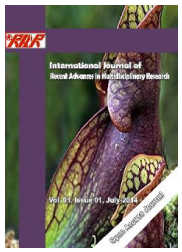

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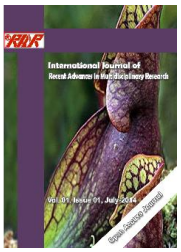

Research Article

VOLUMETRIC ANALYSIS OF MANDIBLE FOR DENTAL IMPLANTS IN CBCT IMAGES

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ABSTRACT

Aim: Osteoporotic patients require particular attention during implant placement, and bone density has been established as a simple method to assess local bone quality and primary implant stability. This study aimed to examine and significantly correlate the relationship of local bone density volumetric analysis as assessed by the CBCT in a group of osteopenic and osteoporotic patients.
Materials and Methods:A total of 30 patients were included in the study. The mandibular Second premolar region was choosen as the site of investigation to prevent Variability in surgical implant placement technique in different locations affecting bone mineral density. Partially edentulous female patients between 51 years and 60 years of age who were scheduled to receive implant placement were recruited for the study. Ultrasound bone densitometer was used in the study to divide the three groups (Group I-Normal patients), (Group II-Osteopenic patients), (Group III-Osteoporotic patients). CBCT (Master Series 3D Dental Imaging) was used for preoperative evaluation of the jaws for each patient.Materialise's Interactive Medical Image Control System (MIMICS) was used to process stacks of 2D images from CBCT. 3-matic software was used to combine CAD tools with pre-processing (meshing) capabilities like the anatomical data coming from the segmentation of medical images (from Mimics). All data were collected and analyzed using SPSS 16.0 for windows version. Student T Test and One way ANOVA were calculated between groups to determine the difference in bone mineral densities.
Results: A total of 30 females participated in the the study. The mean bone density for group I, group II, group III was 60364.36 mm^3, 51789.65 mm^3, 40468.62 mm^3 respectively (Table 1,2,3). The difference in mean bone density in all three groups were statistically significant ($p<0.05$). (Table 4).
Conclusions: The results of this study suggest that bone density values (as measured in mm^3) obtained from preoperative cone beam computed tomography (CBCT) examination may be an objective technique for preoperative evaluation of bone density. This tool when combined with MIMICS software can serve as diagnostic tool for predicting implant success, thus providing the implant surgeon with an objective assessment of bone density, especially were poor bone quality is suspected.

INTRODUCTION

Clinical success in implant practice is influenced by both the volume (quantity) and the density (quality) of bone at the implant site. Bone quality and quantity differ from site to site and from patient to patient. Factors that are important to the success of dental implant treatment include material, biocompatibility, and design issues related to the dental implant; patient factors such as general health, local tissue health, and quality and quantity of bone; and procedural issues such as insertion torque (IT), timing of loading, healing duration, biomechanical loading, and prosthetic design. The quality of the host bone is among the most important factors in implants success, and implants placed in poor quality bone are more likely to fail compared to those placed in optimal quality bone even in a good clinical expertise (**Martin *et al.*, 2009**). Although poor implant site bone quality is associated with greater risk of implant failure, the effect of compromised body bone mineral density on an implant failure is not a definitive. Osteoporosis was defined by world health organization working group according to the bone mineral density measurement made with dual – energy x -ray obsorptiometry (DEXA). It is defined as the bone density T-score at or below 2.5 standard deviation (T-score) below normal peak values for a young adult. The Canadian multicentre osteoporosis more recently

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showed that the prevalence of osteoporosis among 6646 subject was 18.8 % and 3.9% for women and men respectively (**Brunski, 1992**). A few studies have reported on the success rate of dental implants in osteoporotic patients. A retrospective review of 192 female patients 50 years of age are older at the time of implants placed who received a total of 646 implants showed that the osteopenic or osteoporotic patients are more likely to suffer from implant failures compared to patients with normal bone mineral density (**Jaffin and Berman, 1991**).

A special attention to a surgical technique has been recommended for the osteoporotic patients. For example, soft tissue dissection should be limited to the extent necessary to avoid compromised periosteal blood flow. The size of the last surgical drill should be decreased in relation to the implant diameter to improve primary stability. Also it would appear that the larger implant diameter may let to improved peri implant stress distribution in such a patient (**Engquist *et al.*, 1988**). Thus, it is evident that osteoporotic patient require particular attention to their implant site bone quality as an indication of prognosis and may require modified surgical technique.

