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ACCURACY OF CONE BEAM COMPUTED TOMOGRAPHY WITH STANDARD RESOLUTION FOR DETECTION OF MESIOBUCCAL ROOT CANAL ANATOMICAL VARIATIONS IN MAXILLARY MOLARS

Shrouk Fathy Khalifa[1], Wael Selim Amer[2], Asmaa Youssry Abdullah[3]

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KEYWORDS

CBCT standard resolution, clearing and staining technique, root canal morphology.

- E-mail address: shrouk_fathy@dent.suez.edu.eg

1. Demonstrator at Oral Radiology Department Faculty of Dentistry Suez Canal University.
2. Professor of Oral Radiology Faculty of Dentistry Suez Canal University.
3. Lecturer of Oral Radiology Faculty of Dentistry Suez Canal University.

ABSTRACT

Introduction: Successful endodontic treatment requires identification of the root canal morphology. The inability of dentists to accurately determine the location of all root canals lead to failure in endodontic treatment. Therefore, an accurate diagnostic tool is necessary to detect whole root canals' morphology. **Aim**: To determine the accuracy of standard resolution cone-beam computed tomography (CBCT) in detection of the Mesiobuccal root canal morphology of maxillary molars. **Material & Methods**: The present in-vitro study was conducted on 78 human extracted maxillary molar teeth. The teeth were imaged by standard resolution CBCT, then stained and cleared. The canal staining and clearing technique was considered the gold standard because of its ability to provide an accurate three-dimensional view of the root canal system. The CBCT scans were assessed for detection and identification of mesiobuccal (MB) canal morphology according to Vertucci's classification, then compared with the gold standard. **Results**: Statistical analysis showed a non-significant difference between the standard resolution CBCT and the clearing technique regarding the ability to detect MB root canal morphology ($p < 0.05$), in addition to diagnostic accuracy of 96.6%. The results show that the standard resolution mode can be employed to detect MB root canal variations as it provides high diagnostic accuracy with reduced patient radiation exposure. **Conclusion**: CBCT is a non-invasive imaging modality that can be used to accurately detect root canal morphology when other intra-oral low-dose imaging techniques do not provide conclusive results.

INTRODUCTION

Successful non-surgical root canal treatment requires accurate mechanical debridement and 3D filing of the whole canal and filling it with biocompatible materials (1).

Supposing that the root has a "single" canal with a "single" apical foramen has recently become a mistaken assumption. The morphology of the root canal is complex, presenting canals deviations and reunions, isthmuses, accessory canals, and apical deltas, therefore, it has been called a system. Considering that the aim of root canal therapy is the accurate removal of all necrotic or vital tissue, bacteria, and microbial by-products from the whole canal, therefore, the detection of the anatomy of the root canal and its variations is a basic step for the proper endodontic therapy (2).

Failure in maxillary molars endodontic treatment often results from ledge formation, apical transportation, perforations, and untreated second mesiobuccal canals (MB2). It has been found that 42% of non-surgical retreatments are because of missed canals and 93% of them are in the mesiobuccal root, which might lead to progressive symptoms and apical periodontitis [3, 4].

Finding this canal clinically is often not an easy procedure mainly due to the excess dentinal growth on its orifice. Recently, adjunctive tools like magnifying loupes and dental operating microscopes have been increasingly used to facilitate the finding of these canals in clinical practice. Although magnification improved the detection of extra root canals, these microsurgical tools do not show the complete length of those canals. Furthermore, the presence of water and improper access preparation may lead to failure of detection of MB2 canal [5].

There are several methods used for detection of root canal morphology such as observation under a microscope, digital or conventional radiography, micro-computed tomography, and cone beam computed tomography (CBCT). Canal staining and tooth clearing technique (CLT) is believed by some researchers to be the gold standard regarding mapping of canal morphology, owing to its advantages including a three-dimensional view, simplicity, inexpensiveness, and noninvasiveness [6].

However, the major diagnostic tool used in dentistry is the radiographic imaging technology, especially in endodontics for diagnosis, treatment planning and assessment of the success of therapy[7].

