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Accuracy of Dental Operating Microscope versus CBCT in detecting number of root canals for maxillary first molars indicated for retreatment

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Abstract:

One of the main causes of root canal treatment failure, whether primary treatment of retreatment is a practitioner's inability to locate and disinfect all canals present in a root canal system. This notion have been proven time and time again in literature, and hence canal detection aids such as Cone beam computer tomography (CBCT) scans and Dental operating microscopes (DOM) are becoming of more importance and value in the daily clinical life of an endodontist. CBCT scans while currently regarded as the gold standard in terms of an aide in canal detection, cannot be used in every case to avoid exposing patients to high radiation dose. Furthermore, errors in CBCT scan segmentation have been recorded due to inexperience of some practitioner. However, DOM may be a useful aid which avoids the high radiation dose and segmentation errors met when using CBCT scans. **Aim:** to determine the diagnostic accuracy of dental operatong microscopes in detecting the number of canals present in maxillary first molars indicated for retreatment in comparison to CBCT scans. **Materials and methods:** Thirty-six patients with obturated upper first molars, indicated for retreatment were included in this study. A pre-treatment periapical x-ray was taken to aid practitioner in access cavity preparation. A pre-operative CBCT scan was taken for all patients, but not shown to the practitioner performing the access cavity. **CBCT stage:** CBCT scans performed of all participants was randomly distributed upon endodontic specialists for segmentation and the number of canals was recorded. **Clinical stage:** patients were randomly distributed upon 6 endodontic post graduate students* students enrolled in the endodontic master's program at MIU*. The students then proceeded to form access cavities, remove root canal filling, and record the number of canals found. The Data collected in both stages was then compared.

Result: Kappa = 0.930 indicates that there was a very good agreement between the number of canals that were found by means of CBCT and the clinical examination that was performed using a dental operating microscope. The P-value for the two different approaches was 0.097, which indicates that there was no statistically significant difference between the number of canals that were found.

Conclusion: There was no significant difference between detected number of canals by the CBCT and

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dental operating microscope

Introduction:

Root canal treatment is a process in which many objectives must be met in order to avoid treatment failure. These objectives include a thorough cleaning and shaping of the root canal space, as well as, a proper three dimensional filling of the cleaned space. However, one of the most important objectives of root canal treatment is identification of a canals present in root canal system, as a missed canal is one of the main causes which lead to treatment failure. (1) (2)

According to literature, the main reasons why practitioners fail to locate and treat canals are a lack of knowledge of root canal anatomy or a lack of access to proper canal detection modalities, such as dental operating microscopes (DOM) or cone beam computer tomography (CBCT) to aid in canal detection, especially in complicated cases such as those with blocked canals due to calcifications, posts, of broken instrument fragments. (3)(4)

Furthermore, many practitioners who fail to locate all canals present in a root canal system, still depend solely on two- dimensional imaging modalities, which according to Estrella et al (5), when compared to DD imaging modalities such as CBCT scans, 2-D imaging, showed much less accuracy, and that 2-D imaging modalities, when used for detection of apical periodontitis or canal morphology should be used with care because of the high possibility of false-negative results.

The maxillary first molar is a permanent molar known to have variations and complexities regarding its root canal system. These complexities are most known in the form of extra canals or morphological complexities in the canals present. Most notably, the presence a second mesio-buccal canal is quite common in maxillary first molars, with a high incidence rage between 30%-97%, which is suspected to be due to difference in race.(6)Furthermore, according to Walcott et al, retreatment cases exhibit a higher incidence of missed MB2 canals than initial treatment cases, which consequently may lead to a higher chance of bacterial multiplication and recurrence of infection, manifested clinically in the form of persistent pain and radiographically in the form of presence of a persistent periapical lesion(7)