An established method of assessing implant site bone quality is by means of Cone Beam computed tomography (CBCT), bone density, as expressed in Hounsfield unit (HU) , obtainable from CBCT, has been used to illustrate the quality of bone. For example, bone density at implant site was calcified according to Lekholm and Zarb; type I bone was correlated with a CT bone density above 400 HU. Type II and III bone were estimated to the between 200 and 400 HU, and type IV bone exhibited less than 200 HU (**Friberg *et al.*, 1991; Stach and Kohles, 2003; Alsaadi *et al.*, 2008**).

AIM: The purpose of this study to examine and significantly correlate the relationship of local bone density volumetric analysis as assessed by the CBCT in a group of normal, osteopenic and osteoporotic patients.

MATERIALS AND METHODS

This study was conducted in the Department of Prosthodontics, Crown and Bridge, and Implantology, Tagore Dental College and Hospital, Chennai, India. Written informed consent was obtained from those who agreed to participate for performing radiographic examination. All patients are routinely screened with CBCT before Implant treatment.

Inclusion Criteria for patients are

- Between 50 years to 60 years of age.
- Partially Edentulous in Mandibular arch only
- At least 7mm of alveolar bone height in premolar region
- Only female patients.

Exclusion Criteria

- Poor quality radiographs
- Patients under radiation therapy
- Not sufficiently healthy for minor elective dental surgery
- Uncontrolled diabetes or any other metabolic diseases that affect nutritional status

Considering both the inclusion and exclusion criteria for this study. A total of 30 patients were included in the study. The patients were divided into three groups. None of the patients have been reported to possess pathological signs or symptoms or clinical evidence of pathosis as revealed by their clinical examination and reported in their files. The mandibular second premolar, first molar region was chosen as the site of investigation to prevent Variability in surgical implant placement technique in different locations affecting bone mineral density. Partially edentulous patients between 51 years and 60 years of age who were scheduled to receive implant placement were recruited for the study. Preoperative radiographic evaluation the most common means of measuring bone density involves a simple test called Dual Energy X-RAY Absorptiometry (DXA) (**Holahan *et al.*, 2011**)

Ultrasound bone densitometer was used in the heel to measure the bone mineral density. Measuring procedures apply gel to a heel and position the foot, align cylinder then press START key. Within 10 seconds, result is printed out from onboard printer. While CM-200 is connected to PC with optional data management software installed, remote operation and management of database for measured data is available. (Figure 1) The interpretation of ultrasound bone densitometer is as follows

Diagnosis	T-score Relative to Bone Mineral Density
Normal	BMD value with in SD, (T-score-1)
Osteopenia	BMD value more than 1 SD below the mean , (-1 > T-score >-2.5)
Osteoporosis	BMD value 2.5 SD or more below the mean , (T – score ≤ _2.5)
Severe Osteoporosis	BMD value 2.5 SD or more Below the mean with fragility fracture, (T-score ≤-2.5)

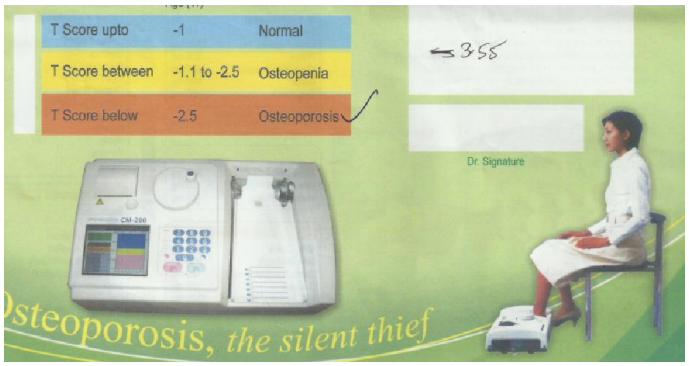

Fig. 1. Ultrasound bone densitometer

CBCT (Master Series 3D Dental Imaging) was used for preoperative evaluation of the jaws for each patient. CBCT scanning of the maxilla or mandible was performed to assess the bone density in Hounsfield units. Materialise's Interactive Medical Image Control System (MIMICS) was used to process stacks of 2D images from numerous formats including: Dicom 3.0 format, BMP, TIFF, JPG and raw images.3-matic software was used to combine CAD tools with pre-processing (meshing) capabilities like the anatomical data coming from the segmentation of medical images (from Mimics). We call it Anatomical CAD (Figure 2, 3).

