Research Article

# Arriving at a definitive bone quality

**Vaishnavi Rajaraman[1], V. Suresh[1], M. Dhanraj[2], Ashish R. Jain[2]***


## ABSTRACT

**Background:** Dental implants are most opted treatment modality, especially in the last three decades because they not only replace lost teeth but also provide permanent restorations that do not interfere with oral function or speech or compromise the self-esteem of a patient. **Aim:** The aim of this study is to use gray scale value (GSV) obtained from cone beam computed tomography (CBCT) scan and derives a precise value of bone density in any region of jaw. This can aid in apt treatment planning and caution during the surgical placement of dental implants. **Materials and Methods:** A sample of 35 CBCT scans was chosen by randomized sampling method from collection of computerized database of the institution. The clinician's interpretation about bone quality at site indicated for implant placement was taken before mathematical calculations (Group 1). The GSVs were noted at coronal site where the crest of implant is planned (Group 2) and at apical sites where the apical part of implant is expected to end (Group 3). A mathematical formula correlating Hounsfield unit (HU) and GSV was used: HU = −61.098 + 1.178 × GSV. All the three groups were compared and statistically analyzed. **Results:** The results of data of the present study showed a statistically significant difference between the groups when Kruskal–Wallis test was performed ($P < 0.05$). **Conclusion:** In this study, HU was derived from GSVs obtained from CBCT, using a mathematical formula derived by Razi *et al*. This provided the exact bone quality in region required. The estimation of exact bone quality at surgical site can help clinicians, interpret, and plan osteotomy before commencement of treatment.


**KEY WORDS:** Bone quality, Cone beam computed tomography, Dental implants, Gray scale values, Hounsfield unit

## INTRODUCTION

Dental implants are most opted treatment modality, especially in the last three decades because they not only replace lost teeth but also provide permanent restorations that do not interfere with oral function or speech or compromise the self-esteem of a patient. Appropriate diagnosis and treatment planning for replacement of lost teeth are required, and diagnostic imaging plays a paramount role to warrant a satisfactory outcome.

The imaging objectives are to provide the clinician with valuable information about the area under observation. Imaging provides the cross-sectional views of the dental arch for visualization of spatial relationship of internal structures of the maxilla and mandible. Minimal image distortion permits accurate measurement. Ideally, the images should allow evaluation of the density of trabecular bone and thickness of the cortical plates bone quality. Imaging studies should help to determine the optimum position of implant placement relative to occlusal loads. In addition,it also detects the presence or absence of pathoses and also is assessible at a reasonable cost to the patient. The utilization of pre-surgical imaging techniques helps the dentist place the implants with relative ease.

Multiple factors affect the selection of radiographic techniques for a specific scenario including cost, availability, radiation exposure, and patient's anatomy. The dentist should try to find a balance between these factors with an aim to abate risk of any complications to the patient. Digital imaging includes computed tomography (CT), tuned aperture CT, cone beam (CB)-CT, and magnetic resonance imaging. Earlier before the inception of three-dimensional (3D) imaging techniques, a panoramic radiograph was used as a diagnostic aid, to facilitate implant placement. This two-dimensional guide was helpful but also had its limitations. The prime purpose of assessing

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[1]Department of Prosthodontics, Saveetha Dental College, Saveetha Institute of Medical and Technical Sciences, Chennai, Tamil Nadu, India, [2]Department of Prosthodontics, Saveetha Dental College and Hospitals, Saveetha University, Chennai, Tamil Nadu, India

***Corresponding author:** Dr. Ashish R. Jain,Department of Prosthodontics, Saveetha Dental College and Hospital, Saveetha University, Ponamalle High Road, Chennai – 600 127, Tamil Nadu, India. Phone: +91-9884233423. E-mail: dr.ashishjain_r@yahoo.com

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quality and quantity of bone was not precise in these imaging methods. Hence, 3D imaging replaced the panoramic radiographs as a better and most opted alternative till today.[1-4] Of these, CT is a proven and established method for acquiring bone scans before dental implant surgery.[4] CT scan has been commonly used for pre-operative quantitative and qualitative assessment of implant sites and is routinely used to determine the bone density (quality) of the bone. It allows precise 3D evaluation of anatomic structures and direct measurement of bone density, expressed in Hounsfield units (HUs).[5]

HUs are standard numbers originating from CT imaging. HUs represent the relative density of body tissues according to a calibrated gray-level scale, based on values for air (−1000 HU), water (0 HU), and bone density (+1000 HU).[6,7]

