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Correlation of bone dimension to radiographic bone density at potential implant sites in mandibular edentulous molar region by using cone beam computed tomography - A cross sectional hospital based study

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Abstract

The aim of the study is to correlate the bone dimension to radiographic bone density at potential implant sites in mandibular edentulous molar region by using Cone Beam Computed Tomography. 150 CBCT scans of patients were selected. The bone height and Buccolingual width of bone was measured at potential implant site. Virtual implant was placed following guidelines and bone density was measured at four buccal, lingual, apical, coronal points. The bone dimensions and density was correlated in three groups (group A, B, C). It was found that the statistically significant positive correlation between two variables i.e. bone height with bone density at lingual intersection

point and bone width with bone density at center intersection point from Group A, B & C at 5% level of significance. It was also seen that, there were statistically significant strong positive correlation between bone height with bone density at buccal intersection point; bone width with bone density at buccal intersection point; bone width with bone density at lingual intersection point; from Group A, B & C at 1% level of significance. There is a significant correlation of bone dimension to radiographic bone density at potential implant sites in the mandibular molar region. Thus, it can be stated that for atrophic mandibular residual ridges the bone density values are at lower side, whereas residual mandibular ridges with minimal resorption shows relatively better score of grey scale values.

Keywords: Dental Implant, Bone Density, Correlation, Bone Dimension, Cone Beam Computed Tomography.

Introduction

One of the goals of modern dentistry is to restore the patient to normal function. Responding to this ultimate goal, dental implants are an ideal option for people in good general oral health who have lost a tooth (or teeth) due to periodontal diseases, an injury, or some other reasons.[1] Dental implants not only provide a more efficient solution, but also give a long-term survival rate.[2] The use of dental implants for the oral rehabilitation of fully and partially edentulous patients has greatly broadened the scope of clinical dentistry.[3] The quality and quantity of bone tissue is closely related to the implant success.[4] All treatments involving dental implants are based on the concept that the implants are attached directly to the surrounding bone tissue and appropriately transmit the incoming occlusal forces to the alveolar bone. The trabecular bone surrounding the implant plays an important role in dispersing the stress.[5] The volume of bone available and quality of the bone are highly associated with the type of surgical procedure and the type of implant, and both of these factors play a vital role in the success of dental implant surgery.[6]

Bone quality affect the success of dental implants.[7] Bone Mineral density(BMD) is determined by the amount of mineral mass contained in a certain volume of a structure, described in units of mass per area (in bidimensional images) or per volume (in tridimensional images), where only mineral content is considered.[8] Height of bone was measured as the vertical distance along an axis parallel to the midsagittal plane from the alveolar crest to the closest anatomical landmark.[9] Higher failure seems to be associated with the implants in which the surgeon observes a poor degree of bone mineralization or limited bone resistance by tactile assessment while drilling.[10] It is very important for the dentist to have proper knowledge about bone density so as to come up with a proper surgery plan; hence an in depth understanding of bone density and its variations has become an important issue to evaluate.[11]

Radiographic imaging, which is relatively easy and noninvasive, is used to measure bone quality. Bone quality is a comprehensive term that encompasses bone physiology, degree of mineralization, morphology and the type of trabecular pattern.[12] CBCT offers comprehensive radiographic information for the structural and qualitative analysis of the bone and studies reported that the Hounsfield unit derived from CBCT voxel values exhibited strong correlation with actual bone density parameters.[13] CBCT is regarded as the most efficient three-dimensional imaging modality for dental implants treatment.[14] It provided superiority to show anatomical structures compared to panoramic radiographs. It supplies a very valuable information in all multiple planes compared to CT with a low radiation dose (15 times) and short time of scanning.[15] CBCT is

commonly used in dentistry because it involves a relatively low dosage of radiation exposure in patients, requires only a short measurement time, is low cost, and produces images of relatively high resolution.[16]