CBCT may provide a non-invasive solution to deter the incidence and post-operative effect of missed canals in root canal treatment. CBCT scans are capable of providing practitioners with an accurate and high resolution 3-D representation of the internal root canal configuration. The scans 3-dimensional natures help avoid problems caused by superimposition of surrounding anatomical structures, seen in their 2-dimensional counterparts. In addition, as opposed to micro-CT, which is capable of providing an even more detailed vie of the internal canal configuration, CBCT scans have an alterable field of view (FOV) and a radiation dose which permits their clinical use (8). However, according to Vizzotto et al, CBCT scans sensitivity and specificity regarding canal detection in retreatment cases can be affected in cases where the canals were previously obturated or in cases where large voxel size was used. Therefore they recommended the removal of root canal filling material, as well as, using limited FOV to assure the use of the smallest voxel size, assuring the highest resolution possible.(9)

Another aide that if used could significantly increase a practitioners canal detection capability is the DOM. A DOM's high magnification and coaxial illumination capabilities improve clinicians' clinical capabilities significantly, as proven by Buhrley LJ et al, practitioners aided by magnification of DOM, are three times more likely to locate MB2 canals in comparison to practitioners unaided by magnification.(10) furthermore, in retreatment cases with blocked canals due to broken instruments, Jun-qi Ling at al, stated that operators using DOM combined with ultrasonic tips showed a 76% chance of success with variation according to the location of the broken fragment.(3)

The aim of this study is to determine the diagnostic accuracy of dental operatong microscopes in detecting the number of canals present in maxillary first molars indicated for retreatment in comparison to CBCT scans.

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Materials and methods:

Materials:

Table 1: **Materials, instruments and devices used in the study:**

Item	Manufacturer	Country	Specifications
Dental Operating Microscope	Leica M320D	Germany	Magnification 16X, using fully integrated 4K camera
Hand Piece	NSK Pana-air	Japan	High Speed Contra-angle handpiece.
Bur	Mani	Japan	TR13 diamond stone
Rubber Dam	Sanctuary Dental Dam	Malaysia	Latex Free (6*6)- Heavy
Rubber Dam Clamp	Hygienic, Coltene	USA	Size 8 Winged Molar
Ultrasonic Tip	NSK E4 and E15D	Japan	Power 3W
Irrigation	JK Dental Vision	Egypt	Sodium hypochlorite Concentration 2.5%
Irrigation Needles	Fanta	China	Side Vented Needles
Endodontic Probe	Dentsply Sirona	Germany	DG16
Manual File	Mani	Japan	#10 K- File # 25 H-file
Transmetal bur	Premia	Pakistan	Hook tip
Crown splitter elevator	Premia	Pakistan	5mm tip length
Gates Glidden Drills	Mani	Japan	Sizes 1-4
Periapical Radiograph	Fona XDG X-ray	Italy	Digital exposure settings (0.21 MAs, 70 KVP, focal spot 0.4)
Sensor	Vista Scan PSP Sensor (Durr Dental)	Germany	Size 2 with resolution of 22 LP per mm and 16 bit greyscales.
CBCT	Soredex Cranex 3D Dental Imaging System	Finland	XS FOV dimensions 61 x 41 mm (HxD) (XS FOV High resolution 90 kV / 4 - 12.5 mA / 6.1 s)
Image Reading Software	VistaSoft 2.4.13/2022	Germany	Brightness and contrast will be standardized automatically.
CBCT Software	OnDemand software (version 2015.09)	USA	DICOM Format
Randomization Software	Microsoft Office Excel	USA	.xlsx

Methodology:

36 Patients were referred to MIU dental clinics complex indicated for retreatment of permanent upper first molars. Upon signing informed consent, the patients underwent a CBCT scan using Endo mode before treatment initiation.

The CBCT scans were coded based on patients file numbers instead of names; they were then randomized using randomization software (Microsoft Office Excel, USA) for interpretation.

