity. The term bone quantity is most often

Vishal Kulkarni, Hemant Gupta, Swati Gupta[1], Sirsendu Ghosh[2], Shubhankar Chaudhuri[1]

Department of Oral and Maxillofacial Surgery, Command Military Dental Centre, Lucknow, Uttar Pradesh, [1]Department of Prosthodontics, BBD CODS, Lucknow, Uttar Pradesh, [2]Department of Oral and Maxillofacial Surgery, Army Dental Centre (Research and Referral), New Delhi, India

Address for correspondence: Dr. Vishal Kulkarni, Department of Oral and Maxillofacial Surgery, Command Military Dental Centre, Lucknow, Uttar Pradesh, India.
E-mail: vishalkulkarni2aug@rediffmail.com

Received: 05 November 2023, **Revised:** 30 December 2023, **Accepted:** 05 February 2024, **Published:** 16 November 2024

Access this article online	
Website: www.njms.in	Quick Response Code
DOI: 10.4103/njms.njms_200_23	

How to cite this article: Kulkarni V, Gupta H, Gupta S, Ghosh S, Chaudhuri S. Comparative evaluation of bone density after implant placement using cone-beam CT analysis in augmented versus non-augmented. Natl J Maxillofac Surg 2024;15:448-53.

understood as the amount of bone (e.g., height and width of the alveolar crest) available for implant installation.[3-5] In contrast, bone quality is a far more comprehensive term with no clear definition, encompassing several aspects of bone physiology, degree of mineralization, and structural properties (architecture, morphology).[6-9] The importance of each aspect of implant treatment is still not fully understood.

Numerous studies report implant treatment outcomes using the classification of bone quality proposed by Lekholm and Zarb, which is mainly based on the subjective feeling of the surgeon during drilling.[10-12] Various approaches have been used to assess the quality of bone peri-operatively during implant procedures such as conventional radiography insertion torque resistance dual-energy X-ray absorptiometry digital image analysis ultrasound and computed tomography (CT). The choice of the technique depends on the operator choice and ease of usage.[13,14]

In recent years, the paradigm shift is toward applying the oral imaging field and concentration on measurements of X-ray absorption.[15] The use of CT has justified the requirements; nevertheless, the systematic use in clinical practice has been limited by concerns about high radiation doses. This can be negated by lowering the dose output of the scanner and usage of cone-beam CT (CBCT).[16,17]

MATERIALS AND METHODS

Study design

This prospective cohort study was conducted at a tertiary level teaching hospital from March 1, 2021 to September 30, 2023. Cases that were requiring replacement of missing teeth by dental implants were considered for the study. Inclusion criteria included adult patients in the age group of 18 to 65 years, who had consented to participate in the study. Exclusion criteria included patients with systemic illnesses that affected their bone metabolism, individuals with deleterious habits that could affect the outcome of implant stability (smoking, smokeless tobacco consumption, etc.), cases where anterior tooth replacement had to be done, and cases that failed for follow-up. A total of 129 cases were considered for the study after the cases fulfilled the laid-down criteria. The cases were evaluated by obtaining a CBCT immediately after implant placement (T0) and after 06 months of placement (T6).

Study variable and collection methods

The predictor variables were assembled into the following accompanying sets: demographics (age and gender), location (maxillary and mandibular), and osseo-integration (pre- and post-op Hounsfield unit values).

Study groups

The patients were divided into two groups. Group I includes those cases where no augmentation was done before or after implant placement. Group II includes cases where augmentation was done using bone graft. The graft material used in our study was NovaBone® putty.

Surgical procedure

Patients who met with the laid-down inclusion and exclusion criteria were taken up for implant placement after obtaining informed consent. The patients were prepped using a standard anti-septic protocol. Induction of local anesthesia was done using lidocaine with 1:80000 adrenaline (Septodont Inc). Pre-operative planning was done using CBCT. Implant placement was done by a single operator for placement of endosteal implant (AB implant system Inc®). All implants were placed using a minimum insertion torque of 25 Ncm as assessed by the physio-dispenser (NSK). The sulcus former was inserted with a torque of 15 Ncm as per the manufacturer's instruction. The flap was re-approximated using 3-0 Vicryl intermittent sutures.

Rehabilitation

The patient was taken up for rehabilitation 06 months post implant placement. The sulcus former was retrieved, and a standard abutment was placed at a torque of 25 Ncm. The impression was obtained using addition silicone material (Aquasil putty and light body, Dentsply). A metal-ceramic crown was fabricated and cemented using zinc phosphate cement.

