sciendo
Polish Journal of Medical Physics and Engineering
The Journal of Polish Society of Medical Physics
ISSN 1898-0309, doi: 10.2478/pjmpe-2025-0015

June 2025
Vol 31, Issue 2

Scientific Paper

Are the bone density measurements around dental implants varied with different angles of CBCT view?

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(received 13 December 2024; revised 12 March 2025; accepted 17 April 2025)

Abstract

Background: To obtain a precise picture and an accurate clinical evaluation post-dental implantation. Accurate testing of bone density is essential. Various angles may yield disparate attenuation readings, thereby causing inconsistencies in the perceived density of bone surrounding the implanted tooth. This study examines bone density measures in Hounsfield units (HU) surrounding dental implants to determine the impact of varying cone beam computed tomography (CBCT) image angle measurements. The study also examined the influence of age, gender, and tooth placement on measurements taken from various angles.

Materials and methods: The sample comprised thirteen patients, eight females (61.54%) and five males (38.46%), aged between 18 and 60 years, with a mean age of 48.53 ± 12.97 years. A total of 38 implant CBCT scans were collected from thirteen patients; 24 (63.16%) scans were conducted on females and 14 (36.84%) on men. The bone density surrounding dental implants has been assessed at various approximate angles, specifically 0 and 90 degrees (anticlockwise), with the filter disabled, utilizing CBCT images. Furthermore, the influence of age, gender, and tooth implant location on bone density measurements was considered. OnDemand software assisted in conducting the measurement.

Results: The t-test was employed since it was presumed that data distribution was normal. Measurements of bone density taken at various angles with the filter off showed no substantial difference (p= 0.58). There was no discernible variation in the measurements of body density, even after accounting for a multitude of parameters such as gender, age, and the installation of dental implants.

Conclusion: No differences exist in bone density measurements at varying angles. Even after dividing the participants into groups to investigate the effects of age, gender, and tooth position, this remains the case. Further research is necessary.

Key words: Bone density; dental implant; angle; CBCT

Introduction

The success rates of dental implants are high, accurate, and well predictable. For those dealing with tooth loss, dental implants have emerged as a competitive substitute for fixed partial dentures in recent years[1]. Bone density has a major impact on how well an implant's main stability works. Proper procedure and implant stability are essential for the implant's effectiveness[2]. Osteoporosis can be detected, and human bone mass directly estimated by bone mineral density (BMD) testing. Therefore, it is necessary to evaluate the amount and quality of bone at the dental implant location precisely. There are several techniques for evaluating bone quality, such as dual-energy X-ray absorptiometry, sonography, and stained sections[3-5]. However, these techniques are not appropriate for routine clinical applications because they are not capable of accurately measuring bone density. Cone beam computed tomography (CBCT) and computed tomography (CT) are the most widely used procedures[6-11]. The advent of CBCT in maxillofacial imaging ushers in a genuine paradigm change from 2D to 3D imaging in the dental field. CBCT, as an alternative to medical CT, has gained popularity in the diagnosis and treatment planning of maxillofacial and oral lesions. Compared to more traditional 2D methods and medical CT, this imaging modality has many benefits for the dental field[11,12]. CBCT technology is a relatively recent imaging method, that was initially established in 1982. It was primarily utilized for angiography, and later it was used for maxillofacial imaging. Dentistry has endorsed CBCT as a CT substitute[13]. The need for 3D information, which followed an evolutionary trajectory, led to the development of this method in the 1990s[14]. The field of view (FOV), X-ray cone quality and quantity, pixel size, jaw arch, and other picture parameters impact the CBCT image, and its characteristics, including noise, resolution contrast, and artifacts[15]. Various artifacts can impair CBCT quality

Authors' contribution: A – Research concept and design, B – Collection and/or assembly of data, C – Data analysis and interpretation, D – Writing the article, E – Critical revision of the article, F – Final approval of the article.