Study regarding the relationship between cortical thickness and bone density at the dental implant site has been performed. These high correlations between the cortical thickness and bone density variable may afford the clinician to estimate the intraoperation bone density during the implant placement from the preoperative CBCT information.[17] Bone density is essential in choosing the type of implant, and it decreases with age. Investigating the bone density of prospective dental implant sites is crucial both for choosing the implant type and for choosing the drilling procedure best suited to ensure implant stability and osseointegration.[18] Preoperative bone evaluation could prevent some complications such as perforation and injury to vital structures which can subsequently affect the success of dental implant. Moreover, satisfied alveolar bone volume, thickness, and height are important to achieve esthetically pleasing dental implant restorations.[19] In a recent studies CBCT was used preoperatively to ensure that the alveolar bone ridges were of satisfactory dimensions and density and to determine the correct length and width of the implant.[20]

Rationale of The Study

Assessing bone height, width, and quality is fundamental for successful dental implant placement, It demands require precise planning. These parameters directly influence implant stability, osseointegration, and long-term outcomes. Previous literature has discussed the bone thickness and bone density at potential implant before and after implant surgery and its effect on implant stability; we rarely found the studies which have addressed the effect of bone dimension on bone density at potential implant sites. Correlating bone height, width, and density in mandibular molar implant sites is essential for optimizing implant stability, biomechanical load distribution, and long-term success. These parameters collectively influence surgical planning, implant selection, and risk mitigation in a region characterized by anatomical complexity and variable bone quality. Since the quantity and quality of the bone at the residual alveolar ridge is a key factor for the success of implant surgery it will be important to know whether a small sized residual alveolar ridge also has a reduced bone density and vice versa. After reviewing the literature, a study gap appears to exist in the area where pre-operative bone density and bone dimensions are not correlated for a possible implant site. Therefore, the aim of the study is to correlate the bone dimension to radiographic bone density at potential implant sites in mandibular edentulous molar region by using Cone Beam Computed Tomography.

Materials and Methods

This cross-sectional radiographic study was conducted in the Department of Oral Medicine and Radiology after obtaining the approval from the institutional ethical committee (I.E.C. number – OMR/RP/01/23).

The present study included CBCT scans of patients; who were referred for pre-treatment assessment and were selected from the database of the department of oral medicine and radiology. 150 such CBCT scans fulfilling the inclusion criteria were then selected. CBCT scans of patients within the age range of 18 to 50 years, depicting missing mandibular first molar and showing radiographic evidence of remodeling at the region of interest were included in the study.

CBCT scans showing Low image quality, artifacts, partial image, showing bony pathology in region of interest like cyst, tumors, malignancy, developmental

defects, inflammatory, infectious diseases, scans with impacted teeth in the area of interest, radiographic evidence of trauma and surgery also scans of patients with systemic diseases affecting bone metabolism like diabetes, osteoporosis, Medication-related osteonecrosis of the jaw (MRONJ), Paget's disease, hyperparathyroidism, etc. as elicited by patient's history/clinical data were excluded.

CBCT machine (ORTHOPHOS XG 3D manufactured by SIRONA, Germany with volume 8cm X 8cm). The data was visualized using, SIDEXIS Version 1.9.4497.23802(ID7) software.

Methodology

150 CBCT scans of patients were selected from the database of the department. A perpendicular line was drawn from the most superior point of the alveolar crest till superior margin of the inferior alveolar nerve. This distance is considered as the bone height. (figure 1 - Line A). A perpendicular line was drawn from buccal cortical plate to the lingual cortical plate 2mm apical to alveolar crestal bone at implant site. This distance was considered as the Buccolingual width of bone. (figure 1 - Line B)

The virtual implant was placed at a potential implant site in a prosthodontically driven way. (Figure 2). These rules were followed while implant placement. The DICOM file of the selected implant site was imported into the proprietary software (3DIM VIEWER) to determine the Hounsfield unit values at various sites. Bone density in Hounsfield unit was measured at intersection point of virtual implant margin and bone. The buccal, lingual, apical and central intersection points were considered for bone density measurements. (Figure 3)

All the data was grouped into 3 categories as Group A (vertical height less than 8mm and Buccolingual width less than 4mm), Group B (vertical height 8mm to 10 mm and Buccolingual width 4mm to 6 mm) and Group C (vertical height greater than 10 mm and Buccolingual width greater than 6 mm). The measured bone dimension and radiographic bone density at potential implant site in mandibular molar region was correlated. The selected data was tabulated and then it was subjected to further statistical evaluation.

