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Reliability of Three-Dimensional Micro-Computed Tomography Root Canal Analysis Using Drishti Software: A Pilot Study

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Cover Page Footnote

I would like to convey my profound gratitude to the Department of Geology at the University of Malaya for providing us with the microcomputed tomography (micro-CT) scanner, which was important in carrying out our work. Lastly, I would like to express my gratitude to my family for their unwavering support and encouragement during my academic journey.

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ORIGINAL ARTICLE

Reliability of Three-Dimensional Micro-Computed Tomography Root Canal Analysis Using Drishti Software: A Pilot Study

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ABSTRACT

In recent years, micro-computed tomography (micro-CT) has become a promising tool for non-destructive imaging and the study of root canal morphology in endodontics. However, the reliability of such analyses heavily relies on the accuracy and consistency of the software used for image processing. **Objective**: This study aims to investigate the reliability of two different micro-CT voxel sizes using open-source three-dimensional (3D) software (Drishti v3.0) used to identify and quantify the Apical Foramen (AF) and Apical Constriction (AC) in mandibular premolars. **Methods**: Eight mandibular premolars were divided into two groups, with four samples in each group. Samples were scanned using a ZEISS X-Radia 520 Micro-CT system with two different voxel sizes of 23 µm (Group A) and 17 µm (Group B), respectively. The micro-CT data were reconstructed and transferred to Drishti Software, and individual image rendering was performed to visualize the images for data analysis. The position and measurement of AF and AC to the anatomical apex were measured individually and independently by single operators. **Results**: The reliability of the measurements assessed using Intraclass Correlation Coefficients (ICCs) between two voxel sizes was excellent and on par with previous research. This pilot study suggested that results for voxel sizes of 23 µm and 17 µm were comparable. Both voxel size 3D images demonstrated excellent and high-quality visualization of the root canal configuration, lateral and accessory canals, apical deltas, major AF, and AC. **Conclusion**: It is feasible and reliable to visualize and analyze 3D micro-CT images using open-source software (Drishti v3.0). Both voxel sizes of 23 µm and 17 µm are recommended for use in root canal study.

Key words: Drishti software, high-resolution 3D images, micro-CT study, root canal configuration

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INTRODUCTION

Anatomical variations of the root canal system are frequent in specialized endodontic practice and pose a challenge that must be resolved with compassion and thoroughness, starting with a precise diagnosis phase, and establishing the most efficient treatment plan. The complexity of root canal morphology cannot be observed in conventional radiographs (two-dimensional (2D) radiographs). Hence, the researchers discovered the complexity of root canal morphology using the three-dimensional (3D) radiograph. This includes the use of cone-beam computed tomography (CBCT) and micro-computed tomography (micro-CT) technology to help the clinician and researcher understand the variation of root canals, thereby facilitating the treatment of complex root canal morphology.[1-4]

Micro-CT used in endodontics enables 3D evaluation of variation in root canal morphology, C-shaped canals, root canal preparation, and obturation quality, allowing for the detection of failure zones and voids.[5-7] Micro-CT systems with high-resolution detectors and micro-focal spot X-ray sources enable projections to be rotated via different viewing directions to create 3D reconstructed photographs of material.[8] Even though the micro-CT machine produced high-resolution micro-CT images for research analysis, the researchers might still face difficulties reconstructing the 2D images into 3D images due to cost-effectiveness, technical difficulties, and a lack of knowledge about the right conditions, settings, and software.[9] The review study published the micro-CT analysis utilized in assessing root

canal configuration with various micro-CT machine types, voxel sizes, and software types to produce the 3D images in the investigations.[10] To enable greater resolution for prospective implementation in subsequent investigations, the appropriate methodological refinement was required. Despite the difficulty in obtaining data, it appears that a significant number of researchers concur that micro-CT provides more objective information than conventional 2D radiograph approaches.[11]

The major goal of the current investigation was to evaluate two different micro-CT voxel sizes using open-source 3D software intended for generating micro-CT images in a forthcoming large-scale study. This preliminary study was crucial for determining whether any adjustments were needed to the study protocol before proceeding with the main research. Specifically, we wanted to see if Drishti software developed by Ajay Limaye, an open-source 3D software, could effectively generate 3D images in a real micro-CT examination of the apical morphology of mandibular premolars in a specific Malaysian subpopulation.