CBCT stage: In this stage, a pre-operative CBCT scanning was done using Soredex Cranex 3D Dental Imaging System, FINLAND, with the following parameters ((XS FOV dimensions 61 x 41 mm (HxD)) (XS FOV High resolution 90 kV / 4 - 12.5 mA / 6.1 s)). Scan field of view was limited (Endo mode) to provide optimal image resolution using the smallest voxel size available. The samples were randomly assigned to 2 co-supervisors for segmentation and determination of the number of canals. Upon interpretation and segmentation of the CBCT scans using OnDemand software (USA). (11) (12) (13) (14)

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CBCT Analysis:

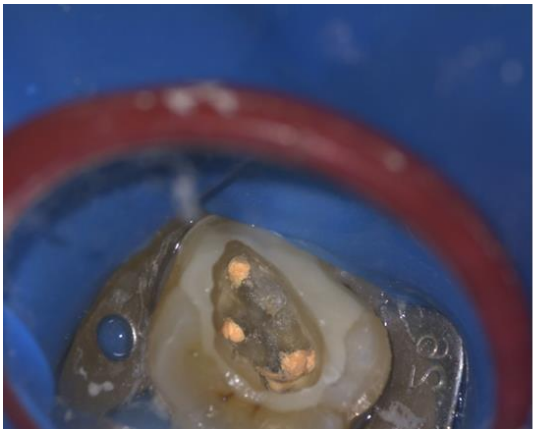
The images were magnified by 150% and the axial axis of each maxillary first molar was rectified on the sagittal plane.

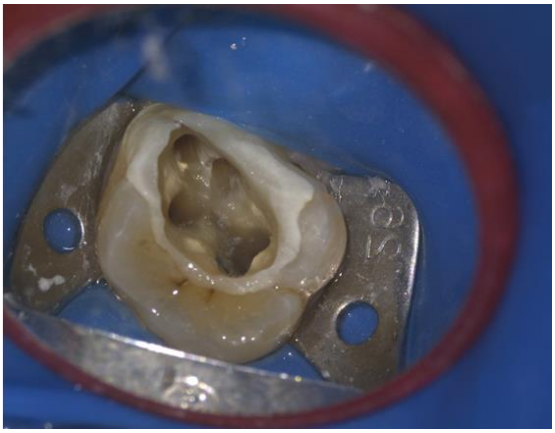
To determine the presence of a missed canal, the axial plane of each maxillary first molar was viewed throughout the roots, starting from the cemento-enamel junction to the root apex.

Furthermore, if the 2 co-supervisors disagreed upon the number of canals, a radiologist was brought into participation until a consensus was reached.[14]

Clinical stage: This is a clinical stage where the 36 patients were randomly distributed upon 6 post grad students using randomization software. Practitioners then proceeded in access preparation under dental operating microscope, (Leica M320D using magnification 16X, using fully integrated 4K camera). (Figure2)

Upon confirmation by clinic supervisors, that all previously present root canal filling has been removed and that complete cleaning and shaping of the canals was carried out to full working length. After the study procedures were tabulated all cases were obturated on a later date, by the same researcher. [15]





(Leica M320D16X magnification) (figure1)

Grouping of samples:

The data aquired was then split into two groups based on the canal detection methodology

Group I: CBCT: the number of canals identified through segmentation of CBCT scans done by 2 endodontic specialists (considered the gold standard).

Group II: Clinical: Number of root canals detected clinically using DOM after access cavity preparation conducted by a postgraduate student.

Results

Statistical Analysis

Qualitative data were presented as frequencies and percentages. Friedman's test was used to compare between numbers of canals detected by the three methods. *Kappa* statistic was used to assess agreement between different methods. *K*appa values ranging from 0.6 to 0.8 indicate good agreement while values ranging from 0.8 to 0.99 indicate very good agreement. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp. ROC (Receiver Operating Characteristic) curve was constructed to determine the diagnostic accuracy measures of DOM in relation to CBCT. ROC curve analysis was performed with MedCalc® Statistical Software version 19.5.1 (MedCalc Software Ltd, Ostend, Belgium; https://www.medcalc.org; 2020).

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Table 2: Descriptive statistics and results of Friedman's test for comparisons between detected number of canals by the three methods

Number of canals	CBCT (n = 36)		Clinical examination (n = 36)		*P*-value
	n	%	n	%	
Three canals	9	25	9	25	0.097
Four canals	27	75	26	72.2	
Five canals	0	0	1	2.8	

**: Significant at P ≤ 0.05*

There was no statistically significant difference between detected number of canals by the two methods (*P*-value = 0.097).
There was very good agreement between the number of canals detected by CBCT and clinical examination (*Kappa* = 0.930).

