BULLETIN OF STOMATOLOGY AND MAXILLOFACIAL SURGERY
Volume 21, Issue 5

DOI: 10.58240/1829006X-2025.21.5-235

THE EFFECT OF DIFFERENT RECONSTRUCTION PARAMETERS ON CONE BEAM CT IN THE ASSESSMENT OF TRABECULAR BONE MICROSTRUCTURE AT PLANNED DENTAL IMPLANT SITES

Mohamed Gamal Saad Elbanna[1*], Gihan Omar[2], Hany Omar[3], Ahmed Mohamed Hossam[4]

[1] Ph.D. candidate at the Department of Oral & Maxillofacial Radiology, Faculty of Dentistry, Cairo University, Egypt. Assistant lecturer at Oral and Maxillofacial Radiology Department Faculty of Dentistry MSA University, Cairo, Egypt.**Email:** mohamed.elbanna@dentistry.cu.edu.eg

[2] Professor of Oral & Maxillofacial Radiology Department, Faculty of Dentistry, Cairo University, Cairo, Egypt.**Email:** gihan.omar@dentistry.cu.edu.eg

[3] Professor of Oral & Maxillofacial Radiology Department, Faculty of Dentistry, Cairo University, Cairo, Egypt.**Email:** hanan.omar@dentistry.cu.edu.eg

[4] Professor of Oral & Maxillofacial Radiology, Faculty of Dentistry, MSA University, Cairo, Egypt.
Email: ahossam@msa.edu.eg

Corresponding author: Mohamed Gamal Saad Elbanna Department of Oral & Maxillofacial Radiology, Faculty of Dentistry, Cairo University, Egypt. Oral and Maxillofacial Radiology Department Faculty of Dentistry MSA University, Cairo, Egypt. **Email:** mohamed.elbanna@dentistry.cu.edu

Received: *May 2. 2025;* ***Accepted:*** *May. 28, 2025;* ***Published:*** *Jun. 30,202*

ABSTRACT

Background: Cone beam computed tomography (CBCT) has become a valuable tool for evaluating trabecular bone microarchitecture before implant placement. However, CBCT-derived measurements may be influenced by reconstruction parameters such as voxel size and threshold level, potentially affecting the reliability of clinical assessments.

Objectives: This study aimed to evaluate the impact of CBCT reconstruction voxel size and threshold values on the measurement of trabecular bone microstructure to guide accurate image processing and interpretation.

Materials and Methods: Twenty-seven patients underwent CBCT scanning with a standard acquisition voxel size of 75 µm³. The images were reconstructed at voxel sizes of 75, 115, and 150 µm³ to assess the influence of reconstruction resolution. Additionally, the effect of threshold variation was examined by modifying the global threshold value by ±15%. Trabecular parameters including bone volume fraction (BV/TV), trabecular thickness (Tb.Th), trabecular number (Tb.N), and trabecular separation (Tb.Sp) were analyzed using CTAnalyser software. Statistical evaluation was performed using one-way ANOVA with Tukey's post hoc test ($p < 0.05$).

Results: Reconstruction voxel size had no significant effect on BV/TV, Tb.Th, or Tb.Sp, but Tb.N differed significantly between the 75 µm and 150 µm voxel sizes ($p = 0.010$). In contrast, threshold variation significantly affected all trabecular parameters ($p < 0.001$), with all pairwise comparisons showing statistical significance.

Conclusion: While CBCT reconstruction voxel size showed limited influence on trabecular metrics, threshold level had a major effect on all measured parameters. These findings emphasize the importance of threshold standardization in clinical CBCT analysis.

Keywords: CBCT, trabecular bone, voxel size, threshold value, bone microstructure, image reconstruction

