Cone-beam computed tomography assessment of bone using grayscale values in patients with diabetes mellitus. A case–control observational study

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Abstract:

Background: The density of cortical and cancellous bone is a key reason for implant anchorage which might be severely affected during diabetes. Aim: The aim of the study was to establish the role of cone-beam computed tomography (CBCT) using grayscale values in determining bone density in different jaw sites and in comparing the values in healthy with diabetic patients. Materials and Methods: Bone densities in 322 possible implant sites in healthy and diabetic patients were evaluated using NewTomGiano CBCT machine. Cross-sections obtained were assessed for bone densities in terms of Hounsfield Unit on different sites using New Net Technologies software version 6.1. Statistical Analysis: Data were statistically analyzed using SPSS software (version 19.0). Results: Age-wise cortical and cancellous bone densities were compared and no statistical significance was obtained. Gender-wise bone density was compared and significant results were found in males. Jaw-wise bone density was compared and was found to be significantly high in the mandible. The mean cortical bone density in control group was 1608.572 (±380.36), whereas in diabetic group was 1395.368 (±296.97), and the mean cancellous bone density in control was 906.918 (±185.40) and in diabetic was 559.868 (±128.16). Teeth wise in cortical bone significant values were found at premolar region (P = 0.046) and in cancellous bone significant values were found at canine and premolar region (P = 0.012) and highly significant values were found at molar region (P = 0.001). Conclusion: CBCT unveils a distinct pattern of cortical and cancellous bone density. A high degree of concordance between different regions of the mouth in cortical and cancellous bones was obtained in different study groups. CBCT could be used for bone density analysis.

Key words: Bone density, cone-beam computed tomography, diabetes mellitus, grayscale values, Hounsfield units, implant planning

INTRODUCTION

Bone quality and quantity during dental rehabilitation of patients in the anterior and posterior regions of jaws plays a key role in prognosis of the treatment.[3] It is also associated with success and failure of implant treatment.[3] Systemic diseases such as diabetes mellitus influence the bone quantity and quality of the jaws which is before well-documented in the literature.[7-8] The use of cone-beam computed tomography (CBCT) for bone density evaluation of these future implant sites in these patients may play an important role during their treatment planning.[3] The stability of implants in these patients is also influenced by the site of placement of implant which may vary from the anterior or posterior maxillary and mandibular jaws.[9] This is also influenced by the placement of implant into cortical or cancellous part of these bones.[3,10] Studies have reported that thin cortical bone is often associated with the risk of implant failures.[11] The present study was undertaken to assess bone density using CBCT in the anterior and posterior maxilla and mandible in normal people and to compare it with bone density in subjects with an earlier history of controlled diabetes mellitus. A case–control observational study. J Indian Soc Periodontol 2020;24:560-6.
or uncontrolled diabetes mellitus. The study also evaluated differences in bone densities in cortical and cancellous bones in normal people and compared them with subjects with diabetes.

**MATERIALS AND METHODS**

A total of 322 patients with partial or complete edentulous sites in the maxilla and mandible who reported to a Diagnostic Centre in Delhi National Capital Region (NCR) were examined as a part of dental implant preassessment planning. The patients who gave consent for undergoing CBCT scan and agreed to the use of their scans for research purpose were included in the study. These 322 prospective implant sites were further categorized into two different groups, Group I (control) with 164 sites. Patients in this group were free from any systemic illness and had complete and partial edentulous sites. Group II classified as diabetic group with patients having complete or partial edentulous sites with 158 sites in this group. Patients in Group II had glycosylated hemoglobin (HbA1C) value of 6.5% and above. The diabetic status of the patient was determined in accordance with American Diabetes Mellitus Association where HbA1C values determined the collective glycemic history of the preceding 3 months of the patient.\(^2\) The CBCT scans of the patient were grouped into three age groups that is 31–50 years, 51–70 years, and above 70 years and gender wise as males and females. The cortical and cancellous bone quality was assessed with respect to the age and gender of the patient in each group at each site.

