EURASIAN JOURNAL OF HEALTH SCIENCES
e-ISSN 2651-3501

Eurasian JHS 2026; 6: 1-7

Research Article/ Araştırma Makalesi

Correspondence: Zuhal OVUZ
E-mail: dtzuhalozates@gmail.com

Preoperative Assessment of Bone Density for Dental Implants: A CBCT-Based Software Comparison Study

Zuhal OVUZ[1,a]

[1] Department of Maxillofacial Radiology, Faculty of Dentistry, Çankırı Karatekin University, Çankırı, TURKEY

ORCID: [a] 0000-0002-2419-9793

ABSTRACT

Objective: In dental implant procedures, accurate assessment of bone density in the implant site is essential to ensure primary stability and achieve successful osseointegration. The aim of this study is to compare bone density in the mandibular mental foramen region using three different software programs and to contribute to implant planning. Method: In this study, cone-beam computed tomography (CBCT) images of 100 individuals with partial edentulism were retrospectively analyzed. Bone density values in the mandibular premolar region were measured using three different image analysis software programs and compared in Hounsfield units (HU). Results: No significant difference was observed in the HU measurement values obtained with the three software programs in the mandibular premolar region. All software programs provided similar and consistent results regarding bone density in the region. Conclusion: Considering the limitations of this study, the objective assessment of bone density in the target area prior to implant placement is clinically useful in determining implant size and planning patient-specific drilling protocols. The fact that different software programs yield similar results suggests that such measurements can be reliably used in implant planning.

Key words: Bone Density, CBCT, Dental Implant, Hounsfield Units.

Dental İmplantlar için Preoperatif Kemik Densitesinin Değerlendirilmesi: KIBT Tabanlı Bir Yazılım Karşılaştırma Çalışması

ÖZ

Amaç: Dental implant uygulamalarında primer stabilite ve başarılı osseointegrasyonun sağlanabilmesi için implant yerleştirilecek bölgede kemik yoğunluğunun doğru bir şekilde değerlendirilmesi gereklidir. Bu çalışmanın amacı, mandibular mental foramen bölgesindeki kemik yoğunluğunu üç farklı yazılım kullanarak karşılaştırmak ve implant planlamasına katkıda bulunmaktır. Yöntem: Çalışmada, parsiyel dişsizlik gösteren 100 bireye ait konik ışınlı bilgisayarlı tomografi (KIBT) görüntüleri retrospektif olarak incelendi. Mandibular premolar bölgedeki kemik yoğunluğu değerleri üç farklı görüntü analiz yazılımı kullanılarak ölçüldü ve Hounsfield birimi (HU) cinsinden karşılaştırıldı. Bulgular: Üç yazılım ile elde edilen HU ölçüm değerleri arasında mandibular premolar bölgede anlamlı bir fark gözlenmedi. Tüm yazılımlar bölgedeki kemik yoğunluğuna ilişkin birbirine yakın ve uyumlu sonuçlar sundu. Sonuç: Sonuçlarımız, CBCT tabanlı farklı yazılımların mandibular premolar bölgede güvenilir ve tutarlı kemik yoğunluğu ölçümleri sağladığını göstermektedir. Bu bulgular, implant planlamasında objektif kemik yoğunluğu değerlendirmesinin klinik uygulamada rutin olarak kullanılabileceğini desteklemektedir.

Anahtar kelimeler: Dental İmplant, Hounsfield Birimi, Kemik Yoğunluğu, KIBT.

DOI: 10.53493/avrasyasbd.1842930 Received: 15.12.2025 Accepted: 10.02.2026

INTRODUCTION

The amount and density of the surrounding bone are closely linked to the clinical success of dental implants (Aranyarachkul et al., 2005). A well-established technique for acquiring bone images prior to dental implant surgery is computed tomography (CT). In addition to directly measuring bone density at HU, which provides critical information regarding bone characteristics, CT scans offer an accurate three-dimensional evaluation of anatomical structures (Aranyarachkul et al., 2005).