and, in rare cases, make diagnosis challenging. Metal artifacts frequently appear during CBCT scans, primarily due to the metal nature of implants. Researchers have proposed numerous variables and strategies to reduce the artefact[13]. Many researchers have proposed CBCT as a diagnostic method to measure bone mineral density[16-21]. Bone density measurements in teeth after implantation are heavily influenced by the angle of measurement. Variations in the angle can impact clinical decisions about implant placement and success by causing variances in perceived bone density[22]. The angle of measurement can be a key element in calculating bone density, because there are a lot of different aspects to consider. Firstly, there is a significant impact on the composition of images. The mineral content of bones, or their density, is one component that contributes to their physical strength. The angle at which bone density is measured has no bearing on its true density. On the other hand, the imaging angle can influence the perceived bone density in pictures[23]. Bone remodeling is the second concern. Following implant placement, osseointegration occurs, during which the adjacent bone grows into and into the implant. Gradual variations in bone density may occur as a consequence of remodeling processes[24]. The measuring angle is not the source of these changes, though; rather, they are a normal aspect of the body's natural healing process. Because the scanner slices through the bone, imaging angles during follow-up scans can reveal varying degrees of remodeling or density. An erroneous reading of the degree of bone remodeling could result, for instance, from a CBCT scan performed at an angle not perpendicular to the bone structure. This may cause people to misjudge the condition of the bone surrounding the implant. Thirdly, measurement angles of bone density can impact clinical decision-making. The durability of the implant and the necessity of additional procedures, such as bone grafting, can be misjudged if the clinician incorrectly assesses bone density owing to an angle-induced artifact[25]. Accurately evaluating the condition of the bone surrounding the implant and ensuring it is sufficient for long-term implant support requires proper imaging technique, which includes employing numerous angles and defined protocols. Implant placement success depends on precise measurements of bone density. Because angles can change, imaging methods need to be carefully thought through to make sure that the data used for therapeutic decisions is reliable[26]. Finally, evaluation of bone quality. Bone quality, which correlates with bone density, determines implant success. If the measuring angle distorts the bone's quality, it could compromise the clinician's ability to evaluate osseointegration and implant stability. The long-term success of the implant may depend on the accuracy of the density measurements used to inform treatment decisions. According to Genisa et al. (2015)[27], there is a strong correlation between the angle of measurement and bone density assessments. In particular, higher angles (15 and 30 degrees) on CBCT give less accurate Hounsfield Unit readings than CT, which can make evaluations done after implantation less sure of their accuracy. To overcome these issues, it is necessary to have an accurate measurement of bone density. The aim of this study was to investigate the effects of measuring BMD around dental implants at approximate angles of 0 degrees and 90 degrees (anti-clockwise), with the filter off, taking into consideration the impact of age, gender, and tooth position at various angles using the CBCT.

Materials and methods

This cross-sectional study included the CBCT data of 13 patients (8 females and 5 males) with an age range of 18-60 years who presented with a single or multiple missing teeth that were restored with implant-supported prostheses. The data were obtained from the Oral and Maxillofacial Radiology Department at Al-Shaheed Gazi Al Hariri Hospital during the 2023 and 2024. All the CBCT scans were part of the routine work up of the patients and were performed by the same operator using the same CBCT machine (KAVO OP 3D PRO, Germany) set at 89 kV, 9.2 mA, and 8.1 seconds with a 13 × 15 mm FOV and 0.5 mm slice thickness. The analysis was performed using the OnDemand 3D software (Cybermed Inc., Seoul, Korea). The sample included 38 dental implants that were installed in maxillary and mandibular arches. The bone density was measured by the following steps. The first step was to adjust the axial perspective such that each fixture was plainly visible. Also, the measurement centre of the implant was used to align the coronal and sagittal reference lines. The long-axis parallel reference lines of each implant might be seen by modifying the sagittal and coronal viewpoints. A polyline tool was used for HU value analysis to measure the density of bone mineral. Finally, tiny measurement icons were used to outline the target region. Each implant had a 1 mm buffer zone around it, with an additional 0.5 mm of space between it and the implant's surface. This distance permits evasion of metallic objects in both the sagittal and coronal views[28] (**Figure 1**).