Since periapical radiographs provide a two-dimensional for a three-dimensional structure, multiple radiographs are needed with different angulations for root canal visualization. In addition, they acquire several drawbacks such as superimposed structures and image distortion, especially within the canals located at the buccolingual plane which could not be easily detectable from each other. CBCT is an alternative three-dimensional radiographic modality used when conventional radiographs fail to reach an accurate diagnosis, and when more details are desired. CBCT has multiple advantages including lower size and cost (compared to conventional CT), less acquisition time, better resolution, less patient radiation dose, and simplified software analysis [1,8].

In addition, it is a noninvasive method, that permits conducting large-scale studies on different populations to quantitatively and qualitatively assess the effect of several variables such as different ethnicity, aging, and gender on the root canal morphology, as well as the fine anatomical properties of a tooth group [9].

The routine uses of small-field CBCT in endodontic treatment of molar teeth is a judicious use of radiation dose. The ALARA concept (As Low As Reasonably Achievable) can be applied with great benefits to the patient, where imaging the maxillary molars using CBCT with a minimal field of view has an effective radiation dose 1.4 times the radiation dose of a digital PA film [10].

The diagnostic accuracy of different CBCT systems vary according to the detector type, resolution, and exposure parameters (such as exposure time, voltage, amperage, and field of view), such factors also affect the patient's radiation dose. Besides that, some CBCT systems permit the selection of a high- or standard (low)-resolution scanning mode, which is considered one of the main factors affecting image quality [11].

In digital systems, spatial resolution *(the capacity for distinguishing fine detail in an image)* mainly depends on voxel size, a factor that greatly affects the image quality and the reconstruction time. The smaller the voxel size is, the higher the spatial resolution can theoretically be. The principal determinants of nominal voxel size in a CBCT image are the matrix and pixel size of the detector. Detectors with smaller pixels capture fewer x-ray photons per voxel and result in more image noise *(unwanted disturbance of a signal that obscures information content)* (12). Consequently, CBCT imaging using higher resolutions are designed to use higher radiation dosages to achieve a reasonable signal-to-noise ratio for improved diagnostic image quality (13).

However, there are still no evidence-based criteria that determine the ideal CBCT scan parameters in demonstrating small anatomical structures such as MB2 canal. Given the pervasive use of CBCT in dentistry and the high significance of knowing the morphology of canals in root canal treatment, the aim of the present study is to assess the accuracy of standard resolution CBCT in detecting mesiobuccal root canal morphology in maxillary molars.

MATERIALS AND METHODS

I.1 Study design

The present study was carried out in the Oral Radiology Department, Faculty of Dentistry, Suez Canal University after the approval of Research Ethical Committee (155/2018). Seventy-eight human maxillary first and second molars extracted recently for therapeutic purposes were collected from the outpatient clinic of the Oral Surgery Department, Faculty of Dentistry, Suez Canal University regardless of the age, gender and race of patients.

I.2 Sample Size Calculation

Sample Size Calculation was performed using G*Power software version 3.1.9.2. The effect size was 0.5 using alpha (α) level of 0.05 and Beta (β) level of 0.05, i.e., power = 95%, the minimum estimated sample size (n) was a total of 54 teeth. The sample was increased to 78 teeth for compensation in case of sample damage during clearing and staining technique.

II. Sample preparation:

The exclusion criteria for teeth were primary teeth, open apex, external root resorption and fractured roots, in addition to, presence of any kind of restoration and previous root canal treatment.

The teeth were stored in 5% sodium hypochlorite solution. 13 Wax models were prepared as (U) shaped jaw models for radiographic assessment, with six teeth embedded in each wax model, three in each side.

III. Cone Beam Computed Tomography imaging

CBCT imaging of all models was conducted at the Oral Radiology Department, Faculty of Dentistry, Suez Canal University as follows: The extracted human maxillary molars were scanned by Scanora 3DX Cone Beam Computed Tomography scanner[1]. The wax model was placed on the machine and adjusted by the aid of the triple light beam system. All teeth were scanned with 5×5 cm FOV,10 mA and 90kVp with standard resolution (voxel size 0.15mm) and exposure time 4.5 seconds using flat panel detector. Each side of the models with the three maxillary molars was scanned separately.