Diagnostic accuracy of DOM in relation to CBCT

ROC curve analysis of DOM for detection of number of canals utilizing CBCT as the Gold Standard is presented in Table (3) and Figure (2). ROC curve analysis showed that DOM has high sensitivity (92.6%), excellent specificity (100%) and high diagnostic accuracy (94.5%).

Table (3): Sensitivity, specificity, predictive values, diagnostic accuracy, Area Under the ROC curve (AUC) and 95% confidence interval (95% CI) of the (AUC) for DOM using CBCT as the Gold Standard

Sensitivity %	Specificity %	+PV %	-PV %	Diagnostic accuracy %	AUC	95 % CI
92.6	100	100	81.8	94.5	0.963	0.840-0.998

+PV: Positive Predictive Value, -PV: Negative Predictive Value

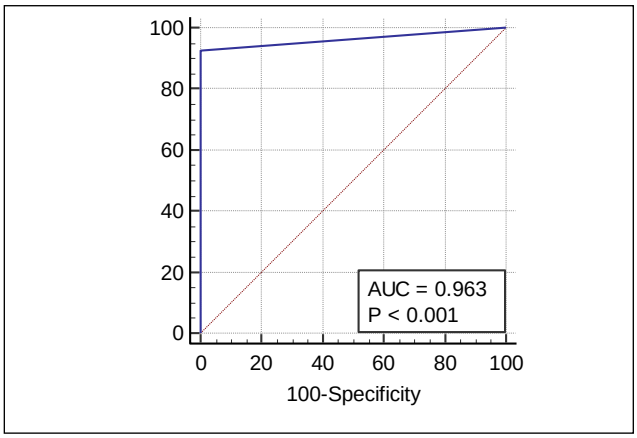

Figure (2). ROC curve of DOM accuracy of detecting number of canals using CBCT as the Gold Standard

Table (4)

	Canal Type In the mesio-buccal root	Inter orifice distance	Standard of deviation in IOD
Case 1	IV	2.5mm	
Case 2	II	2.7mm	
Case 3	IV	2.1mm	
Case 4	II	2.9mm	
Case 5	II	1.38	
Case 6	II	2.3mm	
Case 7	II	2.32mm	
Case 8	II	1.9mm	
Case 9	I	NA	
Case 10	II	2.95mm	
Case 11	II	1.9mm	
Case 12	IV	4mm	

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Case 13	II	2.7mm	0.753482
Case 14	I	NA	
Case 15	IV	3.7mm	
Case 16	II	1.97m	
Case 17	I	NA	
Case 18	I	NA	
Case 19	I	NA	
Case 20	II	4mm	
Case21	II	2.73mm	
Case 22	II	3.22mm	
Case 23	IV	2.9mm	
Case 24	I	NA	
Case 25	II	2.39mm	
Case 26	I	NA	
Case 27	II	2mm	
Case 28	I	NA	
Case 29	II	1.8mm	
Case 30	II	1.5mm	
Case 31	I	NA	
Case 32	I	NA	
Case 33	II	1.1mm	
Case 34	IV	1.7mm	
Case 35	IV	1.9mm	
Case 36	II	2.6mm	

The table above shows a description of all cases in this study. The first two columns describe canal type of the mesio-buccal root and IOD. The last column is concerned with the standard of deviation regarding the different inter orifice distances (IOD's). A Low, standard deviation indicates that the distances are clustered tightly around the mean IOD of all canals.

Discussion:

In regards to the relationship between canals that have not been treated and the emergence of periapical diseases in teeth that have undergone endodontic therapy, it was discovered that 82.6% of teeth that had not had treatment for all their canals were linked to periapical diseases. Furthermore, molars with an undetected canal had a 3.1-fold increased likelihood of developing periapical disease compared to molars that had been treated for all canals. The researchers found a strong and meaningful connection between the presence of untreated canals and the occurrence of apical periodontitis in teeth that have undergone endodontic therapy. [16]