Data will be collected, tabulated, formulated and will be analyzed using SPSS statistical software 17.0 version. Level of significance is taken as 5% for this research and hence statistical test will be considered significant if P value is equal to or less than 0.05. Pearson correlation test was used to determine the correlation between bone dimension (bone height and bone width) and bone density among each group.

Results

Table 1. It was found that, there were statistically significant positive correlation between two variables i.e. bone height and bone density at apical intersection point with 0.510* correlation coefficients value for Group A at 5% level of significance. However, for the other remaining variables mentioned in the above table there were no any statistically significant correlation found.

Table 2. In group B there was not any statistically significant correlation found between bone dimension and radiographic bone density.

Table 3. In group C there was not any statistically significant correlation found between bone dimension and radiographic bone density.

Table 4 It were found that, there were statistically significant positive correlation between two variables i.e. bone height with bone density at lingual intersection point and bone width with bone density at center intersection point having 0.166* and 0.165* correlation

coefficients value respectively from Group A, B & C at 5% level of significance.

It was also seen that, there were statistically significant strong positive correlation between two variables i.e. bone height with bone width; bone height with bone density at buccal intersection point; bone width with bone density at buccal intersection point; bone width with bone density at lingual intersection point; 0.752**; 0.234**; 0.324**; 0.246** correlation coefficients values respectively from Group A, B & C at 1% level of significance.

Discussion

Radiographic bone density reflects quality of trabecular and cortical bone, which directly impacts implant stability and osseointegration. CBCT allows for precise assessment of bone density through Hounsfield Unit (HU) measurements, providing insights into both cortical and trabecular characteristics. Bone dimensions, including height and width, are essential for defining the feasibility of implant placement. Adequate vertical bone height ensures sufficient anchorage for implants, reducing the risk of implant failure owing to insufficient apical support.

For implant results to be successful, bone density and dimensions must interact. The significance of dimensions analysis in conjunction with density evaluation is shown by the fact that bone height and width are better indicators of post-implant accomplishment than over-all bone density. According to buccal-lingual plate correlation, molar areas require consistent stress distribution during loading, which is ensured by symmetry in the buccal and lingual cortical densities. Because apical and central sections may take different trabecular densities, site-specific changes must be evaluated for the best implant placement.

Table 1 shows the Correlation of bone dimension (bone height, bone width) to radiographic bone density at buccal, lingual, apical, central intersection points at potential implant site in mandibular molar region by using CBCT in Group A. The strongest correlations are observed between adjacent points (e.g., buccal and lingual, apical and central), indicating that spatial proximity may play a role in shared bone density characteristics in Group A. Bone height is positively correlated with points like apical density but negatively correlated with surface points like buccal and lingual densities, suggesting that taller bone structures might have denser cores rather than surfaces.

Strong Correlation between **Buccal and Lingual Density** and Their strong interdependence indicates that both sides should be considered together during implant planning to ensure balanced support. **Apical and Central Density**, their positive correlation highlights the importance of assessing deeper regions for implant stability, especially in cases requiring longer implants. The findings emphasize the need to focus on deeper areas (apical and central) meant for assessing bone quality when considering implant placement in the edentulous mandibular molar region.

Table 2 shows the Correlation of bone dimension (bone height, bone width) to radiographic bone density at buccal, lingual, apical, central intersection points at potential implant site in mandibular molar region by using CBCT in Group B. In Group B, bone height showed no significant correlations with density at any intersection point, contrasting with Group A (where height associated with apical density). Similar to Group A and studies, bone width lacked significant correlations with density. The strong positive Buccal-Lingual bone density Correlation (r=0.421∗∗r=0.421∗∗) aligns with studies showing interdependent density patterns in

buccal/lingual regions. It suggests balanced cortical support is essential for long-term outcomes.

The strong positive Apical-Centre bone density Correlation (r=0.389∗∗r=0.389∗∗) mirrors Group A (r=0.544∗∗r=0.544∗∗) and reflects the trabecular-cortical transition in deeper regions, which is critical for implant anchorage. The apical and central regions' correlation (r=0.389∗∗ r=0.389∗∗) highlights their importance for primary stability. A significant positive weak Central-Lingual Correlation is found (r=0.341∗r=0.341∗) which contrasts with Group A's nonsignificant results.