III.1. Image analysis:

The imaging data was transferred into DICOM format for image analysis using On Demand

1. Scanora 3DX, Soredex, Finland.

software application [1]. The mesiobuccal root of each scanned molar was divided into three-equal sections: coronal (from the cementoenamel junction to 1/3 of the root length), middle (from 1/3 to 2/3 of the root length) and apical (from 2/3 of the root length to the radiographic apex). All teeth were evaluated in sagittal, axial and coronal planes. The assessment of the root canal morphology using CBCT scans was carried out by two observers with 5- and 12-years' experience in the field of oral and maxillofacial radiology for assessment of inter-observer reliability. Then, the assessment was repeated two weeks later by each observer for intra-observer reliability. Each radiologist was free to adjust the brightness and contrast of the image according to his needs. Each radiologist neither knew the result of the gold standard nor the other radiologist's results (blinded assessment). The two investigators assessed the root canal morphology according to Vertucci's [(14)] classification, who classified the root canal system into eight types as follows:

- Type I (1-1): Single canal runs from orifice to apex.
- Type II (2-1): Two canals arise from pulp chamber which join and terminate into one.
- Type III (1-2-1): One canal arises from pulp chamber and during its course divides into two. These two canals again join into one before exiting from apex.
- Type IV (2-2): Two canals run separately from orifice to apex.
- Type V (1-2): One canal arises from floor of pulp chamber and during its course divides into two.
- Type VI (2-1-2): Two canals start from pulp chamber, during its course; they unite into one and then again divide into two before exiting from root apex.
- Type VII (1-2-1-2): One canal leaves the pulp chamber then divides into canals and again unite into in its course and finally divides into two before exiting from apex.
- Type VIII (3-3): Three canals leave the pulp chamber and run independently towards the apex [(14)].

IV. Clearing and staining technique:

After imaging, the teeth were removed from the wax models and prepared for clearing and staining according to **ToMar et al.** [(15)] recommendations. First, the root surfaces were debrided with a curette. Then endodontic accesses were prepared for all teeth and the pulp tissue was removed with a barbed broach. The teeth were immersed in 3.25% sodium hypochlorite over night to remove adherent soft tissue. The teeth were then rinsed under running water. A 30-gauge endodontic irrigation needle was used to inject Indian ink[2] into the root canal system. The teeth were decalcified in 5% nitric acid for 3 days. After completion of decalcification, the teeth were washed under running tap water. The teeth were then dehydrated using ascending concentrations of ethyl alcohol starting with 70% for 12h, followed by 90% for an hour and 100% for 1hour. The dehydrated specimens were afterwards placed in methyl salicylate which made them transparent after approximately 2 hours. Once the teeth were cleared and stained, the mesiobuccal root canal types for all teeth were visually evaluated twice by each investigator (observer 1 and observer 2) based on Vertucci [(14)] classification at two weeks' interval period.

1. On Demand Cybermed.Co., Seoul, Korea.

2. GRM5259-23ML, HIMEDIA Co., Indian Ink.

Statistical analysis

The morphology of MB root canals obtained directly from the clearing and staining technique (gold standard) and standard resolution CBCT scans were collected, checked, revised, and organized in tables and figures using Microsoft Excel 2016. The collected data was checked for outliers, then, was analyzed and described statistically using SPSS for Mac OS version 26.0. For both inter and intra-observer reliability analysis, Cronbach's alpha reliability coefficient and Intra-Class Correlation Coefficient (ICC) was applied. Significance level was set at $P < 0.05$

The association between records obtained from CBCT standard resolution in comparison to gold standard were assessed using Monte-Carlo test to analyze the relation between the standard resolution CBCT and the gold standard in detection of MB root canal types.

The diagnostic accuracy represents the accurate detection of the MB root canal type by standard resolution CBCT. The sensitivity values were calculated in order to reveal the power of the test to detect MB root canal morphology. The specificity values were also calculated with 95% confidence limit for standard resolution CBCT scans.