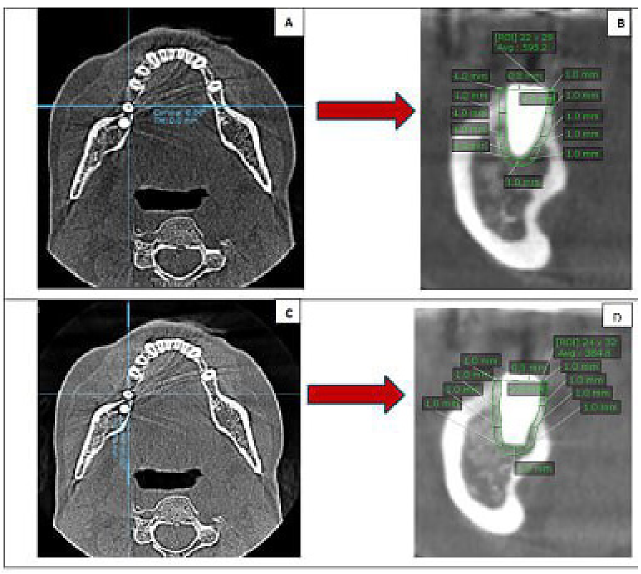

Figure 1. Density measurements at approximate 0 and 90 degree: A: the axis at 0 degree. B: the bone density measurements at coronal view C: the axis at 90-degree (anti clockwise) D: the bone density measurements at sagittal view

The patients were assessed utilizing varying angle settings (0 and 90 degrees (anticlockwise)) of the software exclusively during measurements, adhering to the same protocol. The filter has been removed before the measurement. An improved view of bone density fluctuations may be possible despite the image's noise and the fact that it's challenging to understand even with the filter removed[29,30].

The data was gathered, collated, and evaluated using Microsoft Excel. The investigation concentrated on the mean bone density as well as the standard deviation. The student paired t-test was used to reveal if there were significant differences in bone density between angles of 0 degrees and 90 degrees. It was based on a normality distribution. A P-value that was less than 0.05 was considered to be indicative of statistical significance.

Results

The study included 13 patients with an average age of 48.53 years. A total of 38 dental implant CBCT photos were acquired from various patient locations. Twenty CBCT photos, or 52.63% of the total, were under the age of 55, with an average age of 38.6 ± 10.39 years; eighteen CBCT photos, or 47.37%, were 55 or older, with an average age of 59.56 ± 0.86 years. There are 24 CBCT images of females, with a mean age of 53.42 ± 7.94 years, and 14 CBCT images of males with an average age of 40.14 ± 15.73 years, reducing the total to 37%. The results of this study reveal that there are no statistically significant differences between bone density measurements at 90-degree angles and 0 degrees, as shown in **Table 1** ($p = 0.58$).

Table 1. Statistical descriptions of the bone mineral density around the implant at angles of 0 and 90 degrees (anticlockwise) at filter off

Group	No. of CBCT	Density Hounsfield units (HU)	P. Value
A (Angle 0)	38	333.74 ± 131.67	0.58
B (Angle 90)	38	339.79 ± 133.90	

As far as the influence of age on bone density measurements is concerned, the findings in this study demonstrated that there is no considerable difference between patients aged ≥55 years (59.56±0.86) ($p = 0.16$) and <55 years (38.60±10.39) ($p = 0.18$) at either the 0 or 90^0 (anticlockwise) angle, approximately (**Table 2**).

Table 2. Statistical descriptions of the density of bone mineral surrounding the implant at two distinct angles, 0 and 90 degrees (anticlockwise), between two age groups, (≥55 and < 55).

Age (ys)	No. of CBCT	Density at angle 0 (HU)	P. Value	Density at angle 90 (HU)	P. Value
≥55	18	366.61 ± 164.90	0.16	371.61 ± 156.54	0.18
< 55	20	304.15 ± 86.52		311.15 ± 105.67	

In terms of gender and its effects, there are no significant variances between the two when bone density measurements were compared between 0 degrees and 90 degrees (**Table 3**).

Table 3. Statistical descriptions of the density of bone mineral surrounding the implant at two distinct angles, 0 and 90 degrees (anticlockwise), between male and female.

Gender	No. of CBCT	Density at angle 0 (HU)	P. Value	Density at angle 90 (HU)	P. Value
Male	14	296.96 ± 84.08	0.135	322.64 ± 103.74	0.515
Female	24	355.19 ± 150.30		349.79 ± 149.92	

When comparing the mandible and maxilla, the mean values of bone density were higher in the mandible at both 0 and 90 degrees. However, there was no significant difference in statistical terms, as demonstrated in **Table 4**.