Qualitative measurements of bone densities were obtained for four regions of the proposed implant site in the cortical and cancellous bone in the buccal, palatal/lingual, crestal, and apical in terms of Hounsfield Unit (HU) displayed by New Net Technologies (NNT) Software (version 6.1). QR Sri, Company, Verona, Italy.

The scans were selected according to the following inclusion criteria:

1. Patients of both the sexes with age ranging from 31 to 75 years
2. Patients with either fully or partly edentulous spaces
3. Patients not taking any drug that may influence the bone quality
4. Patients without any systemic disease except diabetes mellitus (with HbA1c values of 6.5% and above)
5. High-quality reconstructed images.

Patients were asked to stand in a vertical place, stabilized with a headband and chin support, and monitored to make sure that they remained motionless throughout the scan. After the head place was stanardized and located with vertical and horizontal reference lines. All high-resolution CBCT images were obtained by the NewTom Giano unit (QR SRL Company, Verona, Italy) with a 8 cm × 5 cm field of view (FOV) and exposure parameters of kVp = 90, mAs = 14.64, and exposure time = 3.6s. The image acquisition protocol consisted of 360° rotation with an X-ray tube and a flat panel amorphous silicon detector. The CBCT volumes obtained were displayed with a 0.250-mm thickness.

The images obtained in Digital Image Communication in Medicine (DICOM) format were transferred to a separate workstation and the measurements were done in a quiet windowless room with proper lighting conditions. The images were viewed on HP Envy Spectre x360 Convertible 13-ac059tu, 13.3 inch diagonal HD Brightview light-emitting diode-backlit Display, Core i7 7500U processor (Hewlett-Packard Company, 71004 Böblingen, Germany) at a 1920 × 1080 resolution, and measurements were done in axial and coronal cross-section views. Raw data were reconstructed using CBCT software NNT viewer software version 6.1, QR Sri, Company, Verona, Italy. This system has a smart beam intelligent program that mA and kVp are selected automatically depending on body size.

The DICOM file of a new CBCT scan was opened in NNT Viewer software. Multiplanar mode tool was selected to create a new panoramic image. A new multiplanar tool was selected to draw a curved line along the respective maxillary and mandibular arches in the middle of the alveolar bone to get a new generated panoramic image which was further saved to acquire cross-sections at different regions in the maxilla and mandible. Four regions of interest (ROIs) were determined in each maxillary and mandibular arch for edentulous residual bone corresponding to the maxillary central incisor, maxillary canine, maxillary premolar, and maxillary molar regions on the right and left sides. Multiple cross-sections were created perpendicular to each ROI.

Cross-sections showing the greatest height and width of the residual ridge, among the entire cross-sectional image (ROI), were selected for implant placement. Insert “Implant Tool” was selected from the tools available within the software. After the choice of proper implant with the desired height and width in a particular ROI, the virtual implant was placed at the selected site and angle of implant placement was modified according to the available bone. Similar cross-sections were generated for all ROIs in the maxilla and mandible [Figure 1]. Where bone height and width were deficient, measurements and profile tracing were performed without any virtual implant stimulation [Figures 2 and 3].

Observers were allowed to use twofold magnification and change screen brightness. With the zooming tool available within the software, the cross-sectional image was zoomed in for easier visualization of the desired area. The “Trace Profile” tool was selected from the tools available in the software to measure the greatest and least bone density of the sites in HUs as displayed by NNT Software (version 6.1). The same was repeated for different aspects, i.e., crestal, buccal lingual/palatal, and apical aspects in the cortical bone. Furthermore, the “Trace Region” tool was selected to measure the minimum, maximum, standard deviation, and mean density of the cancellous bone as displayed by NNT Software (version 6.1) where the virtual implant was placed for different ROIs and different values were obtained for different regions of the cortical bone and cancellous bone [Figure 4]. Bone quality was assessed in the planned implant site using voxel gray values and corresponding HU values were obtained by the software mentioned above.