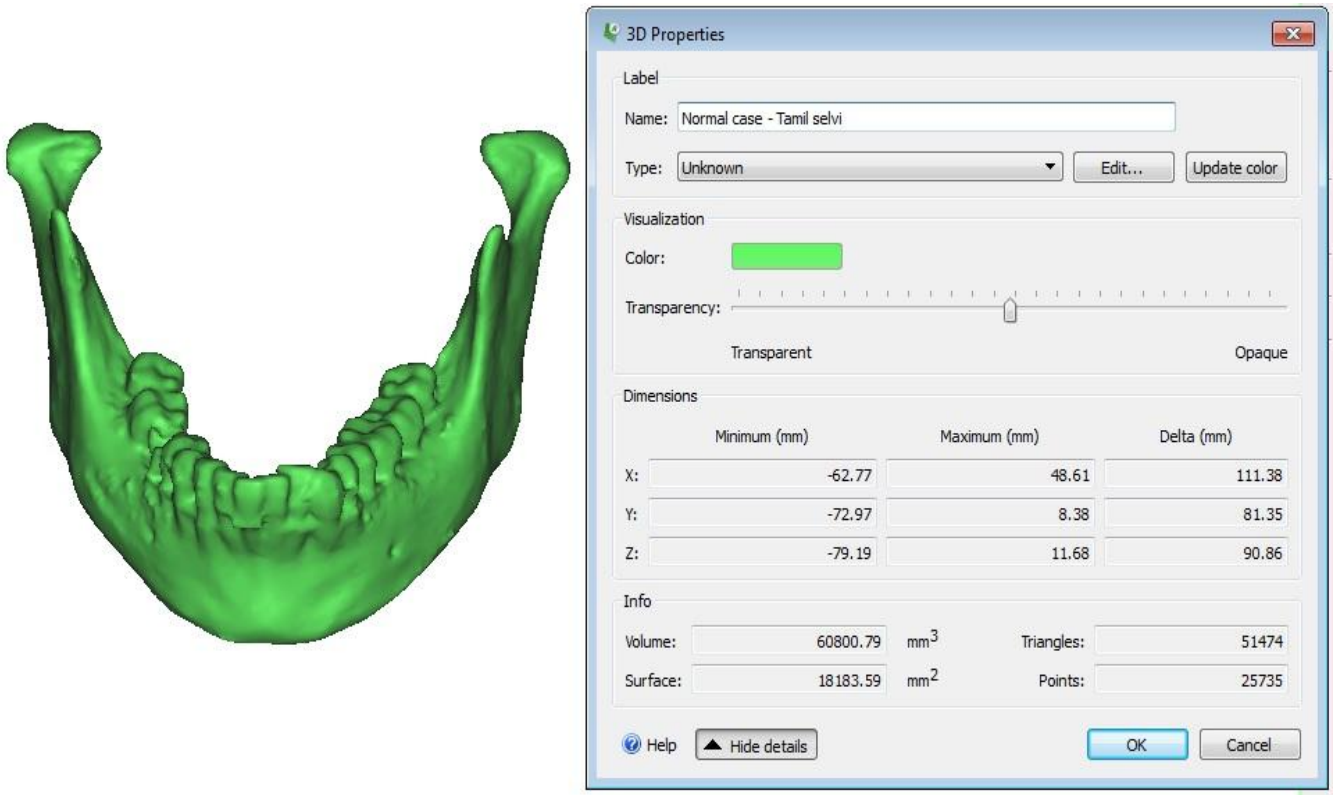

Fig. 2. Bone density measurement in mm^3using MIMICS software in normal patients

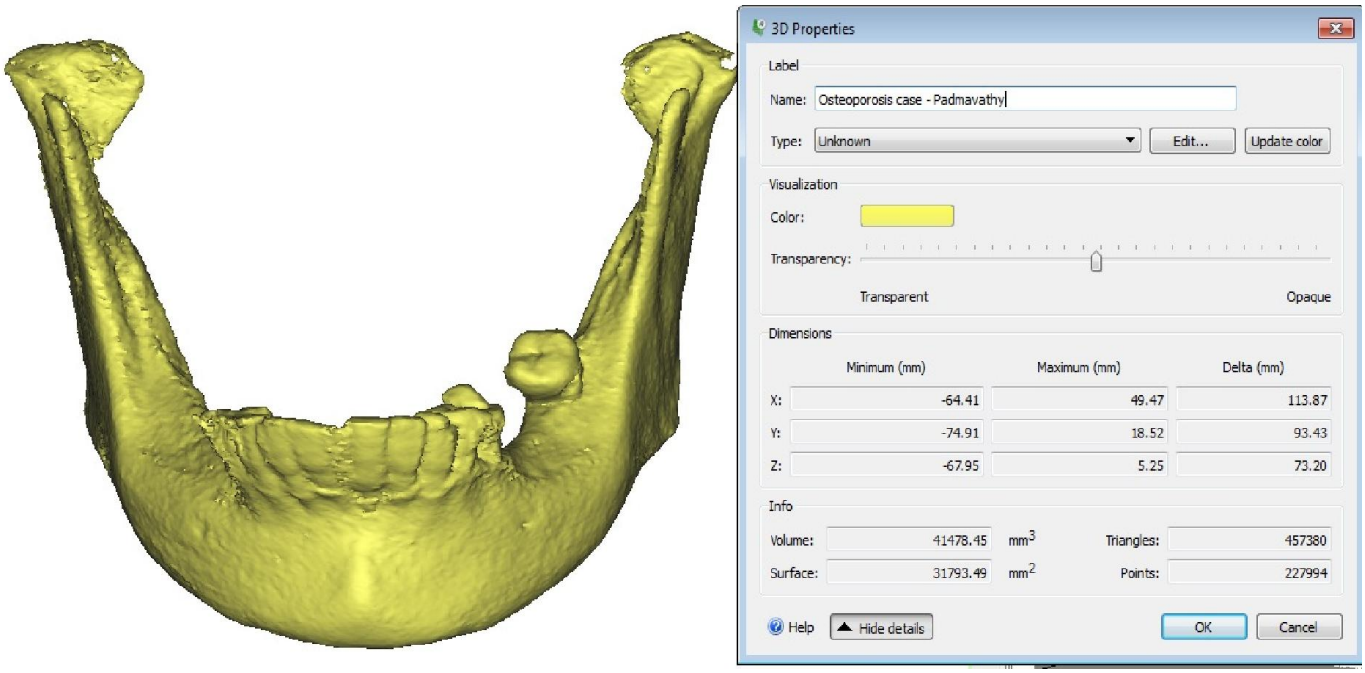

Fig. 3. Bone density measurement in mm^3using MIMICS software in Osteoporotic patients

Statistical Analysis:All data were collected and analyzed using SPSS 16.0 for windows version. Student T Test and One way ANOVA were calculated between groups to determine the difference in bone mineral densities.

Level of significance @ 5% (0.05)

Power @ 90%

RESULTS

A total of 30 females participated in the study. The mean age of subjects was 56.4±2.2 yrs. The mean bone density for group I, group II, group III was 60364.36 mm^3, 51789.65 mm^3, 40468.62 mm^3respectively (Table 4). The difference in mean bone density in all three groups were statistically significant ($p<0.05$).

Table 1. Distribution of bone density for Group 1(Normal patients), Group II (Osteopenic patients), and Group III (Osteoporotic patients)

S.No	Bone density volume(mm^3)		
	Group I (Normal)	Group II (Osteopenic)	Group III (Osteoporosis)
1	58775.81	51334.11	39995.47
2	57881.96	51556.94	40834.78
3	59345.33	50441.56	40229.31
4	58689.43	50213.87	39143.33
5	60800.79	52970.05	41478.45
6	61665.43	51657.81	42997.92
7	60667.24	52567.11	42222.66
8	61449.33	52490.42	38995.77
9	62589.55	52886.36	39230.33
10	61778.81	51778.29	39558.21

Table 2. Mean bone density for various groups

Parameter	Mean	SD
Group I (normal)	60364.36	245.69
Group II (osteopenic)	51789.65	227.57
Group III (osteoporotic)	40468.62	201.16