Table 4. Statistical descriptions of the density of bone mineral surrounding the implant at two distinct angles, 0 and 90 degrees (anticlockwise), between the implant position.

Position	No. of CBCT	Density at angle 0 (HU)	P. Value	Density at angle 90 (HU)	P. Value
Maxilla	26	305.81 ± 98.90	0.122	311.24 ± 111.11	0.098
Mandible	12	394.25 ± 173.92		401.64 ± 161.72	

Discussion

The success of dental implants relies on accurate post-implantation bone mineral density (BMD) assessments that provide insights about bone quality, stability, and surgical techniques. Osseointegration is being adversely impacted by it[31]. This investigation was conducted to ascertain the extent to which the angle axis influenced the measurements. Bone density was assessed in a CBCT image at various angles, including approximately 0 degrees and 90 degrees (anticlockwise), while the filter was deactivated. According to the researcher's knowledge, this study is considered the first of its kind. The current research findings demonstrate that there is no statistically significant variance in comparing the two angles. The limited sample size makes this explanation the most credible. Larger or more diverse sample sizes may yield different conclusions. Another possibility is that the bone density is not uniform over the entire bone, which could be the cause of the problem. It is possible for different parts of the same bone, such as the cortical and trabecular regions, to have densities that are completely different from one another[32]. It's possible that a single CBCT angle won't be able to show enough differences in density across the whole area of interest, which will mean that there is no correlation. Perhaps it's because the subject isn't properly positioned when being scanned: Where the person is positioned could affect the scan's angle. Scanned apparent density may not be reflective of real bone density if the individual is not properly positioned (even with little changes in angle). The outcomes of this study indicated that there was no substantial difference in bone density measurement at both various angles with the filter off when comparing two age groups: one with a mean age of 59.56 years (age ≥55 years) and the other with an average age of 38.60 years (age <55 years). This may be due to the limited number of younger samples (≤ 30 years), which constitute 15.4% of the total samples. One probable explanation is that this is due to the well-known fact that bone density naturally declines with age. Additionally, it is known that the process of demolition by osteoclasts, which becomes faster and more effective than the process of building by osteoblasts, is also a factor that is considered to be important for bone maintenance. In point of fact, this decrease in bone density is the cause of low Implant Stability Quotient readings in participants of this age range[33]. An investigation in 2022 supported our findings, revealing that neither elderly patients (mean age of 55.9 years, 41-60 years) nor youthful patients (mean age of 34.8 years, 18-40 years) exhibited any apparent alterations in their bone densities. The aim of this study was to determine the changes in bone density obtained using cone-beam computed tomography surrounding dental implants after a short period of time in the maxilla. The bone density was assessed both at the time of the surgery and sixty days after the investment[28]. With regards to the gender, the findings of this study revealed that there was no significant difference in bone density between males and females when the filter was turned off and bone density was assessed at various angles. This may be attributed to the disparity in the percentage of females, 63.16%, and males, 36.84%. In fact, periodontal and dental health are adversely affected by the continuous hormonal changes that females undergo throughout their lives, including pregnancy and the postmenopausal period. This can lead to early tooth loss, necessitating the pursuit of both aesthetic and functional dental replacements. In 2022, the same study mentioned above confirmed the findings of this study, with six males and six females, showing no statistically significant difference in maxillary bone density between the sexes at surgery and sixty days after the investment[28]. Our research showed that at angles of 90° (anticlockwise) and 0°, the mean bone density values at the maxillary site were lower than those at the mandibular site when the filter was not in use. However, to the best of our knowledge, there was no clearly discernible connection between the two locations. In 2022, Leonard Morar et al. utilized specialist software to analyse Hounsfield units (HU). The mandibular first molars had higher HU values than the maxillary ones. Researchers in this study scanned the relevant portions of radiographs taken from forty individuals with partial tooth loss using CBCT[34]. This conflicting to our result may be due to reason that the number of mandibular is lower 12 scans (31.58%) than to the maxilla 26 scans (68.42%).

Conclusions

The results of this investigation demonstrated that changing the CBCT image angles had no effect on the bone density measurements. Further investigation is necessary.

Acknowledgement

The author is grateful to Dr. Hiba Basim Mohammed for her support during the data collection procedure.

Conflict of interest

Author declares there is no conflict of interest.

Funding

None.

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