Two fundamental concepts underlie the use of CT to assess bone density. The first step involves determining the radiological density of the tissue by calculating the attenuation coefficient of the X-ray beam. This allows CT to generate a more precise two-dimensional representation of an object on the basis of its three-dimensional characteristics, which is the second key principle (Romans, 2025). To evaluate the radiological density via CT, measurements are made using the Hounsfield scale, a quantitative scale that assigns a precise density value to each tissue type. Air has a value of -1000 (black on the grayscale), whereas bone values range from +700 (sponge bone) to +3000 (dense bone, such as in the cochlea). This scale is crucial for evaluating bone density in imaging, as it enables clear differentiation between soft tissues and air, allowing for detailed analysis of anatomical features such as the maxillary sinuses (Glide-Hurst et al., 2013).

Consequently, the Hounsfield scale, which is calibrated on the basis of air, water, and bone densities, provides a relative density depiction of tissue on a calibrated grayscale scale. A study by Nickaerts demonstrated a strong linear correlation between grayscale values in CBCT and HU values in CT, further validating the accuracy of both techniques (Nackaerts et al., 2011). It should be emphasized that HU values obtained from CBCT images represent relative density measurements rather than absolute HU values as provided by conventional medical CT systems. The primary stability of dental implants is determined by the amount and quality of bone at the implant site, as well as the implant geometry and surgical placement method (Liu et al., 2017). Various factors that influence bone resistance also impact bone quality. However, most clinicians use bone density, as measured by the Hounsfield scale, as an objective and quantifiable indicator of bone quality (Liu et al., 2017).

Implants placed in low-density bones are more likely to exhibit poor initial stability and higher failure rates (Javed et al., 2013). Therefore, a comprehensive preoperative evaluation of bone density can guide clinicians in selecting the appropriate implant type, drilling protocol, and surgical approach (Rios et al., 2017). Primary stability, or the initial mechanical stability achieved during surgical insertion, is influenced by the implant's macrostructure and the chosen surgical technique. The long-term success of the implant is attributable to secondary stability, which develops through the osseointegration process as the bone heals. During the bone remodelling process following implant insertion, primary stability decreases, whereas secondary stability increases as new bone formation occurs (Misch CE, 2021).

CBCT has become the most widely used method for assessing bone quantity and quality in dental implant planning, significantly influencing the field of oral implantology. Numerous studies have evaluated the accuracy of CBCT in assessing bone density (Pauwels, 2013; Radi et al., 2018). A study by Parsa et al., which compared CBCT with traditional and microcomputed CT, revealed a strong correlation between the two, confirming that both techniques provide comparable accuracy in evaluating bone density (Parsa et al., 2013). However, metallic implant artefacts can degrade image quality and hinder diagnostic utility. The presence of metallic artefacts in reconstructed CBCT images significantly reduces diagnostic performance, although advanced deep learning techniques have been developed to minimize these metal artefacts (Parsa et al., 2013). In a study examining the impact of exposure parameters on metal artefacts in dental implants placed at different bone densities, peri-implant artefacts were observed in all bone types. To minimize metal artifacts, the use of a lower field of view (FOV) is recommended (Shokri et al., 2019).

A macrostructure-based bone classification system was proposed by Lekholm and Zarb, wherein the distribution and morphology of cortical and trabecular bone dictate bone quality (Lindh et al., 1996). Misch initially categorized bone mineral density using CT values (HU), classifying bone as follows: D1 bone, with an HU value above 1250; D2 bone, with an HU value between 850 and 1250 near the implant–bone interface; D3 bone, with an HU value between 350 and 850 at the implant site; D4 bone, with an HU value between 150 and 350; and D5 bone, with an HU value below 150 (Ahmed et al., 2021). Trisi and Rao demonstrated a strong correlation between bone resistance measurements in D1 and D4 bones and histomorphometric analysis of trabecular bone volume on the basis of Misch's categorization. However, there was significant variability in D2 and D3 bones (Trisi et al., 1999).