1. INTRODUCTION

Evaluating the trabecular bone microarchitecture using cone beam computed tomography (CBCT) images prior to implant placement is an increasingly adopted approach in treatment planning, aimed at enhancing the success rate and long-term stability of dental implants [1]. This approach is warranted because the microstructural characteristics of trabecular bone have been demonstrated to significantly influence primary stability at the time of implant placement [2, 3]. Moreover, the condition of the trabecular bone microarchitecture prior to implant placement serves as a reliable predictor of primary implant stability [4]. However, the evaluation of trabecular bone parameters from CBCT images may be

affected by the reconstruction settings employed during image processing, including reconstruction parameters such as voxel size and threshold values.
The reconstruction voxel size refers to the voxel dimensions applied during the image reconstruction process from raw data. Typically, a larger reconstruction voxel size than that used during image acquisition is selected to decrease reconstruction time, minimize computational demands and reduce the radiation dose[5]. This approach is commonly employed in certain applications, such as the analysis of large-scale finite element models derived from micro-CT-based imaging [5-7]. However, it is generally assumed that utilizing a reconstruction voxel size larger than the acquisition voxel size may lead to a reduction in image accuracy [8]. Previous investigations into the effects of CBCT reconstruction voxel size have predominantly addressed its influence on image quality [9] and the three-dimensional assessment of dental morphology [10]. However, the influence of reconstruction voxel size on the measurement of trabecular bone microstructure remains insufficiently understood.
Segmentation refers to the process of distinguishing bone or soft tissue from surrounding structures in imaging, a procedure that can be influenced by the selected threshold values [11]. Numerous studies have employed micro-computed tomography (μCT) to examine the impact of threshold values on trabecular microstructural parameters, including trabecular number (Tb.N), trabecular thickness (Tb.Th), trabecular spacing (Tb.Sp), and bone volume fraction (BV/TV), particularly in small animal models [12]. While numerous studies have explored scanning parameters in μCT, research on the influence of reconstruction parameters in CBCT remains limited. Given the emerging use of CBCT for assessing trabecular bone to support surgical treatment planning, it is essential to investigate how CBCT reconstruction parameters affect these measurements. Thresholding is widely employed for image segmentation due to its simplicity and practicality, particularly in bone volume measurements [13]. Consequently, this study also examines the impact of threshold values on the quantification of trabecular bone microstructure.

OBJECTIVES

This study aimed to evaluate how different CBCT image reconstruction settings specifically, the threshold value and voxel size affect the analysis of trabecular bone microstructure.The goal is to offer clinicians evidence-based recommendations for selecting appropriate voxel sizes and threshold settings when reconstructing CBCT images for accurate assessment of trabecular bone features.

MATERIAL AND METHODS

27 patients were referred from the oral and maxillofacial surgery clinic, Faculty of dentistry MSA university, Giza, Egypt to take a pre implant CBCT scan (Medically free male or female patients,age ranging from 20 to 40 years) any patient with developmental anomalies or pathological conditions affecting the edentulous area were excluded from the study(Fig.1). The study protocol was approved by the Ethics Committee of fucalty of dentistry cairo university, and informed consent was obtained from all participants.

Figure 1. NewTom Gino HR CBCT Machine

Every Patient was imaged once using CBCT System (NewTom Gino HR) Fig (1) at Oral and Maxillofacial Radiology department. Faculty of Dentistry, MSA University. The CBCT scanning parameters employed in this study included a voxel size of 75 μm³, a field of view (FOV) of 6 × 6 cm, and a 360° arm rotation. Image acquisition was performed at 70 kV, 8 mA, and an exposure time of 11.3 seconds. Later on, another 2 volumes were reconstructed with voxel size 115, 150 μm³ respectively. The patients' heads were positioned where the mid-sagittal plan perpendicular to the floor and the Frankfort plane was parallel to the floor. The acquired images were converted to DICOM format and imported into DataViewer (version 1.5, SkyScan, Kontich, Belgium) to generate Axial views for subsequent image processing and analysis using CTAnalyser software (version 1.15, SkyScan, Kontich, Belgium).
Image reconstruction was performed using three different voxel sizes 75, 115 and 150 μm³ resulting in three distinct datasets Fig (2). For the initial dataset, a region of interest (ROI) measuring 14 × 8 mm was selected for the reconstructed volume at a voxel size of 75 μm³. The identical ROI was subsequently used for the reconstructed remaining two datasets with voxel sizes of 115 μm³ and 150 μm³, respectively (Fig. 2). Accordingly, three sets of ROIs were obtained, each of which was thresholded and binarized using a global threshold value automatically generated by CTAnalyser software (version 1.15, SkyScan, Kontich, Belgium).