DISCUSSION

One important parameter for predicting the long term success of dental implant therapy is bone density at the future implant site. Thus a thorough understanding of how osteoporosis affects dental implant treatment planning, procedures, and prognoses cannot be neglected. Osteoporosis is a multifactorial pathologic condition that affects the entire skeleton and is characterized by low bone mass in combination with micro architectural changes particularly in cancellous and cortical bone. Osteoporosis is the end result of bone loss and is the most common type of the metabolic disorders of bone. The condition is characterized by reduced bone mass and increased risk of fracture (fragility). Osteoporosis occurs when bones lose minerals, such as calcium, more quickly than the body can replace thinner and less dense so that, eventually, even a minor bump or accident can cause serious fractures. These are known as fragility or minimal trauma fractures. Osteoporosis, which literally means ‘’porous bone”, is a disease that reduces the density and quality of bones. As the bones become more porous and fragile, the risk of fracture is greatly symptoms until the first fracture occurs (**Richards *et al.*, 2007; Holahan *et al.*, 2008; Slagter *et al.*, 2008; Tsolaki *et al.*, 2009; Reginster and Burlet, 2006**).

Based on the World Health Organization (WHO) definition of Osteoporosis, **Melton (1995)** estimated that 30% of post-menopausal white women in the United States have osteoporosis. Asthmatics, other lung patients, or rheumatoid arthritis patients treated with high dose corticosteroids lose trabecular bone and experiences fractures, as do patients with Cushing’s syndrome. Other disorders including renal failure and certain types of cancer cause bone loss, along with chronic use of drugs such as anti convulusants, anticoagulants, excess alcohol, and too much thyroid medication. Young women who experience amenorrhea due to athletic activity, weight loss, stress, nutritional deficiency, bulimia, anorexia nervosa, or those who have early natural or surgical menopause and do not take estrogen replacement therapy lose bone. Not all of the patients in these groups will develop osteoporosis. However, most of them will lose some bone and thus increase their long-term risk for fractures (**Becker *et al.*, 2000; WHO 1994**). Therefore to diagnose such conditions different types of bone mineral density tests are available,

- Ultra sound
- DEXA (Dual Energy X-ray Absorptiometry)
- SXA (single energy x-ray absorptiometry)
- PDXA (Peripheral Dual Energy X-ray Absorptiometry)
- RA (Radiographic Absorptiometry)
- DPA (Dual Photon Absorptiometry)
- SPA (Single Photon Absorptiometry)
- MRI (Magnetic Resonance Imaging)
- QCT (Quantitative Computed Tomography)
- Laboratory tests

Dual energy x ray absorptiometry (DXA) measures the bone by computing the difference in absorption of low energy photons and high energy photons by the mixture of soft tissue and bone in the path of the beam and can generate a 2-dimnensional Image for localization of the bone. While DEXA uses x rays, the radiation dose is less than during a chest x ray. Each patient’s bone density is plotted against the”norm” for a healthy young adult or against age matched control data. A Radiologists or other physician then interprets the data and creates a concise repot on the status of the patient’s bone density. DEXA systems have recently received US Food and Drug Administration (FDA) clearance.The accuracy of bone mineral density testing is high, ranging from 85% to 99%.DEXA is the most accurate and widely available BMD test. The interpretation of individual DXA studies is not difficult. However, the responsibility of a physician overseeing a densitometry service lies more in familiarity with the conceptual context as it relates to the role of densitometry in and the management of osteoporosis (**Song *et al.*, 2009**)

CBCT is an imaging technique that shows human anatomy in cross sections and provide a three dimensional dataset that can be used for image reconstructions and analysis in several planes or three dimensional settings. CBCT provides relatively low dose imaging with high isotropic spatial resolution acquired

with a single gantry revolution. CBCT parameters can be optimized to produce isometric voxels as small as 150 × 150× 150 μm^3 at the isocenter. CBCT also provides information about tissue attenuation. Direct Hounsfield unit measurements for bone density may be used to examine bone quality. CBCT accurately measures bone density. CBCT density measurements method can be used as to separate the trabecular bone from the cortical shell and the posterior elements of vertebrae. CBCT density measurements have shown superiority to other modalities using CT for density measurements (**Holahan *et al.*, 2011; Richards *et al.*, 2007; Song *et al.*, 2009**)

3-matic is unique software that combines CAD tools with pre-processing (meshing) capabilities. To do so, it works on triangulated (STL) files and as such it is extremely suitable for organic/freeform 3Ddata, like the anatomical data coming from the segmentation of medical images (from Mimics). We call it Anatomical CAD. Import anatomical data in 3-matic to start doing real Anatomy, like thorough 3D measurements and analyses, design an implant or surgical guide, or prepare the mesh for finite element modeling. Since 3-matic can import CAD data, but also do reverse engineering of anatomical data to CAD data (http://uc.materialise.com/mimics).