Cone-beam CT analysis

A CBCT was obtained immediately and 06 months post-operatively. The measuring tool software was used, and a horizontal line was drawn on the most apical part of the implant. Then a line was determined from that line to the area of first bone contact on buccal, lingual, mesial, and distal aspects. Similar measurements were made on the crestal part of the implant also. The Hounsfield units (HU) were recorded at all times. Similar measurements and

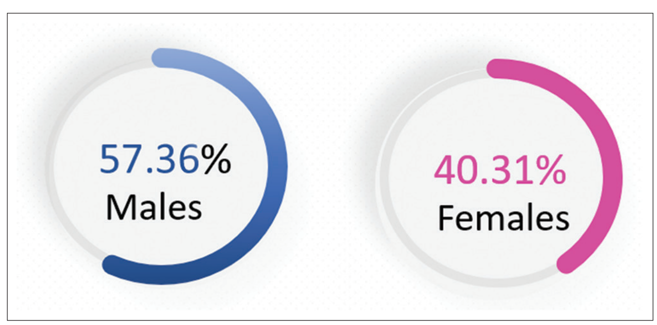

Figure 1: Demographic data

recordings were repeated for the 06 months post-operative period.

Ethical committee clearance obtained from Army Dental Centre (Research & Referral) dated: 30 Dec 23.

RESULTS

Demographic data

A total of 129 cases which were documented peri-operatively for dental implant placement were divided into two groups as per study criteria. In total, there were 74 (57.13%) males and 52 (40.31%) females. Group I (n = 44) includes the cases in which implant placement was augmented with bone graft, and Group II (n = 85) includes the cases where implant placement was done without any augmentation [Figure 1].

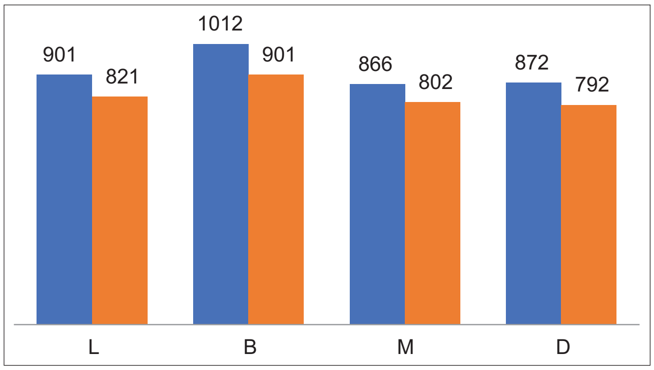

Figure 2: Intra-group variation of HU numbers in Group I

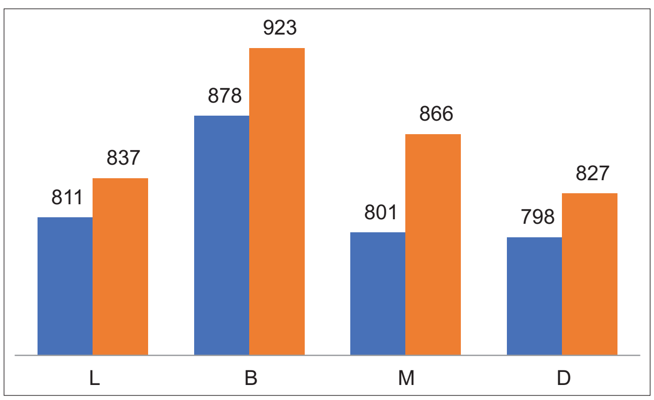

Figure 3: Intra-group variation in HU numbers in Group II

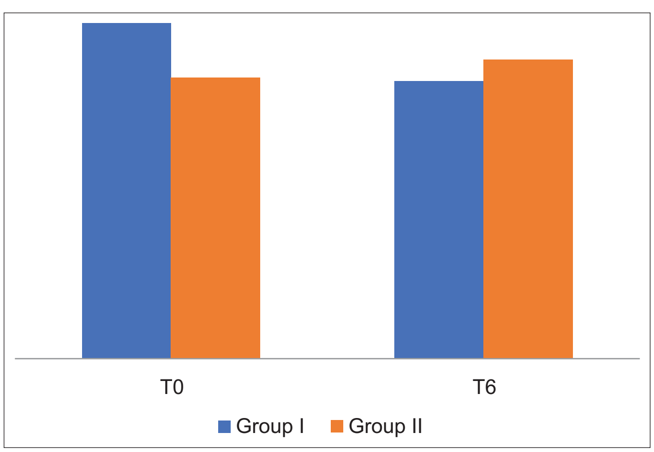

Figure 4: Intergroup variation in HU numbers (Collective)

Descriptive statistics

The minimum statistic of 7.01 and the maximum statistic of 9.14 was observed in Group I cases at T0. The skewness and kurtosis values were obtained, which suggested that the sample was homogeneous with no greater changes in standard deviation. Similar values were seen in T2. However, the slight increase in T0 (1012 ± 0.27) of HU values in augmentation cases may have been due to increased radio opacity after the graft had been placed. The values of HU of T2 (836 ± 1.84) in Group I approached near normal values, which is with probability that the graft had been incorporated into the site. The values with Group II had relatively lower values at T0 (848 ± 0.44) and later had increased HU values at T2 (901 ± 2.03) [Figures 2-4].