This automatically generated global value was adopted as the optimal threshold for each patient in the study. Subsequently, trabecular bone analysis was conducted using the same software to evaluate the influence of varying reconstruction voxel sizes on the measurement of trabecular bone parameters, including trabecular number (Tb.N), trabecular thickness (Tb.Th), trabecular spacing (Tb.Sp), and bone volume fraction (BV/TV

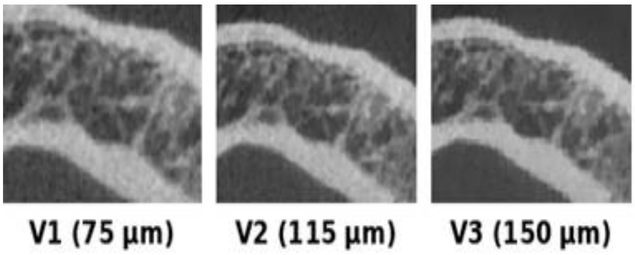

Figure 2. Three reconstructed images using voxel size of 75 µm3 (V1), 115 µm3 (V2) and 150 µm3 (V3)

To evaluate the effect of varying threshold values on the CBCT datasets, the first dataset with voxel size 75 µm³ was used as the baseline. Three datasets were generated by adjusting the global threshold value as follows: Dataset A with the original automatically generated global value and was used as a reference, and Datasets B 15% decrease and C with a 15% increase relative to the original global threshold value (Fig. 3). All three datasets were imported into CTAnalyser software (version 1.15, SkyScan, Kontich, Belgium) for ROI selection. Subsequently, three dimensional analyses were conducted to assess trabecular bone parameters, including trabecular number (Tb.N), trabecular thickness (Tb.Th), trabecular spacing (Tb.Sp), and bone volume fraction (BV/TV).

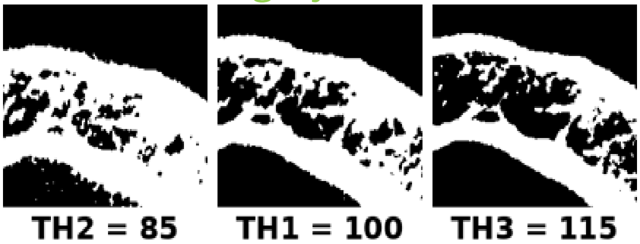

Figure. 3 Images were thresholded ±15% from the global threshold value (85, 100: global threshold value and 115) and binarised in the CTAnalyser software

STATISTICAL ANALYSIS

All statistical analyses were performed using the Microstat7 for Windows statistical package (Microstat Co). The normality of the data was confirmed using the Kolmogorov–Smirnov test, which showed no significant deviation from a normal distribution (D = 0.11226, p = 0.84844). One-way analysis of variance (ANOVA) was conducted to evaluate the effect of voxel size (75 µm, 115 µm, 150 µm) and threshold level (+15%, global, –15%) on trabecular bone microstructure parameters including bone volume fraction (BV/TV), trabecular thickness (Tb.Th), trabecular number (Tb.N), and trabecular separation (Tb.Sp). When significant differences were found, post hoc comparisons were conducted using Tukey's test. A p-value < 0.05 was considered statistically significant.

RESULTS

Effect of Voxel Size

No statistically significant differences were observed in bone volume percent (BV/TV), trabecular thickness (Tb.Th), or trabecular separation (Tb.Sp) among the three voxel sizes (p = 0.860, 0.184, and 0.078, respectively). However, trabecular number (Tb.N) showed a statistically significant difference between the 75 µm and 150 µm voxel sizes (p = 0.010), indicating sensitivity to voxel resolution for this parameter. Table 1

Table 1. Effect of Voxel Size on Trabecular Parameters

Parameter	75 µm (Mean ± SD)	115 µm (Mean ± SD)	150 µm (Mean ± SD)	p-value
Bone Volume Percent (BV/TV %)	52.25 ± 22.42	49.41 ± 22.50	49.06 ± 24.88	0.860
Trabecular Thickness (µm)	534.3 ± 166.15	554.71 ± 163.10	616.52 ± 177.77	0.184
Trabecular Number (1/µm)	0.00095 ± 0.0002	0.00085 ± 0.0003	0.00076 ± 0.0003	0.015
Trabecular Separation (µm)	540.02 ± 180.63	597.55 ± 188.22	658.79 ± 201.10	0.078