RESULTS

The obtained results indicated very good intra- and inter-observer agreement regarding to the detection of mesiobuccal root canal types by the two statistical methods (Cronbach's alpha values > 0.950 and interclass correlation (ICC) > 0.9) for all assessments. **(Table 1,2)**

Table (1) *Cronbach's alpha and Inter-Class Correlation Coefficient (ICC) for intra-observer agreement.*

Measurement	Observer	Resolution/ readers		Intra-observer agreement		Difference		Sign.
		r1	r2	Cronbach's alpha	ICC	value	%	
Clearing	1	3.274	3.205	0.986	0.972	-0.068	-0.021	<0.001***
	2	3.270	3.324	0.996	0.992	0.054	0.017	<0.001***
Standard	**1**	3.056	3.042	0.987	0.974	-0.014	-0.005	<0.001***
	2	3.000	3.014	0.993	0.987	0.014	0.005	<0.001***

** Significant at p<0.05; ** highly significant at p<0.01; *** highly significant at p<0.001*

Table (2). *Cronbach's alpha and Inter-Class Correlation Coefficient (ICC) for inter-observer agreement.*

Measure	Resolution/ observers		Inter-observer agreement		Difference		Sign.
	O_1 Mean±SD	O_2 Mean±SD	Cronbach's alpha	ICC	value	%	
Clearing	3.06±1.71	3.12±1.79	0.975	0.951	0.068	0.022	<0.001***
Standard	3.24±1.80	3.24±1.77	0.951	0.907	0.058	0.018	<0.001***
High	3.05±1.78	3.01±1.69	0.958	0.920	-0.042	-0.014	<0.001***

** Significant at p<0.05; ** highly significant at p<0.01; *** highly significant at p<0.001*

Concerning the correlation between standard resolution CBCT and GS regarding all different MB root canal types, a high significant correlation was noticed as evidenced by Monte-Carlo test(P=<0.001*). As regards canal **Type I**, standard CBCT resolution showed 17 similar cases to the GS (100%). For canal **type II**, standard CBCT resolution showed 12 similar cases out of the 14 cases detected by the GS (85.7%) in addition, there were 2 cases misdiagnosed as type I and IV. For canal **Type III**, standard CBCT resolution showed 3 similar cases GS (100%) while for canal **type IV**, standard CBCT resolution showed similarity in 25 out of 28 cases (89.3%) and there were 3 cases misdiagnosed as type I and II. For canal **type V**, standard CBCT resolution showed similarity in 5 out of 9 cases (55.6%) and 4 cases were misdiagnosed as type I and III. Regarding canal **type VI**, standard CBCT resolution showed similarity in only 1 out of the 3 cases (33.3%) where there were 2 cases misdiagnosed as types IV and V. Finally, for canal **Type VII**, standard CBCT resolution showed 4 similar cases to GS (100%). **(Table 3) (fig.1)**

Table (3) *Correlation between Standard resolution CBCT & Gold standard.*

Standard resolution	*Clearing technique*							P
	Type I	**Type II**	**Type III**	**Type IV**	**Type V**	**Type VI**	**Type VII**	
Type I	17(100%)	1(7.1%)	0(0%)	2(7.1%)	2(22.2%)	0(0%)	0(0%)	<0.001*
Type II	0(0%)	12 (85.7%)	0(0%)	1(3.6%)	0(0%)	0(0%)	0(0%)	
Type III	0(0%)	0(0%)	3(100.0%)	0(0%)	2(22.2%)	0(0%)	0(0%)	
Type IV	0(0%)	1(7.1%)	0(0%)	25(89.3%)	0(0%)	1(33.3%)	0(0%)	
Type V	0(0%)	0(0%)	0(0%)	0(0%)	5(55.6%)	1(33.3%)	0(0%)	
Type VI	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)	1(33.3%)	0(0%)	
Type VII	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)	4(100.0%)	

Data expressed as frequency (Number-percent), P: Probability, Test used: Monte-Carlo.