Materialise's Interactive Medical Image Control System (MIMICS) is a software tool for visualizing and segmenting medical images (such as CT and MRI) and rendering 3D objects. The software comes in two editions: Research and Medical. Only the medical edition may be used as a medical device, within the limits described in the intended use statements of these editions. Mimics may be used to load and process stacks of 2D images from numerous formats including: Dicom 3.0 format, BMP, TIFF, JPG and raw images. Once images are processed, they can be used for numerous applications of Engineering on Anatomy including measuring, designing, modeling and 3D printing. Mimics Base enables users to control and correct the segmentation of medical images such as CT and MRI-scans. A trained software user can easily and accurately define 3D models for visualization and/or production. The software also provides a way to remove image artifacts that may appear due to a patient's metal implants (http://uc.materialise.com/mimics). In the present study, CM-200 a bone densitometer using ultrasound to measure speed of sound (SOS) in the heel was used. As it does not use radioactive X-ray, the measurement is safe and it is perfect for primary screening of children and pregnant women. Because the size and weight are so small, it can be carried to any place for measurement. Advantages of using ultrasound bone densitometer in the present study are, Safe and speedy measurement, High correlativity to DEXA, Ultra-compact and Ultra-light weight, Easy-to-view Color LCD Display, Data management on PC available (http://paltechsystems.com). As discussed earlier, clinical results have not shown that osteoporotic patients are more likely to suffer from implant failure than normal patients. It cannot be said that osteoporosis per se is a contraindication to dental implant therapy but many have advocated that particular attention be paid to local bone conditions, which affect bone quality and implant stability. The present study revealed that bone density as represented by mm^3 obtained from Interactive Medical Image Control System (MIMICS) software is statistically significant in a group of osteopenic and osteoporotic patients when compared with normal patients. It is difficult to compare the present study with previous studies, as many of these studies on bone density were from CT and cadaver specimens, so the results are not equivalent (**Turkyilmaz *et al.*, 2007; de Oliveira *et al.*, 2008; Turkyilmaz *et al.*, 2009; Ikumi and Tsutsumi, 2005; Beer *et al.*, 2003**).

Norton and Gamble reported strong correlation between bone density and subjective bone quality scores. Those authors used simplant software (Columbia scientific) for CT analysis, while the present study uses 3matic and MIMICS software for CBCT analysis (**Norton and Gamble, 2001**). The mean bone density values observed here are slightly lower than those reported by other studies (**Turkyilmaz *et al.*, 2006; Turkyilmaz *et al.*, 2007**). Shapurian *et al.* reported mean bone density in posterior mandible as SD: 321 in a group of normal patients, where as present study reveals bone density as slightly, lower SD: 246. This difference may be attributed to age of patients and implant sites in posterior mandible (**Shapurian *et al.*, 2006**). Thus local bone density, which may be indicated with CBCT and MIMICS software as shown in the present study may be a more appropriate indicator when predicting implant prognosis. However more scientific evidence is necessary to substantiate this hypothesis.

STUDY LIMITATIONS

1. Bone density in present study was measured only at premolar region of mandible
2. Only partially edentulous patients were selected for the study
3. Only female patients were included in the study.
4. Bone density was measured only in elder group of patients and not in younger age groups

FUTURE PROSPECTIVES

1. Further studies with a large sample of patients are needed to better understand the relationship between age, gender and bone density in both partially as well as completely edentulous patients
2. Further studies needed to measure the amount of stress, strain and displacement (Insertion Torque) in the three types of bone condition on various forces and estimating the average force to be applied while placing an implant with an implant wrench.

Conclusion

The results of this study suggest that bone density values (as measured in mm^3) obtained from preoperative cone beam computed tomography (CBCT) examination may be an objective technique for preoperative evaluation of bone density. This tool when combined with MIMICS software can serve as diagnostic tool for predicting implant success, thus providing the implant surgeon with an objective assessment of bone density, especially were poor bone quality is suspected.

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