T-test

In order to formally test the means of population in Groups I and II, test of equality of means was used, which suggested a significant difference in the mean of the two groups. The data obtained and charted suggested that the sample was normally distributed among the population and also suggested that the variances were equal in distribution. The statistical test was needed to analyze equality of variances; Levene's test was considered to ascertain the level of significance. Although the variance of subjects in Group I is significantly different from that of Group II, the test concludes that equal variances are not assumed. This prompts us to reject the null hypothesis at hand.

DISCUSSION

CBCT is the most widely used technique to ascertain the level of ossification after implant placement. The evaluation of trabecular bone density is an important factor for achieving good osseo-integration and is a determinant to suggest that there is a strong implant–tissue interface, thus providing secondary stability. It also is responsible for a good biologic response and thus helps in mechanical support to the implant.[18,19] In the present study, the authors made use of CBCT to determine the level of bone formation. Original axial images were used without the application of external software.

The studies conducted by Norton Gamble[15] and Lindh *et al*.[20] and the definition of Taguchi *et al*.[21] made studies based on externally applied software or by defining the region of interest (ROI); however, the software in our studies was available in the system and we had not adjusted the volume manually.

The mean trabecular density as per studies conducted by Shapurian *et al*.,[22] suggests that the density of bone is equal at all areas of the jaw. This is in contradiction to the studies conducted by de Oliveira *et al*.,[23] where the studies mentioned that the trabecular bone density is 24% lesser in the anterior maxilla (canine and incisor sites) and in the posterior region (molar and pre-molar sites), the mean trabecular bone densities were 19% and 28% lower, respectively, than the corresponding total bone densities. The mean bone densities (HU) of the different bone types were not distributed anatomically as reported by Norton and Gamble.[15]

The authors conducted the measurements of such types to evaluate the treatment outcome of how long an interval between the first- and second-stage surgical procedures and loading is ideal; this is in sync with studies conducted by Jaffin *et al*. and Friberg *et al*.[5,18] According to Ericsson and Nilner,[9] an objective tool for the evaluation of bone tissue must be developed so that clinicians can more easily determine when to load an implant: immediately, earlier, or later.

A density scale, rather than absolute values, would be more flexible and accurate in helping the clinician categorize bone quality, as a diagnostic predictor. Such a scale, like the one proposed by Norton and Gamble, would accommodate the "gray zones" between the bone groups, which exist due to standard deviations. Quantitative parameters for bone type 4 were all values below 200 HU. This type of bone requires a meticulous surgical technique. Intermediary values between 200 and 400 HU represent conditions favorable for osseo-integration (bone types 2 and 3),[11] and values above 400 HU indicate a denser bone (bone type 1), which has a greater risk of overheating during implant installation[11]. The difficulty in differentiating between bone types 2 and 3 based on a subjective visual evaluation or quantitative bone density measurements in the present study was also found previously by authors.[24]

Information about bone density can be obtained pre-operatively by radiographic examination. The HU is a standardized scale for reporting reconstructed CT values.[22] For CBCT, however, there is no standard unit such as HU because no calibration has been conducted as yet; rather, the terms "CT number" and "density value" were used in previous studies.[25] Therefore, the bone density obtained by CBCT was expressed in "density value," in the present study. However, various studies do mention about HU numbers in CBCT also. For CBCT-derived density assessment, the rectangular area of each implant site was out-lined on the cross-sectional images, which had 1-mm slice intervals, and the mean bone density of the implant area was measured on each cross-section. An overall mean of all cross-sections (about 5 or 6 sections for an implant site) was used for radiographic density measurements of each implant site. The present study made use of software that was providing us with HU numbers; hence, the software was used for the study.