All images were observed and evaluated by two independent observers, both experienced maxillofacial radiologists blind to the details of age and sex of the subjects. All the measurements were taken twice by the same observers, and
was obtained using SPSS software (version 19.0) (IBM Inc. Chicago, Illinois, USA) and descriptive statistical methods were used by Chi-square test with 5% level of significance to determine the relationship of Group I and Group II with demographic variables such as age and gender. Independent $t$-test was used to determine the significant difference between the means in the two unrelated groups. Mann–Whitney U-test, ANNOVA test, and Kruskal–Wallis H-test have been used to find the significance of study parameters on an ordinal scale between two or more than two groups. The obtained data were statistically processed to get a correlation between the mean value of bone density in cortical and cancellous bones of jaws.

**RESULTS**

Age-wise mean cortical and cancellous bone densities were compared among different age groups and no statistical significance was obtained ($P = 0.642$, $P = 0.593$, respectively) [Table 1]. Males showed higher cortical and cancellous bone densities when compared with females with statistically significant differences ($P = 0.047$ and $P = 0.040$, respectively) [Table 2]. A very highly statistically significant difference was obtained in the mean cortical bone density of the mandible as compared to the maxilla ($P < 0.001$). Furthermore, a statistically significant difference was obtained in the mean cancellous bone density of the mandible as compared to the maxilla ($P = 0.048$) [Table 3].
Table 2: Gender-wise comparison of cortical and cancellous bone density in the control group

| Bone Density          | Male     | SD       | Female   | SD       |
|-----------------------|----------|----------|----------|----------|
| Cortical bone density | Mean     | Minimum  | Mean     | Minimum  |
|                       | 559.26   | 626.30   | 591.50   | 605.01   |
|                       | SD       | 2092.66  | 284.38   | 1066.12  |

Table 3: Jaw-wise comparison of cortical bone density between the maxilla and mandible in the control group

| Bone Density          | Maxilla  | SD       | Mandible | SD       |
|-----------------------|----------|----------|----------|----------|
| Cortical bone density | Mean     | Minimum  | Mean     | Minimum  |
|                       | 545.18   | 549.76   | 559.86   | 569.36   |
|                       | SD       | 229.78   | 209.28   | 290.46   |

The mean cortical bone density in Group I (control) was 1608.572 (±380.36), and in Group II (diabetic), it was 1395.368 (±296.97); however, the results were statistically nonsignificant. The mean cancellous bone density in Group I was 906.918 (±185.40), and in Group II, it was 559.868 (±128.16), and the results were statistically very highly significant ($P < 0.001$) [Tables 4a and b]. The mean cortical bone density was found to be more in the premolar region in both the control and diabetic groups with a statistically significant value ($P = 0.046$). The mean cancellous bone density showed a highly statistically significant value ($P = 0.001$) in the molar region, in both control and diabetic groups, whereas canine and premolar regions showed statistically significant values in different groups ($P = 0.012$) [Tables 5a and b].

**DISCUSSION**

The use of dental implants for rehabilitation of edentulism has gained popularity in recent years. A number of factors such as age, gender, and systemic status of the patients along with implant placement procedures play a key role in the successful completion of implant therapy. Osseointegrated implants are used with a high rate of success. Osseointegration affects primary implant stability and is directly related to patient choice, treatment planning, implant design, suitable implant materials, good surgical technique, and restorative treatment. Factors that negatively influence this process include poor bone quality and measure of available bone and underlying systemic factors such as metabolic bone diseases. Bone density plays a pivotal role in the success of implant therapy. Preoperative radiologic assessment of bone density using various densitometric techniques has been before established in the literature. Currently, with the advent of CBCT and its dispersion in different fields of dentistry, the era of digital imaging has revolutionized. Images obtained from CBCT provide highly accurate fine anatomic details with high resolution and much less radiation exposure compared to computed tomography (CT).

HU’s in CT is considered as a gold standard to assess bone density. However, due to high radiation exposure, the use of CT in the maxillofacial region is limited. The present knowledge on HU in CBCT images provides limited information and acknowledges lacunae between HU and gray scale (voxel values) obtained from present CBCT systems. Literature has reported that this deficiency is due to the degree of X-ray attenuation shown in CBCT systems as gray scales (voxel value), whereas in CT, it is represented as HU which is assigned to each pixel in that image and represents the density of the tissue. Furthermore, in another study conducted by Turkylmaz et al., it was found that it is not possible to prevent the scattered radiation entering the two-dimensional CBCT detector when compared with multi-slice CT which uses an anti-scatter grid and further prevents beam hardening effect, partial volume averaging, and under sampling, thus resulting in changes in gray values of CBCT. Other factors that contribute to differences in density include projection data discontinuity-related effect, differences between CBCT devices in terms of exposure parameters (kVp, mA, exposure time, and voxel size), changes in the volume of the FOV, and changes in the relationships of size and position between the FOV and the object. The accuracy of CBCT to detect variations in bone density and its reliability and comparability of grayscale values.
values with HU in the determination of bone density needs to be carefully assessed and evaluated.