Table 3 shows the Correlation of bone dimension (bone height, bone width) to radiographic bone density at buccal, lingual, apical, central intersection points at potential implant site in mandibular molar region by using CBCT in Group C. Bone height and width show minimal or no significant correlations with radiographic bone density across all intersection points. Bone width has no positive correlations with buccal (r=0.056r=0.056), lingual (r=0.103r=0.103), apical (r=0.140r=0.140), and central (r=0.191r=0.191) points. A strong positive correlation (r=0.449∗∗r=0.449∗∗) between buccal and lingual densities suggests interdependence between these regions. This finding is consistent with Group B results (r=0.421∗∗r=0.421∗∗) and corroborates prior studies emphasizing the importance of balanced cortical support for implant stability.

The strong positive correlation between apical and lingual densities (r=0.298∗r=0.298∗) highlights the potential structural relationship between these deeper regions. Similar findings in Group A (r=0.399r=0.399) suggest that apical density is critical for implant anchorage, particularly in areas with reduced cortical support. The central point shows no significant correlations with other parameters, indicating variability in its density relative to surrounding regions. This result contrasts with Group A, where the central-apical correlation was stronger (r=0.544∗∗r=0.544∗∗).

Table 4 shows Correlation of bone dimension to radiographic bone density at potential implant site in mandibular molar region by using CBCT in all Groups. Strong positive correlation between bone height and bone width (r=0.752∗∗ r=0.752∗∗), indicating that taller bone assemblies in the mandibular molar region tend to also be wider. This makes straight with anatomical patterns where robust bone volume supports both vertical and horizontal dimensions. Bone height shows weak but significant correlations with buccal (r=0.234∗∗r=0.234∗∗) and lingual (r=0.166∗r=0.166∗) cortical density, while bone width correlates more strongly with buccal (r=0.324∗∗r=0.324∗∗) and lingual (r=0.246∗∗r=0.246∗∗) regions. This suggests that wider bones may better accommodate buccal-lingual cortical plate thickness, critical for primary implant stability. Buccal vs. Lingual density. Strong correlation (r=0.538∗∗r=0.538∗∗), reflecting symmetrical bone remodeling patterns in the mandible. This symmetry is clinically relevant for ensuring uniform stress distribution during implant loading.

Apical vs. Centre Density Moderate correlation (r=0.343∗∗r=0.343∗∗), likely tied to trabecular bone architecture in deeper regions. However, weaker correlations between apical density and bone height/width (r=0.019r=0.019 and r=0.073r=0.073, nonsignificant) highlight the independence of apical bone quality from superficial dimensions. This data underscores the importance of multidimensional CBCT analysis for optimizing implant outcomes in the posterior mandible.

Limitations and Future Scope of Study

A key limitation of this study is its small sample size. In future similar multicentric studies with greater sample size should be done.

Conclusion

Thus, within the scope of present study it can be concluded that:

1. There is a significant correlation of bone dimension to radiographic bone density at potential implant sites in the mandibular molar region. Thus, it can be stated that for atrophic mandibular residual ridges the bone density values are at lower side, whereas residual mandibular ridges with minimal resorption shows relatively better score of grey scale values.
2. There was significant correlation between bone height with bone density at lingual intersection point, apical intersection point and buccal intersection point among all three groups.
3. There was significant strong positive correlation between bone width with bone density at central intersection point, buccal intersection point and lingual intersection point among all three groups.

In addition to this, there is a significant difference in mean bone density at apical intersection points between group A and group B, group A and group C.

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Legend Tables and Figure

Table 1: Correlation of bone dimension (bone height, bone width) to radiographic bone density at buccal, lingual, apical, central intersection points at potential implant site in mandibular molar region by using CBCT. (Group A)

GROUP A	Bone Height	Bone Width
Buccal	-0.262	-0.029
Lingual	0.058	-0.075
Apical	0.510*	-0.040
Centre	0.338	-0.055

*. Correlation is significant at the 0.05 level (2-tailed).