Today, CBCT is increasingly substituting multislice CT in dentistry for evaluating mineralized tissues because it provides adequate image quality, associated with a lower exposure dose.[8-10] CBCT also offers advantages such as low cost, fast scanning time, and lower number of image artifacts.[10,11] Over CT, it provides shorter acquisition times, submillimeter resolution, and also delivers good spatial resolution, gay density range, and contrast, as well as a good pixel/noise ratio.[12,13] However, the disadvantage of CBCT is its inability to show the actual HU similar to CT scan.[14] With CBCT, the dimensional accuracy is comparable with CT, but unlike CT, the gray density values of the CBCT images (voxel value) are not absolute.[13,15] Although high levels of radiation scatter and artifacts in CBCT have been reported as the drawbacks of CBCT in the estimation of bone density, many studies have shown a linear relationship between HU in CT scan and gray scale in CBCT and recommended that voxel value in CBCT can be used for the assessment of bone density.

This implies that more studies are required to confirm the proposition that CBCT images obtained by the CBCT scanner can successfully substitute the multislice CT scanner in estimating the bone density. Therefore, given the magnitude of the subject, the lack of consensus of other studies, the aim of this study is to evaluate the validity of the bone density value of potential implant sites in HU obtained by a specific CBCT device. In this study, the correlation between gray scales is used to calculate the HU corresponding to the voxel value in CBCT.

## MATERIALS AND METHODS

In this study, 35 CBCT scans were chosen by randomized sampling method. The scans collected were carried out by Galileos 3D Comfort (Sirona Dental Systems, Bensheim, Germany). The scanning was carried out under 85 kv, 5–7 mA. The sites indicated for implant placement were examined for gray scale values (GSVs) [Figure 1]. The GSVs were obtained at a coronal and an apical point (around 10 mm from the coronal point). The GSV is obtained from a panel of options in the software (Galileos viewer 1.9.4368.23923) [Figure 2].

Clinicians were blinded and their opinion on the bone quality according to same classification was noted before mathematical calculation and was named Group 1. Three readings were obtained at each coronal site, named Group 2, and apical sites, named Group 3, from each scan. An average was calculated of all these readings were recorded.

Razi *et al.* conducted a study and gave a mathematical formula of correlation between GSV and HU. The formula used was HU = −61.098 + 1.178 × gray scale.[12] Using this, HU for the present study was calculated. Bone quality was determined according to Misch classification [Figure 3].[16] A comparison of the

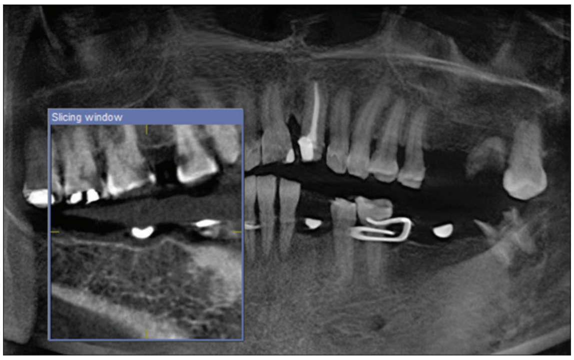


**Figure 1:** A sample site in mandibular posterior region indicated for implant placement is shown in panoramic section of cone beam computed tomography (Galileos viewer 1.9.4368.23923 software)

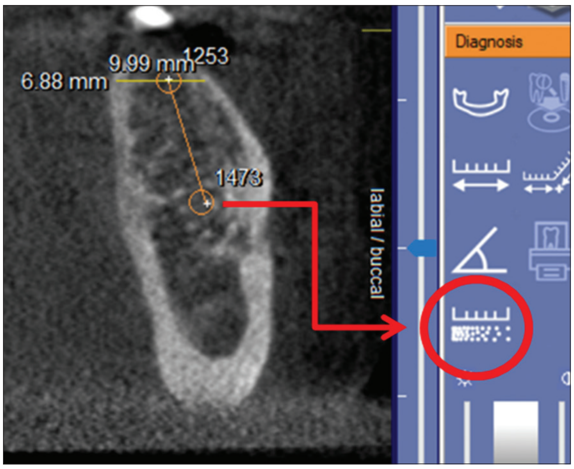


**Figure 2:** Gray scale values shown by the tool marked as red circle, in the Galileos viewer, cone beam computed tomography software

bone quality obtained from the formula at the apical and coronal sites and the clinicians interpretation was compared (comparing Groups 1–3). The statistical analysis was done using SPSS 20 software using Kruskal–Wallis test.