Effect of Threshold Level

Threshold variation significantly influenced all trabecular bone parameters. Statistically significant differences ($p < 0.001$) were found in bone volume percent, trabecular thickness, trabecular number, and trabecular separation across all three threshold levels (+15%, global, –15%). Post hoc Tukey tests confirmed that all pairwise comparisons were statistically significant ($p < 0.001$), indicating a high sensitivity of these measurements to threshold selection. Table 2

Table 2. Effect of Threshold on Trabecular Parameters

Parameter	+15% (Mean ± SD)	Global (Mean ± SD)	-15% (Mean ± SD)	p-value
Bone Volume Percent (BV/TV %)	20.88 ± 10.22	40.61 ± 14.53	66.14 ± 15.08	<0.001
Trabecular Thickness (µm)	404.85 ± 95.87	517.33 ± 115.77	680.54 ± 143.37	<0.001
Trabecular Number (1/µm)	0.0005 ± 0.0002	0.0008 ± 0.0002	0.0010 ± 0.0002	<0.001
Trabecular Separation (µm)	875.55 ± 149.59	718.89 ± 156.97	494.59 ± 140.89	<0.001

DISCUSSION

Trabecular bone plays a central role in bone metabolism due to its high turnover rate [2], making its microstructural assessment crucial for evaluating bone quality. µCT is widely recognized as the gold standard for such assessments because of its proven accuracy and reproducibility [14]. However, its application in clinical settings is limited, as it requires invasive bone removal and cannot be used for longitudinal assessment in living patients.

In recent years, CBCT has emerged as a promising alternative. Multiple studies have demonstrated that CBCT provides valid and reliable assessments of trabecular bone microstructure when compared with µCT [15–18]. Tayman et al. reported excellent agreement between µCT and CBCT in assessing trabecular parameters, although they noted potential discrepancies due to differences between in vivo and ex vivo bone samples [19]. Notably, the current study is the first to investigate these parameters in vivo in human patients, providing clinically relevant insights.

Previous research by Aso et al. using a sheep head model found no significant effect of CBCT reconstruction voxel size on trabecular measurements but called for further investigation using human data [20]. Additionally, it has been shown that while scanning parameters (e.g., voxel size, FOV, rotation) are known to influence CBCT output [21], the impact of reconstruction parameters such as voxel size and threshold level remains underexplored, particularly in human subjects [22, 23].

In this study, CBCT images acquired at a scanning voxel size of 75 µm³ were reconstructed at 115 µm³ and 150 µm³. The results revealed no significant differences in bone volume percent (BV/TV), trabecular thickness (Tb.Th), or trabecular separation (Tb.Sp). A significant difference was only observed in trabecular number (Tb.N) between 75 µm³ and 150 µm³, suggesting limited sensitivity of most parameters to changes in reconstruction voxel size. These findings align with Aso et al.'s results on animal models and with prior work on mandibular cadaveric samples, except for Tb.N [20, 24].

Interestingly, our results contrast with earlier µCT studies, which indicated that BV/TV and Tb.Th are susceptible to reconstruction voxel changes when images scanned at 21 µm³ were reconstructed at 50 or 110 µm³ [8, 25]. This discrepancy may be attributed to the higher original scanning resolution used in µCT compared to CBCT. The influence of voxel size is more pronounced when the difference between scanning and reconstruction resolution is substantial, as shown previously [8, 25].

In contrast to voxel size, threshold level had a significant impact on all trabecular bone parameters in our study. Lowering or increasing the threshold by 15% from the global value significantly altered BV/TV, Tb.Th, Tb.N, and Tb.Sp. These findings corroborate prior research highlighting the sensitivity of threshold selection in trabecular analysis using µCT [26, 27]. Our results also partially agree with Aso et al.'s findings; while both studies observed changes upon lowering the threshold, our study found significant differences with increased thresholds as well. This discrepancy may stem from the in vivo nature of our data, as bone microstructure and mineral concentration may differ in living versus post mortem tissue.

Some variability in measurement may also be due to partial volume effects, which can blur the boundary between trabeculae and surrounding voxels, especially at lower resolutions [28]. Although some studies suggest that Tb.N is less sensitive to threshold variations within realistic limits, our findings showed consistent significant changes across all threshold levels tested.