The earlier studies have reported some correlation between HU values derived from helical CT and implant stability parameters.[26] The use of CBCT in dental officers has led to a better understanding and also its utilization in research establishments in the conduct of studies such as ours, an observation to establish the correlation between bone density obtained by CBCT and primary implant stability needed to seem mandatory for future applications into clinical practice. However, there are only a few studies evaluating the correlation between density values derived from CBCT and implant stability parameters in the literature. Recently, Isoda *et al*.[27] reported significant correlations between bone density values derived from CBCT and implant stability in 18 fresh femoral heads of swine. The clinical study conducted by Song *et al*.[25,28,29] (2009) evaluated 61 implants placed in 20 patients and showed that the bone density obtained by CBCT showed a strong correlation with ISQ. However, the authors of the aforementioned study neither evaluate the correlations between density values and ITV nor assess the correlations about the different variables such as age, gender, and location. Fuster-Torres *et al*.[28] (2011) reported greater mean density values from CBCT in females and younger patients. However, in the present study, greater density values were observed in males and older patients consistent with previous reports in which CT was used. In terms of age distribution, the difference might be obtained due to increased bone resorption, and thus, more basal (corticalized) bone remaining resulted in higher bone density values in the older patients. The difference in the mean bone density value among genders might be associated with hormonal peculiarities in females and generally greater bone mass in males with the additional possible effects of the distribution of the interest sites and the age of the patients. Bone quality and quantity may differ about some clinical variables. Thus, evaluating the efficacy of density value from CBCT and its correlation with implant stability parameters in different clinical variables is crucial. In a recent study, statistically significant correlations between bone density from CBCT and ITV were observed in the anterior mandible, as well as bone density and ISQ values for men. In the present study, significant correlations were observed among density values derived from CBCT, insertion torque, and ISQ values in all clinical variables. The corresponding significant correlations may help clinicians to predict primary stability before implant insertion, which is associated with implant survival rates.

Limitations of the study using CBCT

While CBCT has proven to be a valuable tool for assessing bone formation and trabecular bone density post-implant placement, several limitations should be considered. One notable constraint is the absence of a standardized unit, such as Hounsfield units (HU) used in conventional CT, for reporting bone density in CBCT. The lack of calibration for CBCT makes it challenging to establish a universally accepted density scale, potentially affecting the comparability of results across studies.

Moreover, the reliance on software available within the CBCT system, as opposed to externally applied software, introduces a potential limitation in terms of precision and standardization. The variability in software capabilities and the absence of manual adjustment of the volume in our study may impact the accuracy of the measurements compared to studies utilizing external software or defining specific ROIs.

CONCLUSION

Our study sheds light on the crucial role of CBCT in assessing bone formation and trabecular bone density following implant placement. The use of CBCT, while offering valuable insights, comes with inherent limitations, particularly in the absence of a standardized unit for reporting bone density and the reliance on system-provided software.

Despite these challenges, our findings contribute to the growing body of knowledge surrounding implant stability and bone integration. The proposed density scale based on Hounsfield units (HU) provides a framework for categorizing bone quality, emphasizing the need for a nuanced understanding of bone characteristics to inform clinical decisions.

As we acknowledge the limitations related to CBCT, such as the lack of external software and the potential impact on precision, it becomes imperative for future research to address these constraints. A standardized approach to CBCT-derived density assessment, calibration procedures, and consideration of additional variables, including patient demographics, will enhance the reliability and applicability of findings across studies.