In summary, the prevalence of apical periodontitis in root canal-treated teeth with undetected canals was determined to be substantial, nearing 90%. The majority of these undetected canals were detected in the first molars of both the maxillary and mandibular dental arches. Furthermore, Endodontics is constrained by a compact working environment as it primarily deals with exceedingly minute anatomical features. Hence, doctors dealing with intricate scenarios appear to necessitate an elevated degree of visual acuity and intense focus in order to operate efficiently and identify all canals, thereby preventing any potential failures in root canal treatment. The human eye is limited in its ability to detect objects beyond the level of the canal opening. Moreover, the acuity of unaided vision tends to diminish once an individual surpasses the age of 40.[17]

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Additionally, it is a well-known fact that periapical radiography has limitations, especially in canal detection. This is due to periapical radiographs being a two-dimensional representation of a three dimensional structure, as well as, anatomical landmarks which can cause canal obscurity. A study, attempted to compare number of canal detection in MB roots of maxillary molars, between Micro CT (gold standard), CBCT and digital periapical radiograph. Results showed similar result between CBCT and micro CT while periapical radiographs were less efficient in canal detection. [18]

Over the years multiple studies have found the success rate of primary non-surgical root canal treatment to be approximately 90%. This percentage denotes than there will inevitably be some failures. In case of primary treatment failure, practitioners have three choices: endodontic surgery, extraction, or nonsurgical retreatment. In order to make an informed decision, most endodontists and general practitioner use CBCT. A 2017 study aiming to compare the impact of CBCT on clinical decision making of endodontists and general practitioners after failed root canal treatment showed that practitioners had a tendency to alter their treatment plan in 49.8% of the cases after viewing CBCT as opposed to first viewing periapical radiograph.[19]

The accuracy of CBCT in detecting secondary canal morphology is essential for the clinical decision-making of general practitioners and endodontists. The collective evaluations of the accuracy of CBCT resulted in a sensitivity of 94% and a specificity of 93.1% for second mesio-buccal canal detection in permanent teeth. Cone beam computed tomography (CBCT) is a very useful imaging technique for finding an extra canal. It is important for clinicians to recognize that the accuracy of their findings can vary based on the individual attributes of the teeth and the presence of additional canals in different populations.[20]

All access cavities in this investigation were done using a dental operation microscope. The utilization of magnification methods in the field of endodontics is due to their capacity to enhance treatment outcomes. Presbyopia is the progressive decline in visual acuity that professionals usually start to suffer around the age of 40. The utilization Dental operating microscope (DOM) has proven its efficiency in mitigating age-related visual impairment, due to its magnification and coaxial illumination capabilities. Currently, Dental Operating Microscopes (DOM) are considered the most ideal option for endodontic therapy because to their outstanding ergonomics, magnification, and documentation capabilities. The Dental Operating Microscope (DOM) is ultimately used for several purposes, including the identification of all canals [15]. A retrospective study by Khalighinejad, included maxillary first molars that where referred for retreatment, showed that the MB root was 3 times more likely to have a periapical lesion if initial treatment was done without using an aide in detecting canal morphology, such as DOM. This notion proves the importance of locating all canals in in intial Rott canal treatment procedures, as well as, retreatment procedures. [21]

Another publication compared the use of a dental operating microscope with CBCT in retreatment cases. The results indicate that there is no significant difference between the two methods in canal detection. This highlights the need of using high magnification in the field of endodontics to avoid missed canal occurrence. While both methods of canal detection are generally similar in significance, there is a notable case where the canal was missed in the CBCT scan but found during the clinical examination. This discrepancy may be attributed to the artifact caused by the presence of guttapercha, as well as the voxel size of the CBCT, which can impact the quality of the X-ray.[9]

Conclusion:

Based on the conditions of the present investigation, the following findings were drawn:

- The utilization of a dental operating microscope is essential in the field of endodontics.
- There is no distinction between the Cone Beam Computed Tomography (CBCT) and Digital Oral Radiography (DOM) in accurately determining the number of root canals.
- The interpretation of the X-ray may be influenced by the voxel size and the presence of artifacts in the CBCT.

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Significance in a medical context

The use of a dental operating microscope is advised for retreatment cases, regardless of the CBCT scan indicate regarding the presence of additional canals. A thorough inspection and examination under the dental operating microscope may, in all cases, reveal the existence of extra canals.

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