The systemic status of the patient undergoing implant therapy needs further monitoring as they might alter the bone quality. Delayed wound healing and increased postoperative infection are seen in both types of diabetic patients due to microvascular damage, diminished bactericidal capacity, and deficient leukocyte chemotaxis.\[14\] Most of the clinical and laboratory studies have reported that bone formation around dental implants may be incomplete and delayed, and bone-to-implant contact might be impaired. It is found that newly formed bone is immature and poorly organized with diminished mechanical properties,\[9,11\] Such complications affect the success of implant therapy, Olson \textit{et al.} suggested in their study that the duration of diabetic mellitus is also associated with implant failure.\[11\]

The present study analyzed bone densities of proposed implant sites in both the jaws. To determine bone density in this study, a software-based analysis of images obtained from CBCT was performed.

In our study, age-wise comparison of bone density in control group revealed to be highest in the age group of 51–70 years for cortical bone and above 70 years for cancellous bone. The findings were not completely in accordance with a study conducted by Lee \textit{et al.} who found that cortical bone thickness increases with age and is more in older age group than young people; however, cancellous bone thickness was more in young people than older age group.\[15\] The mean cortical density was significantly more among males in comparison to females ($P = 0.047$); however, the mean cancellous density was significantly more among females in comparison to males ($P = 0.040$). Similar results for cortical density were found by Cassetta \textit{et al.} who found higher values of thickness and density in males than females, with a statistically significant difference ($P \leq 0.05$).\[16\] On the other hand, dissimilar results were found by Lee \textit{et al.} who found in their study that even cancellous bone density is more in males than females.\[15\] As stated by Cassetta \textit{et al.} and Usui \textit{et al.}, the gender difference in cortical and cancellous bone density, recorded, might be expected because males have higher bite forces than females.\[16,17\]

The mean cortical and cancellous bone densities in the mandible were found to be more than maxilla and the results were statistically very highly significant ($P < 0.001$) and significant ($P = 0.048$). Similar results were found by Cassetta...

| Table 4a: Mean cortical bone density in the study population |
|------------------------------------------------------------|
| Group | Control | Diabetic | Independent $t$-test | $P$ |
|-------|---------|----------|----------------------|-----|
| Mean  | SD      | Mean     | SD                   |     |
| Cortical mineral density | 1608.5729 | 380.36117 | 1395.3681 | 296.97964 | 1.391 | 0.180 (NS) |
|       | SD – Standard deviation; NS – Not significant; $P$ – Probability value |

| Table 4b: Mean cancellous bone density in the study population |
|---------------------------------------------------------------|
| Group | Control | Diabetic | Independent $t$-test | $P$ |
|-------|---------|----------|----------------------|-----|
| Mean  | SD      | Mean     | SD                   |     |
| Cancellous bone density | 906.9182 | 185.40311 | 559.8681 | 128.16152 | 4.806 | <0.001 (VHS) |
|       | SD – Standard deviation; VHS – Very highly significant; $P$ – Probability value |

| Table 5a: Teeth-wise mean cortical bone density in different groups |
|------------------------------------------------------------------|
| Cortical mineral density | Group | Control | Diabetic | $P$ |
|--------------------------|-------|---------|----------|-----|
| Mean                     | SD    | Mean    | SD       |     |
| Incisor                  | 1638.4000 | 368.50 | 1595.75 | 298.47 | 1.00 (NS) |
| Canine                   | 1701.0481 | 257.64624 | 1516.9026 | 262.35602 | 0.835 (NS) |
| Premolar                 | 1748.94 | 616.10 | 1527.7644 | 271.61663 | 0.046 (S) |
| Molar                    | 1507.49 | 524.12 | 1497.5714 | 369.75602 | 1.00 (NS) |
| S – Significant; NS – Nonsignificant; SD – Standard deviation; $P$ – Probability value |