Therefore, the aim of this study was to compare CBCT-derived bone density measurements obtained using three different software platforms in the mandibular premolar region and to evaluate the level of agreement between these software programs.

MATERIAL AND METHOD

Ethical approval in accordance with the Declaration of Helsinki was obtained from the Noninterventional Ethics Committee of Cankiri Karatekin University on June 25, 2024, with the application code: E- 6cfe3e88696f42e6. In this retrospective study, patients who visited the Oral and Maxillofacial Radiology Clinic of Cankiri Karatekin University Faculty of Dentistry for CBCT imaging between October 2023 and May 2024 for various reasons were included. Patient consent forms were obtained, lead aprons were provided, and tomographic images were acquired in accordance with infection control protocols and radiographic imaging standards.

CBCT scans of 100 patients (both male and female) were retrospectively analysed. Density measurements were performed on the same mandibular premolar region via three different software programs. CBCT images were selected on the basis that the mandibular region, including the mental foramen area, was within the imaging field and that there were missing teeth in the region. The images were retrospectively reviewed.

The CBCT scans were obtained via the Castellini X-Rad1 US TR10 Plus device, with a tube voltage of 90 kVp, a tube current of 5 mA, and an exposure time of 7 pulses per second. The voxel size and field of view (FOV) were set at 0.3 mm and 10 × 8 mm, respectively. The images were evaluated under appropriate lighting conditions via a Lenovo 15.0 510 80 SR monitor.

In this study, the bone density of the jaws was assessed via the HU scale, with measurements taken from CBCT images via three different software programs: Smart V Pro (Figure 1), Blue Sky Plan DICOM Viewer (Figure 2), and the native viewer software of the Castellini CBCT (Figure 3) device. A standardized region of interest (ROI), measuring 2x2 mm, was selected 4 mm superior to the superior border of the mental foramen. The same ROI was used in all three software programs to measure bone density in HU. Measurements were performed once by a single observer. Smart V Pro and Blue Sky Plan are commercially available software programs, whereas the native viewer software of the Castellini CBCT device is provided by the manufacturer with the imaging system. None of the software programs required additional modifications for density measurement. Blue Sky Plan DICOM Viewer (free version) was used for image analysis.

Figure 1. Measurements made with Smart V pro program. Measurements were made in a 2x2 mm area 4 mm superior to the mental foramen.

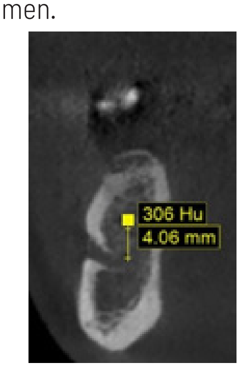

Figure 2. Measurements made with Blue sky plan program. Measurements were made in a 2x2 mm area 4 mm superior to the mental foramen.

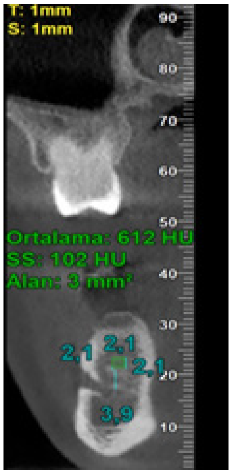

Figure 3. Measurements made with Castellini X-Rad1 US TR10 Plus device. Measurements were made in a 2x2 mm area 4 mm superior to the mental foramen.

Statistical Methods

The data were analysed via IBM SPSS V23. The normality of the data distribution was assessed via the Kolmogorov-Smirnov test. The Friedman test was used to examine differences between the parameters measured by different software programs. The intraclass correlation coefficient (ICC) was employed to assess the agreement between the programs. The results are presented as the means ± standard deviations and medians (minimum-maximum). A significance level of $p<0.05$ was considered statistically significant (Figure 4).