There are, however, limitations to acknowledge. µCT was not used for validation in this study due to its invasive nature and computational demands. Despite this, numerous studies have shown strong correlations between CBCT and µCT for trabecular measurements [17, 29], supporting the reliability of CBCT in this context.

Further studies comparing different CBCT reconstruction settings are recommended to enhance the validity of these findings and support the clinical application of CBCT in evaluating trabecular bone microstructure.

Conclusion

This study demonstrated that variations in CBCT reconstruction voxel size had minimal impact on trabecular bone microstructure measurements, with only trabecular number (Tb.N) showing sensitivity between the smallest and largest voxel sizes. In contrast, threshold level significantly affected all evaluated parameters, indicating its critical role in image segmentation and analysis, among the metrics evaluated, trabecular number appears to be the most consistent and least affected by threshold variations. These findings highlight the importance of standardized threshold selection in clinical assessments using CBCT. Further research involving different CBCT systems and reconstruction protocols is recommended to confirm the generalizability of these results in broader clinical settings.

Author Contributions

- **Mo Gamal:** A- research concept and design; B – collection and\or assembly of data; C – data analysis and interpretation; D – writing the article; F – final approval of article
- **Gihan Omar:** A – research concept and design; B – data analysis and interpretation; E – critical revision of the article; f – final approval of the article
- **Hany Omar:** B – data analysis and interpretation; E – critical revision of the artical; F – final approval of artical
- **Ahmed Mohamed Hossam:** B – collection and\or assemply of data; E – criticle revision of the article; F – final approval of article

DECLARATIONS

Funding

No funding was received from any financially supporting body, and there was no associated grant number.

Competing interests

The authors declare no competing interests.

Ethical approval

Institutional review board statement: The study protocol was approved by the Ethics Committee of fucalty of dentistry Cairo university, Egypt (Approval Number: 6/7/23)

REFERENCES

1. DeTolla DH, Andreana S, Patra A, Buhite R, Comella B. The role of the finite element model in dental implants. J Oral Implantol. 2000;26:77–81.
2. Sakka S, Coulthard P. Bone quality: a reality for the process of osseointegration. Implant Dent. 2009;18:480–5.
3. Fanuscu MI, Chang TL. Three-dimensional morphometric analysis of human cadaver bone: microstructural data from maxilla and mandible. Clin Oral Implants Res. 2004;15:213–8.
4. Ibrahim N, Parsa A, Hassan B, Van der Stelt P, Wismeijer D. Diagnostic imaging of trabecular bone microstructure for oral implants: a literaturereview. Dentomaxillofac Radiol. 2013;42:20120075.
5. Homminga J, Huiskes R, Van Rietbergen B, Rüegsegger P, Weinans H. Introduction and evaluation of a gray-value voxel conversion technique. JBiomech. 2001;34(4):513–7.
6. Ladd AJ, Kinney JH, Haupt DL, Goldstein SA. Finite-element modeling of trabecular bone: comparison with mechanical testing and determination of tissue modulus. J Orthop Res. 1998;16:622–8.

7. Van Rietbergen B, Müller R, Ulrich D, Rüegsegger P, Huiskes R. Tissue stresses and strain in trabeculae of a canine proximal femur can be quantified from computer reconstructions. J Biomech. 1999;32:165–73.

8. Kim D-G, Christopherson GT, Dong XN, Fyhrie DP, Yeni YN. The effect of microcomputed tomography scanning and reconstruction voxel size on the accuracy of stereological measurements in human cancellous bone. Bone. 2004;35:1375–82.

9. Tanimoto H, Arai Y. The effect of voxel size on image reconstruction in cone-beam computed tomography. Oral Radiol. 2009;25:149.

10.Hassan B, Souza PC, Jacobs R, de Azambuja BS, van der Stelt P. Influence of scanning and reconstruction parameters on quality of three-dimensional surface models of the dental arches from cone beam computed tomography. Clin Oral Investig. 2010;14:303–10.

11. Sharma N, Aggarwal LM. Automated medical image segmentation techniques. J Med Phys. 2010;35:3.

12.Christiansen BA. Effect of micro-computed tomography voxel size and segmentation method on trabecular bone microstructure measures in mice. Bone reports. 2016;5:136–40.