Table 2: Correlation of bone dimension (bone height, bone width) to radiographic bone density at buccal, lingual, apical, central intersection points at potential implant site in mandibular molar region by using CBCT. (Group B)

GROUP B	Bone Height	Bone Width
Buccal	-0.089	-0.093
Lingual	-0.077	0.009
Apical	0.153	-0.082
Centre	0.148	-0.099

*. Correlation is significant at the 0.05 level (2-tailed).

Table 3: Correlation of bone dimension to radiographic bone density at potential implant site in mandibular molar region by using CBCT. (Group C)

GROUP C	Bone Height	Bone Width
Buccal	-0.194	0.056
Lingual	-0.075	0.103
Apical	-0.041	0.140
Centre	-0.135	0.191

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4: Correlation of bone dimension to radiographic bone density at potential implant site in mandibular molar region by using CBCT. (All Groups Combined)

Overall	Bone Height	Bone Width
Buccal	0.234**	0.324**
Lingual	0.166*	0.246**
Apical	0.019	0.073
Centre	0.076	0.165*

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

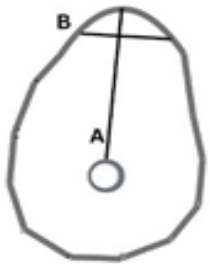

Figure 1: Bone Height(A) And Bone Width(B)

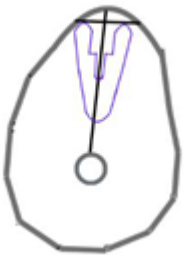

Figure 2: Virtual Implant Placement

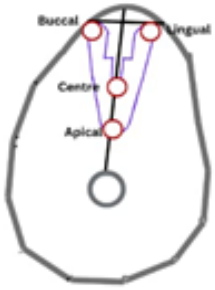

Figure 3: Bone density at four intersection points

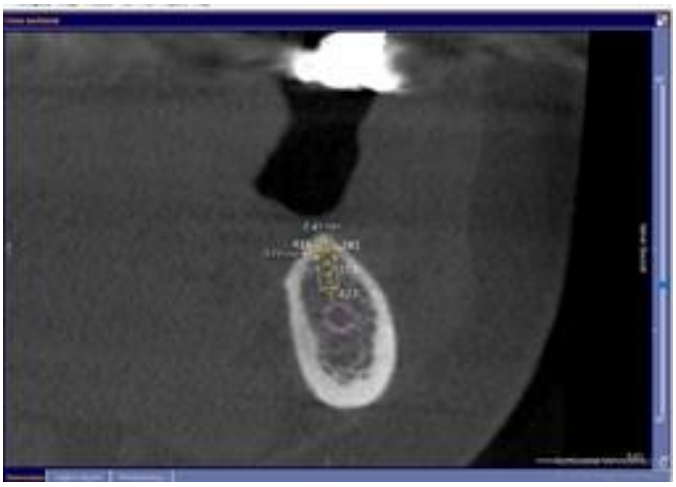

Figure 4: GROUP A bone density measurement at buccal, lingual, apical and centre intersection points

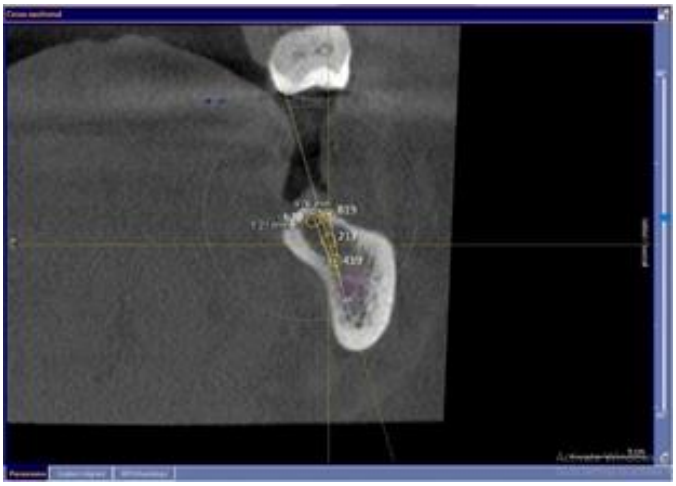

Figure 5. GROUP B bone density measurement at buccal, lingual, apical and central intersection points

Figure 6: GROUP C bone density measurement at buccal, lingual, apical and central intersection points