METHODS

Samples selection

Eight extracted mandibular premolars were selected for this study, comprising 10% of the anticipated sample size for the main study, in accordance with predetermined inclusion and exclusion criteria. The teeth included in this study were extracted for various reasons, including irreversible pulpitis, orthodontic reasons, or periodontal issues. Prior to extraction, patient demographic data, clinical history, and pre-operative periapical radiographs were collected. The inclusion criteria for the selected tooth include the age of the patient, 13 years and above, the permanent mandibular premolar tooth with a straight or curved root, and the tooth with a mature apex. Meanwhile, the exclusion criteria included the tooth with a sign of root caries, the tooth with a sign of root and crown fracture, and the tooth with an immature apex.

Samples preparation

This study was approved by the ethics committee of the Universiti Teknologi MARA (UiTM), Sg Buloh, Malaysia, with references 600-TNCPI (5/1/6); REC/12/2021(MR 930). In addition, the study was performed in accordance with the 1964 Declaration of Helsinki and its later amendments. Moreover, written informed consent was obtained from all the participants prior to inclusion in this study.

The samples were cleaned from debris and calculus, and then each sample was kept in an individual plastic container soaked with Chlorhexidine 2% solution. Prior to scanning, the samples will be dried and submitted for micro-CT scanning at the Department of Geology, University of Malaya, divided into two groups, and two groups of four samples each were scanned using a ZEISS X-Radia Context Micro-CT system. Two samples were included per scanning to reduce the cost of the study budget, and each scanning will provide the raw data for two teeth.

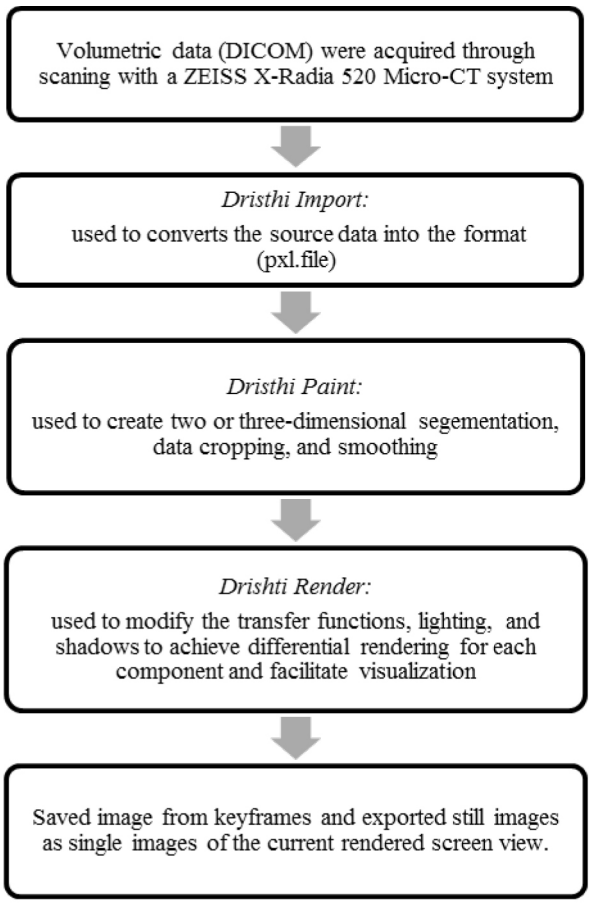

Figure 1. The general workflow of Drishti software for 3D reconstruction and visualization.

Micro-CT imaging

Each group (n = 4) was scanned with ZEISS X-Radia Context Micro-CT systems with parameters of 80kVP, 0.5mm aluminum filter, 3.3 second exposure time, angular rotation 9.92°, and 360° scanning. Two different voxel sizes were utilized: 23 µm for Group A and 17 µm for Group B. The different resolutions of voxel sizes 23 µm (Group A) and 17 µm (Group B) were selected before the micro-CT scanning of the samples based on the previous systematic review study.[10] The micro-CT datasets were then reconstructed using ZEISS Scout-and-Scan Control System Reconstructor software (Carl Zeiss, CA, U.S.A.). Each data in the form of DICOM was imported into Drishti Import according to basic Drishti v3.0 design workflow by Ajay Limaye to form the pxl. File.[12] Then, the pxl. file was imported into Drishti Paint and Drishti Render for segmentation

and manipulation for our data collection (Figure 1). The parameters and measurement of the major Apical Foramen (AF) and minor AF (Apical Constriction (AC) were determined.