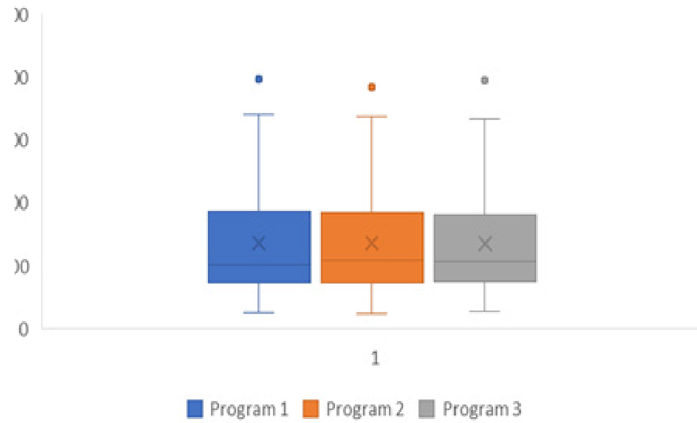

Figure 4. Boxplot Comparison of HU Measurements Across Three Software Programs

RESULTS

No statistically significant difference was found between the programs (p=0.960). The median value was 508.5 for Program 1, 540.5 for Program 2, and 530.5 for Program 3. A statistically excellent agreement was observed between Program 1, Program 2, and Program 3 (ICC=0.997; p<0.001). Owing to the high agreement in the observations, one of the results was selected for further analysis (Table 1.)

Table 1. Statistical Comparison and Intraclass Correlation Coefficient (ICC) Analysis of Three Measurement Programs

Program	Mean ± SD	Median (min-max)	Test Statistic	p	ICC (95% CI)	p
Program 1	674.36 ± 420.74	508.5 (127-1984)	0.082	0.960*	0.997 (0.996-0.998)	<0.001
Program 2	676.86 ± 422.34	540.5 (113-1919)				
Program 3	672.66 ± 422.89	530.5 (131-1972)				

DISCUSSION

Implant therapy is the treatment of choice in contemporary dentistry for all forms of tooth loss. The majority of studies report a 90% to 95% success rate for implant therapy. Success depends on a variety of factors, most of which are related to the patient's characteristics, the implant type, and the expertise of the clinician (Esposito et al., 2005; Kim et al., 2010).

The development of radiological diagnostics and their use in implantology have enabled the selection of the optimal treatment plan and objective preimplant preparation. The introduction of CT, followed by MDCT and CBCT,has facilitated three-dimensional assessment of the jawbone, providing both qualitative and quantitative analysis for implant procedures (Armstrong R, 2006; Omami and F Al Yafi, 2019).

In this study, we used different DICOM viewer applications to quantify bone density and assess the accuracy of CBCT-based bone density measurements. Bone quality was evaluated on the basis of the software analysis of CBCT images, expressed in HU units. Armstrong and Arisan et al. highlighted that there are differences in HU values when analysing material under the same conditions on CT and CBCT (Arisan et al., 2013; Armstrong R, 2006). Both CT and CBCT analyses are valid methods for assessing bone density and are commonly used in preimplantology, with CBCT being favored because of its accessibility, lower radiation dose, and ease of installation.

Mikic et al. conducted a study using animal-derived materials to assess the primary stability of dental implants with different designs (self-tapping and non-self-tapping) in relation to bone density. The study utilized CBCT imaging to examine the effect of bone density on implant stability, using samples from pig ribs and bovine femurs (Mikic et al., 2022).

As noted, Krikos and Misch established correlations between bone density categories and HU in a retrospective study utilizing CT images. They reported that D1 bone density exhibited the highest values, exceeding 1250 HU, followed by D2 bone density (850 to 1250 HU) and D3 (350 to 850 HU). D4 and D5 presented the lowest bone density values, with D4 ranging from 150 to 350 HU and D5 being less than 150 HU. D1 bone density is predominantly located in the anterior mandible, D2 and D3 are located in the anterior maxilla and posterior mandible, and D4 bone quality is found mainly in the posterior maxilla (Misch CE, 2021). Unlike conventional CT, CBCT-derived HU values are not absolute measurements but represent relative grayscale-based density values; therefore, they should be interpreted with caution in clinical decision-making.