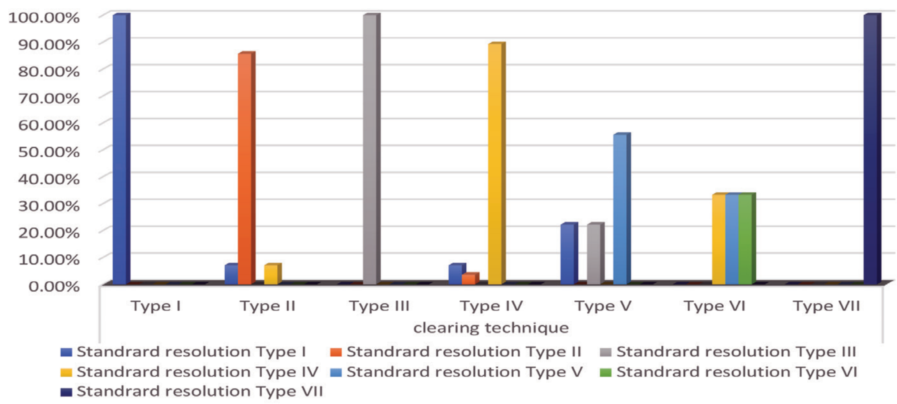

Fig. (1) Bar chart showing correlation between Standard resolution CBCT & gold standard.

Upon comparing the sensitivity, specificity, and accuracy of standard CBCT resolution to the gold standard in the detection of MB root canal anatomy, standard resolution CBCT showed 86.3%, 98% and 96.6%, respectively. **(Table 4)**

Table (4) *Showing sensitivity, specificity, accuracy of the CBCT standard resolution as compared to the gold standard in detection of MB root canal anatomy.*

	Standard Resolution
TP	69
FP	11
Sensitivity	86.3%
specificity	98.03%
Accuracy	96.6%

(TP) True Positive: correct identification of a certain root canal type,

(FP) False positive: misdiagnosing of a certain root canal type.

DISCUSSION

Radiographs could be considered the only noninvasive mean that provide clues about the morphology of root canal systems. They have been proven to be simple, fast, and require minimal equipment. In recent years, the use of cone-beam computed tomography has expanded in different fields of dentistry. Its three-dimensional nature leads to better observation of root canal morphology. [15] Despite having the advantage of providing three-dimensional images, it imposes higher doses to patient compared to other conventional and digital radiographs. Therefore, the present study was conducted to assess the diagnostic accuracy of standard CBCT resolution mode for the accurate detection of root canal anatomy of MB canals in maxillary molars compared to clearing and staining technique which was considered as "the gold standard", so that, the patient radiation dose in CBCT examinations can be decreased, as much as possible.

The sample size was statistically calculated before conducting the study to ensure that the obtained results were applicable, true, and not coincidental. Seventy-eight maxillary molars were found to be sufficient in this study, they were selected based on specific criteria [11]. Permanent maxillary 1st and 2nd molars with intact and mature roots, without fractures (to be sure of the interpretation and not to be interfered by the presence of a fracture or crack), root caries or resorption, open apices and endodontic treatment teeth to avoid metallic artifact production and scattering that could adversely affect the accuracy of imaging [16].

It was advocated in the preoperative recommendations of the position statement by AAE (American Academy of Endodontists) and AAOMR (American Academy of Oral and Maxillofacial Radiology) that limited FOV CBCT should be considered the imaging modality of choice for initial diagnosis and treatment of teeth with the potential for extra canals and suspected complex morphology, such as mandibular anterior teeth, maxillary and mandibular premolars and molars, and dental anomalies. Therefore, CBCT with limited FOV (5×5 cm) has been the choice in the present study [17], additionally, a limited FOV is preferred to reduce scatter artifacts, according to the recommendations of Prasad et al. [18] At the same time, we standardized our imaging technique by keeping all other exposure parameters fixed (90kVp,10 mA).

The ability of CBCT to display anatomic features and pathology is influenced by various factors such as: the field of view, the tube voltage and amperage, and also the voxel size. The advantages of using small FOV for endodontic applications were evaluated in a systematic review by Borges et al. [19] who stated that images obtained by using a small FOV have higher spatial resolution, owing to the smaller voxel size, aiding in root canal morphology visualization in addition to the low exposure dose and shorter reconstruction time.

Many authors based their studies on using CBCT with voxel size 200 μm in endodontic treatment purposes. Martins et al. [20] reported high accuracy of CBCT at this voxel size to detect MB2 canal in maxillary molars. Moreover, MacDonald et al. [21] declared that voxel size should not exceed 200 μm, which is the same as the average width of the periodontal ligament space, to allow each root and its surrounding structures to be evaluated. Therefore, in line with the above data and the studies conducted by Naseri et al. [10] and Kongkiatkool et al. [22], the voxel size used in the study in hand was 0.15 mm.