Statistical analysis

A single examiner, specifically a postgraduate student who received training and calibration from two supervisors, carried out the evaluation of parameter measurements and data interpretation derived from the analysis of three-dimensional (3D) visualizations. The examiner conducted two measurements for each parameter, with a one-month interval between each measurement. The assessment of measurement repeatability by a single examiner was conducted using the intraclass correlation coefficient (ICC). In contrast, the determination of mean differences between two measurements (group A and group B) was performed using an independent t-test.

RESULTS

The image root canal morphology includes the number of canals, lateral canal, major and minor foramina, and apical deltas

The micro-CT images displayed in the Drishti v3.0 software were of good quality and demonstrated the complexity of the root canal system for both voxel sizes. Both voxel sizes produced images with greater clarity, higher resolution, and superior quality (Figure 2 and 3).

The parameters: Apical foramen, apical constriction, anatomical apex, distance from apical foramen to anatomical apex, distance from apical constriction to anatomical apex

According to our pilot study, the micro-CT analysis and reconstruction of 3D images utilizing the Drishti v3.0 software gave the essential parameters for the real study design. The mean and standard deviation for two different voxels are summarized in Table 1.

The average distances between the AF and anatomical Apex (AFA) in Groups A and B were 0.589 mm and 0.423 mm, respectively, while the average distance between the AC and anatomical Apex (ACA) in Group A was 0.677 mm, and Group B was 0.650 mm. However, neither group of the study, Groups A nor B, demonstrated significantly different means. (Table 2)

The root canal measurements (quantitative analysis) include the minor and major diameters of the AF and AC. In contrast, the morphometric analysis consists of the location of the major foramen, lateral canals, isthmus, or apical deltas in mandibular premolars visualized with high-quality resolution in both groups.

This study demonstrated that both voxel resolutions, 17 µm, and 23 µm, produced a higher resolution and high

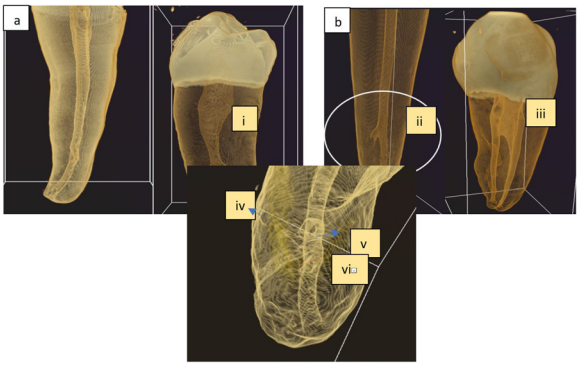

Figure 2. 3D reconstruction of root using Drishti v3.0 of micro-CT images with the resolution of voxel sizes 23 µm (a) and 17 µm (b). Both resolution voxel sizes provided by the internal root canal morphology include the root canal types (i and iii), the lateral canal (iv), and the main canal (v), apical deltas (ii), and major AF (vi).

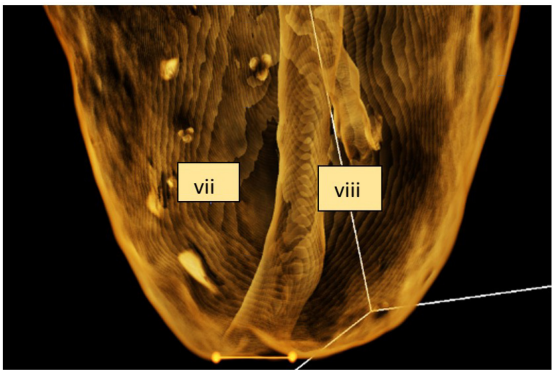

Figure 3. The diameter of AF and height distance from AC to mid AF. The micro-CT image displayed the internal apical morphology, including the major AF, which is indicated as a blue line (vii), and the minor AF (AC), which is indicated as an orange line (viii).