The study serves as a stepping stone toward refining methodologies and tools for assessing bone density in clinical practice. As the field continues to evolve, the integration of CBCT into implant dentistry research offers promising avenues for improved implant outcomes. The complexities highlighted in this study underscore the ongoing need for innovation, standardization, and comprehensive investigation in the realm of CBCT-based bone density assessment.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Herrmann I, Lekholm U, Holm S, Kultje C. Evaluation of patient and implant characteristics as potential prognostic factors for oral implant failures. Int J Oral Maxillofac Implants 2005;20:220-30.
2. Esposito M, Hirsch JM, Lekholm U, Thomsen P. Biological factors contributing to failures of osseointegrated oral implants. (II). Etiopathogenesis. Eur J Oral Sci 1998;106:721-64.
3. Esposito M, Hirsch JM, Lekholm U, Thomsen P. Biological factors contributing to failures of osseointegrated oral implants. (I). Success criteria and epidemiology. Eur J Oral Sci 1998;106:527-51.
4. Friberg B, Jemt T, Lekholm U. Early failures in 4641 consecutively placed Branemark dental implants: A study from stage 1 surgery to the connection of completed prostheses. Int J Oral Maxillofac Implants 1991;6:142-6.
5. Jaffin RA, Berman CL. The excessive loss of Branemark fixtures in type IV bone: A 5-year analysis. J Periodontol 1991;62:2-4.
6. Lindh C, Nilsson M, Klinge B, Petersson A. Quantitative computed tomography of trabecular bone in the mandible. Dentomaxillofac Radiol 1996;25:146-50.
7. Lindh C, Obrant K, Petersson A. Maxillary bone mineral density and its relationship to the bone mineral density of the lumbar spine and hip. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2004;98:102-9.
8. Rosenquist B, Grenthe B. Immediate placement of implants into extraction sockets: implant survival. Int J Oral Maxillofac Implants 1996;11:205-9.
9. Ericsson I, Nilner K. Early functional loading using Branemark dental implants. Int J Periodontics Restorative Dent 2002;22:9-19.
10. Lekholm U, Zarb GA. Patient selection and preparation. In: Branemark, P-I, Zarb GA, Albrektsson T, editors. Tissue Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence; 1985. p. 199-209.
11. Lindh C, Petersson A, Rohlin M. Assessment of the trabecular pattern before endosseous implant treatment: Diagnostic outcome of periapical radiography in the mandible. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1996;82:335-43.
12. Beer A, Gahleitner A, Holm A, Tschabitscher M, Homolka P. Correlation of insertion torques with bone mineral density from dental quantitative CT in the mandible. Clin Oral Implants Res 2003;14:616-20.
13. Chloel L, Duboeuf F, Bourgeois D, Briguet A, Lissac M. Trabecular alveolar bone in the human mandible: A dual-energy x-ray absorptiometry study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003;95:364-70.
14. Jager A, Radlanski RJ, Taufall D, Klein C, Steinhofel N, Doler W. Quantitative determination of alveolar bone density using digital image analysis of microradiographs. Anat Anz 1990;170:171-9.
15. Norton MR, Gamble C. Bone classification: An objective scale of bone

density using computerized tomography scan. Clin Oral Implants Res 2001;12:79-84.
16. Frederiksen NL. Diagnostic imaging in dental implantology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1995;80:540-54.
17. Guerrero ME, Jacobs R, Loubele M, Schutyser F, Suetens P, van Steenberghe D. State-of-the-art on cone beam CT imaging for preoperative implant placement planning. Clin Oral Investig 2006;10:1-7.
18. Friberg B, Sennerby L, Roos J, Johansson P, Strid CG, Lekholm U. Evaluation of bone density using cutting resistance measurements and microradiography. Clin Oral Implants Res 1995;6:164-71.
19. Meredith N. Assessment of implant stability as a prognostic determinant. Int J Prosthodont 1998;11:491-501.
20. Lindh C, Petersson A, Klinge B, Nilsson M. Trabecular bone volume and bone mineral density in the mandible. Dentomaxillofac Radiol 1997;26:10.
21. Taguchi A, Tanimoto K, Ogawa M, Sunayashiki T, Wada T. Effect of size of region of interest on precision of bone mineral measurements of the mandible by quantitative computed tomography. Dentomaxillofac Radiol 1991;20:25.
22. Shapurian T, Damoulis PD, Reiser GM, Griffin TJ, Rand WM. Quantitative evaluation of bone density using the Hounsfield index. Int J Oral Maxillofac Implants 2006;21:290-7.
23. de Oliveira RCG, Leles CR, Normanha LM, Lindh C, Ribeiro-Rotta RF. Assessments of trabecular bone density at implant site on CT scan. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;105:231-8.
24. Trisi P, Rao W. Bone classification: Clinical-histomorphometric comparison. Clin Oral Implants Res 1999;10:1-7.
25. Song YD, Jun SH, Kwon JJ. Correlation between bone quality evaluated by cone-beam computerized tomography and implant primary stability. Int J Oral Maxillofac Implants 2009;24:59-64.
26. Turkyilmaz I, Sennerby L, McGlumphy EA, Tözüm TF. Biomechanical aspects of pri- € mary implant stability: A human cadaver study. Clin Implant Dent Relat Res 2009;11:113-9.
27. Isoda K, Ayukawa Y, Tsukiyama Y, Sogo M, Matsushita Y, Koyano K. Relationship between the bone density estimated by conebeam computed tomography and the primary stability of dental implants. Clin Oral Implants Res 2012;23:832-6.
28. Fuster-Torres MA, Penarrocha-Diago M, Penarrocha-Oltra D, Penarrocha-Diago M. Relationships between bone density values from cone beam computed tomography, maximum insertion torque, and resonance frequency analysis at implant placement: A pilot study. Int J Oral Maxillofac Implants 2011;26:1051-6.
29. Turkyilmaz I, Tözüm TF, Tumer C, Ozbek EN. Assessment of correlation between computerized tomography values of the bone, and maximum torque and resonance frequency values at dental implant placement. J Oral Rehabil 2006;33:881-8.