CBCT scans were analyzed in the 3 planes; the axial sections were the most useful plane to detect the root canal anatomy where images were adjusted perpendicular to the long axis. Moreover, canals were assessed in one additional plane either the sagittal or the coronal. The method of analysis used in our study was applied by several researchers like Domark et al. [23]

The canal's division location is usually described at the respective one-third limit as Wolf et al. [24] described in their study. They assessed the location of the canal's division, in respect to corresponding three thirds of the root seeking a detailed description of the root canals, and this was precisely followed in our study.

The transparent tooth model clearing technique provides the greatest information of the original form and anatomy of the root canals. Hence, it was used in the present study as a gold standard. The same technique was used by Kajan et al. [25], Dinakar et al. [26], in the determination of root canal morphology of maxillary first premolars, different maxillary and mandibular teeth, respectively.

Evaluation of root canals morphology obtained from CBCT scans and clearing technique was made by two radiologists independently blinded to the results of each other in two different sessions and were repeated two weeks later according to the recommendation of Shokri et al. [11] to calculate intra-observer and inter-observer reliability. Root canal morphology was classified according to Vertucci's [14] classification, being the most common classification and is beneficial when categorizing most canal configurations.

The results of the current study showed very good intra-observer and inter-observer agreement regarding all MB root canal types obtained from gold standard and standard CBCT resolution scans which indicates the high reliability and reproducibility of the current technique used for assessment.

There was a non-significant difference between standard resolution and clearing technique, with a highly significant correlation regarding detection and classification of root canal morphology. Standard resolution CBCT recorded all MB root canals type I, III and VII with 100% accuracy. Also, it recorded type II and IV in 85.7% and 89.3% of cases, where one case type II was misdiagnosed as type IV, and 2 cases type IV were misdiagnosed as type II and VI respectively.

This misinterpretation detected by CBCT may be attributed to the small diameter of the mesiobuccal root canals and low contrast of the image of the root canal against the thickness of the root, such factors may contribute to the relative lower accuracy of CBCT in revealing certain root canal forms.

In the assessed maxillary molars after clearing and staining technique, two canals were found to extend from their pulp chamber proper, join within the root's body, and divide into two separate canals adjacent to the apex. CBCT images were unable to reveal such canal's redivided part, probably due to the divided part being covered by the fusion part in the same CBCT section, therefore, a type VI canal was misdiagnosed as type II [(22)].

In addition, type II and VI may faulty be diagnosed as type IV due to intra-canal pulpal calcifications, as suggested by **Kongkiatkool** et al. [(22)], that were visible in their study using multi-slice CT, (MCT) but these appeared to be splits in the canals (that is, two canals) with CBCT.

The error in canal classification might also be due to the fact that the teeth were extracted for therapeutic purposes, and the current study evaluated them regardless of the exact cause of each tooth extraction. This is significant because some teeth may experience irritation for a long time, which can stimulate the canals, resulting in the formation of reactionary dentin or other calcifications, which may lead to difficulty in accurately detecting the canal in CBCT [(27)].

In addition, standard resolution CBCT correctly recorded type V and VI in 55.6% and 33.3% of cases, where two cases type V were classified as type I by CBCT. This may be due to that the single canal observed in this tooth leaves the pulp chamber proper and divides into two separate canals near the root apex with separate apical foramina. CBCT images were unable to identify the lingual one (MB2), possibly due to the canal's smaller diameter than CBCT voxel size. Moreover, the scanned images' noise from the surrounding hard tissues may have contributed to some effects and misinterpretations [(22)].

Also, two cases type V were misclassified as type III, and two cases type VI were faulty classified as type IV and V. This may be due to presence of root canal configuration (RCC) with some complexities or irregularities that may be divided by or joined with a very acute angle, or contained within a very small, divided canal. When combined with low resolution, or some anatomical noise of CBCT, identifications of such root canal configuration (RCC) may be unsuccessful [(22)].

Results of the current study reveal the high diagnostic accuracy of standard resolution CBCT (96.6%) in detecting MB root canal morphology with reduced radiation exposure. Similar results were concluded by Yeung et al. [(28)] who implied that CBCT scans with a low-dose protocol are adequate for evaluation of most root canal systems.