## RESULTS

Of the CBCT scans studied, data were tabulated in the clinician's interpretation of the bone quality, according to Misch classification and the mathematically interpreted bone quality, using formula by Razi *et al*. [Table 1].[12] The percentage of agreement between Group 1 and Group 2 was 11.43% and between Group 1 and Group 3 was 34.28% [Figure 4]. The total agreement between all three groups was only 11.43%, while the total disagreement was 42.86%.

The data of present study when analyzed, showed statistically significant difference between the groups compared. Both between Group 1 and Group 3 and between Group 2 and Group 3 were significant ($P < 0.05$).

## DISCUSSION

CT has been the gold standard in evaluating bone density and gives exact bone quality in HUs. CBCT is most commonly used now as imaging modality in dentistry, for its advantages over CT.[17,18] A major drawback of CBCT was its inability to provide HU. CBCT showed that the gray scale was positive in the solid lesion and negative in fluid and air-filled lesions. Thus, CBCT can help in the differential diagnosis of lesions.[19]

A strong linear relationship between the gray scale and HU values in various CBCT systems was compared and studied.[12,20,21] Mah *et al*. showed a relationship between HU and gray scale through a linear equation using scans from different materials.[20] However, it was noted that because of the homogeneity of tissue-equivalent material, a study on the living tissue was required. In another study, HU and gray scale were compared in physiological structures. The results showed a linear relationship between HU and gray scales, confirming the findings of Mah on the tissue-equivalent material were conducted.[12] The difference in mathematical formula obtained might be related to the materials under study and the type of the device. In a study, a dry human mandible was used so that the density changes seemed relatively normal, and the gray scales were different from the actual ones. According to the results of various studies, using dry mandible to remove the effect of adjacent tissues, such as the tongue and spinal tissues, can lead to interferences in determining the gray scale tissues.[22,23]

In the present study, hard tissues along with the soft ones were studied, and an attempt was made to derive the HU from GSVs given by CBCT, which can provide an insight into the exact bone quality in that region. Furthermore, this will give the details of difference in CBCT interpretation between the clinicians opinionated bone quality to mathematically calculated bone quality. Statistically significant results obtained between clinicians' interpretation and calculation derived values at apical and coronal sites ($P < 0.05$).

The clinical significance of this study focuses mainly on the finding that CBCT may help to facilitate the estimation of exact bone quality at the surgical site can help clinicians interpret and plan the osteotomy before treatment.

The limitations of this study are that GSV is obtained of a circular area, in the cross-section slice of the CBCT, and not a particular point. This gives a larger range of GSVs in that area and a less precise localization of GSVs needed to derive at the bone quality. For future research, studies can be conducted to obtain a more precise GSV, localized to a point in the cross-section slice of the CBCT.

Another limitation was that clinician interpretation was only as a generalized bone quality for the entire cross section not for specific areas within the cross-section slice in CBCT. They could not differentiate between bone qualities at crestal or apical level of the implant length, intended to be placed. It is utmost essential to achieve the primary stability during

| BONE | | DENSITY |
|---|---|---|
| D1 | >1250 HU | Dense cortical bone |
| D2 | 850-1250 HU | Thick dense to porous cortical bone on crest and coarse trabecular bone within |
| D3 | 350-850 HU | Thin porous cortical bone on crest and fine trabecular bone within |
| D4 | 150-350 HU | Fine trabecular bone |
| D5 | <150 HU | Immature, non-mineralized bone |

**Figure 3:** Bone density classification by Misch[16]

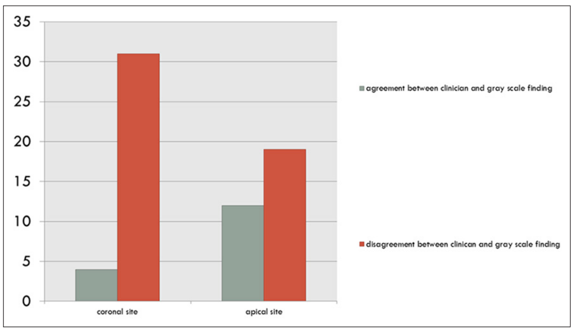


**Figure 4:** Agreement or disagreement between Group 1 and Group 3 (coronal site) and Group 2 and Group 3 (apical site)

**Table 1: Clinician interpretation (Group 1) compared with values collected from CBCT at coronal (Group 2) and apical (Group 3) sites**