| Table 5b: Teeth-wise mean cancellous bone density in different groups |
|------------------------------------------------------------------|
| Cancellous bone density | Group | Control | Diabetic | $P$ |
|-------------------------|-------|---------|----------|-----|
| Mean                    | SD    | Mean    | SD       |     |
| Incisor                 | 1003.40 | 385.56 | 770.35088 | 249.730631 | 0.151 (NS) |
| Canine                  | 869.96015 | 358.774948 | 480.39889 | 139.428630 | 0.012 (S) |
| Premolar                | 986.89 | 797.95 | 570.89231 | 223.947270 | 0.012 (S) |
| Molar                   | 801.78585 | 418.538700 | 537.80236 | 145.856527 | 0.001 (HS) |
| HS – Highly significant; S – Significant; NS – Nonsignificant; SD – Standard deviation; $P$ – Probability value |
et al. who found the mandible to be both thicker and higher in density than the maxilla with a statistically significant difference \( P \leq 0.05 \).  

In another study by Chen et al. in either the Taiwanese or the U. S. cohorts, the mean cancellous bone density in the mandibular sites (anterior, premolar, and molar) was significantly higher than at the corresponding maxillary sites \( P < 0.001 \).  

The mean cortical density was higher in Group I in comparison to Group II; however, the results were nonsignificant, whereas the mean cancellous density was higher in Group I as compared to Group II and the results were very highly significant \( P < 0.001 \). Hence, an inverse relationship was established between mean cancellous bone density and HBA1c. Nemtoi et al. found a significant inverse relationship between bone mineral density and HbA1c. The authors concluded that the bone mineral density of cortical and cancellous bone decreased with an increase in HbA1c values in diabetics. In another study by Nevins et al., it was observed that the bone-implant contact was significantly reduced for diabetic compared with control animals, but the quantity of bone formation was similar. However, dissimilar results were found by a study conducted by Jolly et al. who found no significant changes in bone density between the controlled diabetic and nondiabetic subjects. The authors concluded that diabetes should not be regarded as an absolute contradiction for implant-supported prosthesis therapy, but rather a relative contradiction related to the stability of diabetic blood sugar level. Balshi and Wolfinger also reported in their study a success rate of implant placement and stability in 94.3% in diabetic patients.

Statistically significant values of mean cortical bone density in Group I and Group II was obtained only for premolars \( P = 0.046 \). However, for cancellous bone, statistically significant differences were obtained for canine and premolar \( P = 0.012 \) and highly significant values were obtained for molars \( P = 0.001 \). Hence, it can be interpreted that the mean cortical bone density in the premolar region was significantly less in the diabetic group than the control group. Furthermore, the mean cancellous bone density in canine, premolar, and molar regions was significantly less in the diabetic group and control group. A similar study was conducted in the past by Jolly et al. where bone density values were obtained and compared for controlled diabetics and nondiabetic subjects for anterior and posterior regions in the maxilla and mandible and the results obtained were statistically significant.

The clinical significance of this study is to provide a future guide to the clinicians for assessing bone density at the surgical sites, thereby helping them in radiological preassessment of the osteotomy sites before treatment. Therefore, the bone density values obtained from CBCT can be analyzed in terms of bone quality.

**CONCLUSION**

Implant therapy continues to provide a consistent treatment for partial or complete edentulism. Preassessment of implant site using CBCT plays a pivotal role in the determination of prognosis of this therapy. The bone density of the implant site plays one of the key factors for the stability of implants. Although several drawbacks have been reported with CBCT in terms of its usefulness in bone density assessment, still, many studies have shown linear relationships between HU in CT and grayscale values in CBCT useful for bone density assessment. Therefore, grayscale values obtained from CBCT should be taken into consideration as a predictor for bone assessment and for the successful survival of implants.

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**Conflicts of interest**

There are no conflicts of interest.

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