Additionally, Kongkiatkool et al. [(22)] conducted a study to compare the accuracy of digital periapical radiography (DPR) and cone beam computed tomography (CBCT) (with a voxel size of 0.125 mm) in evaluating the root canal configuration (RCC) of mandibular first premolars in comparison to gold standard by using clearing technique (CLT). Their results showed that CBCT gave as accurate evaluations of the mandibular first premolars RCC as CLT, while DPR provided the least accuracy.

A similar study was conducted by Naseri et al., [(10)] they investigated the accuracy of cone-beam computed tomography (CBCT) with 0.1 mm voxel size in assessment of morphology of root canal and apex in mandibular canines compared with the clearing technique. However, their results showed that CBCT does not have adequate accuracy for assessment of accessory canals in canine teeth.

Such discrepancy in results of different studies might be attributed to differences in methodologies, including the sample size, examination methods, classification systems, the type of CBCT device and tooth type [26]. Additionally, the difference in percentages of accuracy could be also due to the different populations represented in these studies and the variation in ages of the patients studied [29].

CONCLUSION

Standard resolution CBCT is able to detect the MB root canal anatomy with excellent diagnostic accuracy. Therefore, according to the ALARA principle, it should be the scan of choice when 3-D imaging of root canals is required.

REFERENCES

1. Bansal R, Hegde S, Astekar MS. Classification of Root Canal Configurations: A Review and a New Proposal of Nomenclature System for Root Canal Configuration. J Clin Diagn Res. 2018; 12:1- 5.
2. Khosravifard N, Kajan ZD, Hasanpoor H. Cone beam computed tomographic survey of the mesiobuccal root canal anatomy in the maxillary first and second molar teeth of an Iranian population. Eur J Dent. 2018; 12:422-427.
3. Coelho MS, Lacerda MFLS, Silva MHC, de Azevêdo RM. Locating the second mesiobuccal canal in maxillary molars: challenges and solutions. Clin Cosmet Investig Dent. 2018; 10:195-202.
4. Yoo YJ, Lee JK, Perinpanayagam H, Gu Y, Chang SW. Morphological measurements of two separate mesiobuccal canals in maxillary first molars using micro-computed tomography. Clin Oral Investig. 2020; 24:3863-3870.
5. Mittal N, Parashar V, Patel PS. Endodontic Management of Maxillary Second Molar Tooth with a Single Root and Single Canal. Case Rep Dent 2020; 2020: 1–3.
6. SANKAR A, RAMESH S. 2D Vs 3D Imaging in Endodontics-A Review. Annals of the Romanian Society for Cell Biology 2021; 25:1541-1549.
7. Barrington C, Balandrano F. Diaphanization Techniques in the Study of Root Canal Anatomy. In: Versiani MA, Basrani B, Sousa-Neto MD (eds) The Root Canal Anatomy in Permanent Dentition. Cham: Springer Int Pub. 2018:57–88.
8. Jones JA, Karouia F, Pinsky L, Cristea O. Radiation and radiation disorders. Barratt MR, Baker ES, Pool SL (eds). Principles of Clinical Medicine for Space Flight. Springer New York, NY. 2019:39-108.
9. Paqué F. Molar Root Canal Anatomy. In: Peters OA (ed) The Guidebook to Molar Endodontics. Berlin, Heidelberg: Springer. 1–25.
10. Naseri M, Ahangari Z, Bagheri N, Jabbari S, Gohari A. Comparative accuracy of cone-beam computed tomography and clearing technique in studying root canal and apical morphology of mandibular canines. Iran Endod J. 2019; 14:271-277.
11. Shokri A, Eskandarloo A, Norouzi M, Poorolajal J, Majidi G, Aliyaly A. Diagnostic accuracy of cone-beam computed tomography scans with high and low-resolution modes for the detection of root perforations. Imaging Sci Dent. 2018; 48:11-19.
12. Nagarajappa AK, Dwivedi N, Tiwari R. Artifacts: The downturn of CBCT image. J Int Soc Prev Community Dent. 2015; 5: 440–445.
13. Alamri HM, Mirza MB, Riyahi AM, Alharbi F, Aljarbou F. Root canal morphology of maxillary second molars in a Saudi sub-population: A cone beam computed tomography study. Saudi Dent J. 2020; 32:250-254.
14. Vertucci F. Root canal anatomy of the human permanent teeth. Oral Surg Oral Med Oral Pathol. 1984;58 :589-599.
15. Tomar M, Mirdha N, Gill B, Sundesha M, Kakpure S. Efficacy of Different Reagents to Prepare Transparent Tooth Model for Three-Dimensional View of the Root Canal Systems-An In-vitro Study. J Clin Diagn Res. 2020;14: 5-8.
16. Shoshtari SS, Shams N, Dabbaghi A, Rohani A, Dadollahi M, Khosravi N. Effect of Field of View and Resolution in Detection of Horizontal Root Fractures in CBCT images: An In Vitro Study. Iran Endod J. 2018;13 :492-497.
17. Mahasneh S, Horner K, Cunliffe J, Al Salehi S, Sengupta A, AlHadidi A. Guidelines on radiographic imaging as part of root canal treatment: a systematic review with a focus on review imaging after treatment. Int Endod J. 2018; 51:238-249.
18. Prasad AC, Gupta S, Nikhil V, Jaiswal S, Raj S, Arora R. Dimensional correlation between morphology and root