13. Ulrich D, van Rietbergen B, Weinans H, Rüegsegger P. Finite element analysis of trabecular bone structure: a comparison of image-based meshing techniques. J Biomech. 1998;31:1187–92.

14.Nishiyama KK, Campbell GM, Klinck RJ, Boyd SK. Reproducibility of bone micro-architecture measurements in rodents by in vivo microcomputed tomography is maximized with threedimensional image registration. Bone Journal 2010;46:155-161

15.Van Dessel J, Nicolielo LF, Huang Y, Coudyzer W, Salmon B, Lambrichts I, Jacobs R. Accuracy and reliability of different cone beam computed tomography (CBCT) devices for structural analysis of alveolar bone in comparison with multislice CT and micro-CT. Eur J Oral Implantol. 2017;10(1):95–105.

16.Kulah K, Gulsahi A, Kamburoğlu K, Geneci F, Ocak M, Celik HH, OzenT. Evaluation of maxillary trabecular microstructure as an indicator of implant stability by using 2 cone beam computed tomography systems and micro-computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol. 2019;127(3):247–56.

17.Van Dessel J, Huang Y, Depypere M, Rubira-Bullen I, Maes F, Jacobs R. A comparative evaluation of cone beam CT and micro-CT on trabecular bone structures in the human mandible. Dentomaxillofac Radiol.2013;42(8):20130145.

18.Van Dessel J, Nicolielo LF, Huang Y, Slagmolen P, Politis C, Lambrichts I, et al. Quantification of bone quality using different cone beam computed tomography devices: accuracy assessment for edentulous human mandibles. Eur J Oral Implantol. 2016;9(4):411–24.

19.Tayman MA, Kamburoğlu K, Ocak M, Özen D. Effect of different voxel sizes on the accuracy of CBCT measurements of trabecular bone microstructure: A comparative micro-CT study. Imaging Sci Dent. 2022;52(2):171-179

20.Muhammad, A.M.A., Ibrahim, N., Ahmad, R. et al. Effect of reconstruction parameters on cone beam CT trabecular bone microstructure quantification in sheep. BMC Oral Health 2020;10.1186/s12903-020-1035-7.

21.Bechara B, McMahan CA, Moore WS, Noujeim M, Geha H, Teixeira FB. Contrast-to-noise ratio difference in small field of view cone beam computed tomography machines. J Oral Sci. 2012;54:227–32.

22.Pauwels R, Faruangsaeng T, Charoenkarn T, Ngonphloy N, Panmekiate S. Effect of exposure parameters and voxel size on bone structure analysis in CBCT. Dentomaxillofac Radiol. 2015;44:20150078

23.Maret D, Telmon N, Peters O, Lepage B, Treil J, Inglèse J, et al. Effect of voxel size on the accuracy of 3D reconstructions with cone beam CT. Dentomaxillofac Radiol. 2012;41:649–55.

24.Bilgili E. Influence of Voxel Size on Evaluation of Trabecular Bone Microstructure on Human Mandibles: A CBCT Study. J Basic Clin Health Sci. 2022; 6: 791-797.

25.Yeni YN, Christopherson GT, Dong XN, Kim D-G, Fyhrie DP. Effect of microcomputed tomography voxel size on the finite element model accuracy for human cancellous bone. J Biomech Eng. 2005;127:1–8.

26.Waarsing JH, Day JS, Weinans H. An improved segmentation method for in vivo μCT imaging. J Bone Miner Res. 2004;19:1640–50.

27.Rüegsegger P, Koller B, Müller R. A microtomographic system for the nondestructive evaluation of bone architecture. Calcif Tissue Int. 1996;58:24–9.

28.Hara T, Tanck E, Homminga J, Huiskes R. The influence of microcomputed tomography threshold variations on the assessment of structural and mechanical trabecular bone properties. Bone. 2002;31:107–9.

29.Ibrahim N, Parsa A, Hassan B, van der Stelt P, Aartman IH, Wismeijer D. Accuracy of trabecular bone microstructural measurement at planned dental implant sites using cone-beam CT datasets. Clin Oral Implants Res.2014;25:941–5.