| Clinician's opinion before treatment (Group 1) | Coronal sites in cross section (Group 2) | | | Apical sites in cross section (Group 3) | | |
|---|---|---|---|---|---|---|
| | GSV | HU | Bone quality (ACC. to MISCH*) | GSV | HU | Bone quality (ACC. to MISCH*) |
| D3 | 1029 | 679.864 | D3 | 1046 | 699.89 | D3 |
| D3 | 1112 | 1248.638 | D2 | 1110 | 775.282 | D3 |
| D3 | 1147 | 818.868 | D3 | 1686 | 1453.81 | D1 |
| D1 | 1413 | 1132.216 | D2 | 1627 | 1384.308 | D1 |
| D3 | 971 | 611.54 | D3 | 1110 | 775.282 | D3 |
| D2 | 1537 | 1278.288 | D1 | 1340 | 1046.222 | D2 |
| D2 | 1169 | 844.784 | D3 | 1438 | 1161.666 | D2 |
| D2 | 1354 | 1062.714 | D2 | 1259 | 950.804 | D2 |
| D2 | 1420 | 1140.462 | D2 | 1546 | 1288.89 | D1 |
| D3 | 1109 | 774.104 | D3 | 1032 | 683.398 | D3 |
| D2 | 1155 | 828.292 | D3 | 1301 | 1000.28 | D2 |
| D3 | 1130 | 798.842 | D3 | 969 | 609.184 | D3 |
| D1 | 1143 | 814.156 | D3 | 1261 | 953.16 | D2 |
| D2 | 1461 | 1188.76 | D2 | 1288 | 984.966 | D2 |
| D2 | 1397 | 1113.368 | D2 | 1377 | 1089.808 | D2 |
| D2 | 1463 | 1191.116 | D2 | 1380 | 1093.342 | D2 |
| D3 | 1214 | 897.794 | D2 | 902 | 530.258 | D3 |
| D2 | 1212 | 895.438 | D2 | 1213 | 896.616 | D2 |
| D2 | 1615 | 1370.172 | D1 | 1599 | 1351.324 | D1 |
| D3 | 1238 | 926.066 | D2 | 999 | 644.524 | D3 |
| D2 | 1465 | 1193.472 | D2 | 1362 | 1072.138 | D2 |
| D1 | 1532 | 1272.398 | D1 | 1578 | 1326.586 | D1 |
| D2 | 1268 | 961.406 | D2 | 1495 | 1228.812 | D2 |
| D2 | 1802 | 1590.458 | D1 | 1214 | 897.794 | D2 |
| D2 | 1691 | 1459.7 | D1 | 1444 | 1168.734 | D2 |
| D2 | 1335 | 1040.332 | D2 | 1321 | 1023.84 | D2 |
| D2 | 1577 | 1325.408 | D1 | 1320 | 1022.662 | D2 |
| D2 | 1260 | 951.982 | D2 | 1174 | 850.674 | D2 |
| D3 | 1425 | 1146.352 | D2 | 1322 | 1025.018 | D2 |
| D1 | 1725 | 1499.752 | D1 | 1227 | 913.108 | D2 |
| D1 | 1627 | 1384.308 | D1 | 1167 | 842.428 | D3 |
| D3 | 1309 | 1009.704 | D2 | 1147 | 818.868 | D3 |
| D2 | 1326 | 1029.73 | D2 | 1174 | 850.674 | D2 |
| D2 | 982 | 624.498 | D3 | 1285 | 981.432 | D2 |
| D4 | 1134 | 803.554 | D3 | 1198 | 878.946 | D2 |

CBCT: Cone beam computed tomography, GSV: Gray scale value, HUs: Hounsfield units

surgical implant placement procedure. According to a study, the implant primary stability was higher in high bone quality.[24] The primary stability at crestal bone level and basal bone level may be different. Using the HU values from CBCT, there is a scope to analyze if primary stability is achievable in the crestal and apical sites of the site indicated for surgical implant placement. This would mainly revolve around the basis of determining the type of bone quality, with the help of obtained HU values from CBCT.

## CONCLUSION

Within the limitations of this study, it can be concluded that GSVs from CBCT can be used to derive at the HU, required to determine the exact bone quality in that region of the jaw. There also exists a scope, in the future to directly obtain the final HU from GSVs by calculation within the CBCT software. This can be incorporated in the CBCT software used for implant planning and placement.

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