Table 1. Demographic data.

	n	Min	Max	Mean	Std. Deviation (SD)
AFA	8	0.203	0.99	0.50612	0.263
ACA	8	0.418	1.17	0.66362	0.252
HEIGHT	8	0.154	0.653	0.37575	0.155

Table 2. Means and standard deviations of measurement (mm) of the AF and AC in mandibular premolar teeth using different voxel size of the micro-CT system.

Parameters (mm)	Voxel Size		F value	p
	Group A (23 µm)	Group B (17 µm)		
Apical Foramen to Apex (AFA)	0.589	0.423	0.11	0.921
Apical Constriction to Apex (ACA)	0.677	0.650	1.23	0.310
Height/Distance from mid-AF to AC	0.367	0.385	0.51	0.502

quality of internal anatomy. In addition, the Drishti v3.0 can be rendered to visualize the individual images or tooth samples that were previously scanned two samples per scan.

DISCUSSION

Endodontic research has benefited from using micro-CT in several ways, including the study of anatomical aspects, treatment outcomes, and endodontic material properties. To obtain outstanding results without interferences, numerous variables should be considered when photographing and processing them. It is challenging to implement protocols, but improvements can be made in this step to obtain valid and accurate qualitative and quantitative results. This is due to the fact that there is a lack of information in the current literature, particularly in the 3D reconstruction of the image projections obtained from micro-CT scans.

Moreover, there is a lack of knowledge in the recent literature regarding the standardization of essential parameters. This consists of data gathering and reconstructions, which must be established prior to the micro-CT evaluation, as well as the impact of these variables on the assessment in endodontic research, comprising evaluation of root morphology, measurement of AF, the quality of root canal preparation, and obturation.[4,13] A previous study brought up the issue of micro-CT research in dentistry and thoroughly examined the progress and use of micro-CT in dentistry. It may have also included a comparison with other 3D radiographic techniques useful for research purposes.[9] Therefore, to obtain the most accurate and thorough outcomes, it is crucial to perform a precise reconstruction of the micro-CT images for research objectives in the fields of dentistry and endodontics. The non-destructive micro-CT study allows for a thorough investigation of the root canal system in three dimensions and the evaluation of its effects on different procedures.[14]

The apical portion of the root canal and the physical shape, location, and diameter of the foramen are unable to be precisely and clinically identified. Micro-CT is one technique for examining its particular morphology, offering an in-depth, 3D image and performing in-vivo and ex-vivo sections. However, its application is constrained by the expensive and necessary equipment. Furthermore, several micro-CT studies investigated the apical morphology and root canal anatomy in single and multirooted teeth and their application in dental education.[9,15,16] Notably, micro-CT studies are costly and require higher costs; therefore, selecting the right 3D software, particularly free or inexpensive 3D software, was crucial. Hence, estimating and reducing the research expenditure will aid the researchers. In addition, it will assist the researchers in estimating and minimizing the research costs. A recent study utilized micro-CT imaging and the Drishti software to examine the AF in mandibular premolars.[17] The study demonstrated that the micro-CT images offer precise and reliable information on the internal root canal.

In our pilot study, the Drishti v3.0 was utilized to visualize the 3D micro-CT images with two different resolutions of the voxel size of the micro-CT scanner, and both results exhibited no statistically significant differences. The open-source 3D software (Drishti v3.0) was recommended as a research tool for visualization and quantitative and qualitative analysis in dental research with suggested resolution voxel sizes of 23 μm and 17 μm.

CONCLUSION

Within the limitations of this study, we found that the use of Drishti software in micro-CT root canal analysis exhibited promising reliability, highlighting its potential for enhancing endodontic treatments and improving patient outcomes. This pilot study advocates for the continued utilization of micro-CT technology coupled with open-source software for comprehensive root canal analysis. The recommendation of both 23 μm and 17 μm voxel sizes provides flexibility to researchers, allowing them to choose the appropriate resolution based on specific study requirements. Moving forward, further research in this area could explore the application of micro-CT in clinical settings and investigate its potential impact on endodontic treatment planning and outcomes.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest to disclose.

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I would like to convey my profound gratitude to the Department of Geology at the University of Malaya for providing us with the micro-CT scanner, which was crucial in conducting our work. Lastly, I would like to express my gratitude to my family for their unwavering support and encouragement during my academic journey.

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