canal anatomy in mesiobuccal root of permanent maxillary first molar: An ex vivo study. Indian Endod soc (IES). 2019;31 :98-103.

19. Borges CC, Estrela C, Decurcio DDA, PÉcora JD, Sousa NMD, Rossi F G. Cone-beam, and micro-computed tomography for the assessment of root canal morphology: a systematic review. Braz Oral Res J. 2020;34: e056.
20. Martins JN, Marques D, Silva EJNL, Caramês J, Mata A, Versiani MA. Second mesiobuccal root canal in maxillary molars: A systematic review and meta-analysis of prevalence studies using cone beam computed tomography. Arch Oral Biol. 2020; 113:104589.
21. MacDonald D, Angelopoulos C, Scarfe WC. Cone beam computed tomography and maxillofacial diagnosis. Scarfe W., Angelopoulos C (eds). Maxillofacial Cone Beam Computed Tomography Book. Springer International Publishing AG. Switzerland. 2018: 469-551.
22. Kongkiatkool P, Puapichartdumrong P, Tantanapornkul W, Piyapattamin T, Wisithphrom K. Accuracy of digital periapical radiography and cone beam computed tomography for evaluation of root canal configuration in human mandibular first premolars. J Int Dent Med Res. 2020;13:80-85.
23. Domark JD, Hatton JF, Benison RP, Hildebolt CF. An ex vivo comparison of digital radiography and cone-beam and micro computed tomography in the detection of the number of canals in the mesiobuccal roots of maxillary molars. J Endod. 2013;39 :901-905.
24. Wolf TG, Paque F, Woop AC, Willershausen B, Briseno M B. Root canal morphology and configuration of 123 maxillary second molars by means of micro-CT. Int J Oral Sci. 2017;9 :33-37.
25. Dalili Kajan Z, Taramsari M, Khosravi F N, Kanani M. Accuracy of Cone Beam Computed Tomography in Comparison with Standard Method in Evaluating Root Canal Morphology: An In Vitro Study. Iran Endod J. 2018;13 :181-187.
26. Dinakar C, Shetty UA, Salian VV, Shetty P. Root canal morphology of maxillary first premolars using the clearing technique in a south Indian population: An in vitro study. Int J Appl Basic Med Res. 2018; 8:143–147.
27. Alasvand J A, Yazdizadeh M. The accuracy of cone-beam computed tomography in the detection of the number of root canals: An in vitro study. Capian J Dent Res. 2021;10:57-63.
28. Yeung AWK, Harper B, Zhang C, Neelakantan P, Bornstein MM. Do different cone beam computed tomography exposure protocols influence subjective image quality prior to and after root canal treatment. Clin Oral Invest. 2021;25: 2119-2127.
29. Mokhtari H, Niknami M, Mokhtari Z HR, Sohrabi A, Ghasemi N, Akbari G A. Accuracy of Cone-Beam Computed Tomography in Determining the Root Canal Morphology of Mandibular First Molars. Iran Endod J. 2016;11 :101-105.