In a study by Morar et al., bone density was significantly lower at the maxillary level than at the mandibular level. D2 bone density was present in both the maxillary and mandibular central incisor regions, as well as in the mandibular first molar area. D3 bone density was identified in the alveolar crest of the maxillary first molars. These findings emphasize the need for individualized evaluation of bone density, considering both the patient and the anatomical location (Morar et al., 2022).

Sogo et al. studied 30 patients and assessed bone density in the posterior maxillary region according to sex, obtaining values between 120 and 1500 HU. The results revealed that the average bone density in males was significantly greater than that in females ($p = 0.038$) (Sogo et al., 2012).

In our study, no statistically significant difference was found between the programs for mandibular premolar areas ($p=0.960$). The median value was 508.5 in Program 1, 540.5 in Program 2, and 530.5 in Program 3. High agreement between the programs was observed (ICC=0.997; $p<0.001$), and the results were consistent in terms of agreement.

This study has several limitations. First, all measurements were obtained using a single CBCT device, which may limit the generalizability of the results to other imaging systems. Second, CBCT-derived HU values represent relative rather than absolute density measurements and may be influenced by imaging parameters and software algorithms. Therefore, the results should be interpreted cautiously and primarily used for comparative rather than absolute assessment of bone density. Another limitation of this study is that intra-observer reliability could not be statistically evaluated, as all measurements were performed once by the same observer under standardized conditions.

CONCLUSION

The success of dental implants primarily depends on achieving sufficient primary stability and successful osseointegration. Increased bone density enhances osseointegration, thereby contributing to improved implant outcomes. However, in addition to bone density, the vascularity of the bone also plays a critical role in implant success.

CBCT enables the quantitative assessment of bone density. While CBCT provides valuable numerical data regarding bone density, it does not allow for a comprehensive structural or qualitative evaluation of the bone. In other words, the internal architecture and vascular characteristics of the bone cannot be assessed via standard CBCT-based measurements alone.

There is a growing need for studies that integrate both quantitative and qualitative assessment methods to evaluate the bone environment more comprehensively and elucidate the multifactorial determinants of dental implant success.

CONFLICT OF INTEREST

The author declare no conflict of interest.

FINANCIAL DISCLOSURE

The author received no financial support for this research.

INFORMED CONSENT

Informed consent was obtained from all individual participants included in the study.

ETHICAL STATEMENT

Ethical approval in accordance with the Declaration of Helsinki was obtained from the Noninterventional Ethics Committee of Cankiri Karatekin University on June 25, 2024, with the application code: E- 6cfe3e88696f42e6.

REFERENCES

Ahmed M, Ikram Y, Qureshi F, Sharjeel M, Ahmed Khan Z, Ataullah K, Memorial Hospital Lahore Pakistan F. (2021). Assessment of Jaw Bone Density In Terms Of Hounsfield Units Using Cone Beam Computed Tomography For Dental Implant. Pak Armed Forces Med J, 71(1): 221-248.

Aranyarachkul P, Caruso J, Gantes B, Schulz E, Riggs M, Dus I, Yamada JM, Crigger M. (2005). Bone Density Assessments of Dental Implant Sites: 2. Quantitative Cone-Beam Computerized Tomography. Int J Oral Maxillofac Implants, 20(3): 416.

Arisan V, Karabuda ZC, Avsever H, Özdemir T. (2013). Conventional multi-slice computed tomography (CT) and cone-beam CT (CBCT) for computer-assisted implant placement. Part I: Relationship of radiographic gray. Clin Implant Dent Relat Res, 15(6): 893-906. https://doi.org/10.1111/j.1708-8208.2011.00436.X

Armstrong R. (2006). Acceptability of cone beam CT vs. multi-detector CT for 3D anatomic model construction. J Oral Maxillofac Surg, 64(9): 37.

Esposito M, Grusovin MG, Coulthard P, Thomsen P, Worthington HV. (2005). A 5-year follow-up comparative analysis of the efficacy of various osseointegrated dental implant systems: a systematic review of randomized controlled clinical trials. Int J Oral Maxillofac Implant, 20: 557-568.

Glide-Hurst C, Chen D, Zhong H, Chetty IJ. (2013). Changes realized from extended bit-depth and metal artifact reduction in CT. Med Phys, 40(6): 061711. https://doi.org/10.1118/1.4805102

Javed F, Ahmed H, Crespi R, Romanos G. (2013). Role of primary stability for successful osseointegration of dental implants: factors of influence and evaluation. Interv Med Appl Sci, 5(4): 162-167.

Kim SH, Kim S, Lee KW, Han DH. (2010). The effects of local factors on the survival of dental implants: a 19-year retrospective study. J Korean Acad Prosthodont, 48(1): 28. https://doi.org/10.4047/jkap.2010.48.1.28

Lindh C, Petersson A, Dr O, Rohlin M. (1996). Assessment of the trabecular pattern before endosseous implant treatment: diagnostic outcome of periapical radiography in the mandible. Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 82(3): 335-343.

Liu J, Chen HY, Dodo H, Yousef H, Firestone AR, Chaudhry J, et al. (2017). Efficacy of cone-beam computed tomography in evaluating bone quality for optimum implant treatment planning. Implant Dent, 26(3): 405-411.

Mikic M, Vlahovic Z, Stevanović M, Arsic Z. (2022). The Importance of Correlation between CBCT Analysis of Bone Density and Primary Stability When Choosing the Design of Dental Implants—Ex Vivo Study. Tomography, 8(3): 1293-1306.

Misch CE. (2021). Misch's Contemporary Implant Dentistry (4th ed.). Elsevier.

Morar L, Băciuț G, Băciuț M, Bran S, Colosi H. (2022). Analysis of CBCT bone density using the Hounsfield scale. Prosthesis, 4(3).

Nackaerts O, Maes F, Yan H, Couto Souza P, Pauwels R, Jacobs R. (2011). Analysis of intensity variability in multislice and cone beam computed tomography. Clin Oral Implants Res, 22(8): 873-879. https://doi.org/10.1111/j.1600-0501.2010.02076.X

Omami G, AlYafi F. (2019). Should cone beam computed tomography be routinely obtained in implant planning? Dent Clin North Am, 63(3): 63-79.

Parsa A, Ibrahim N, Hassan B, Motroni A, Der Van Stelt P, Wismeijer D. (2013). Influence of cone beam CT scanning parameters on grey value measurements at an implant site. Dentomaxillofac Radiol, 42(3).

Pauwels R. (2013). Cone beam CT for dental and maxillofacial imaging: dose matters. Radiat Prot Dosimetry, 165(1-4): 156-161.

Radi IAW, Ibrahim W, Iskandar SMS, AbdelNabi N. (2018). Prognosis of dental implants in patients with low bone density: a systematic review and meta-analysis. J Prosthet Dent, 120(5): 668-677.

Rios HF, Borgnakke WS, Benavides E. (2017). The use of cone-beam computed tomography in management of patients requiring dental implants: an American Academy of Periodontology best evidence review. J Periodontol, 88(10): 946-959.

Romans L. (2025). Computed Tomography for Technologists: A Comprehensive Text (3rd ed.). Philadelphia: Lippincott Williams & Wilkins.

Shokri A, Jamalpour MR, Khavid A, Mohseni Z, Sadeghi M. (2019). Effect of exposure parameters of cone beam computed tomography on metal artifact reduction around the dental implants in various bone densities. BMC Med Imaging, 19(1): 1-10.

Sogo M, Ikebe K, Yang T, Wada M, Maeda Y. (2012). Assessment of bone density in the posterior maxilla based on Hounsfield units to enhance the initial stability of implants. Clin Implant Dent Relat Res, 14(s1).

Trisi P, Rao W. (1999). Bone classification: clinical-histomorphometric comparison. Clin Oral Implants Res, 10(1): 1-7.