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Original Article

The Accuracy Cone-beam Computed Tomography in Assessment of Endodontically Treated Teeth: An in Vivo Study

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Abstract *- This study compared the CBCT and RVG in the measurement of endodontically treated teeth. A total of 26 (10 mandibular molars, 6 maxillary molars, 5 mandibular premolars and 5 maxillary premolars) teeth were selected, and the presence of missed canal, periapical radiolucency, length of obturation and voids were observed by CBCT and RVG. The differences between the findings by CBCT and RVG were compared by Z two-sample proportion test and a value of p< 0.05 was considered statistically significant. The results showed that RVG did not detect any missed canals from 26 teeth, whereas CBCT recognized missed canals in 4 mandibular molars and one in a maxillary molar tooth. The presence of periapical radiolucency was observed in two mandibular molars by RVG where, where CBCT detected periapical radiolucency in 4 mandibular molars, one maxillary molar, and one maxillary premolar. Regarding the length of obturation, CBCT did not detect overextension in any tooth but was detected in two mandibular molars and two mandibular premolar teeth by RVG. However, RVG did not detect any void in obturation. In contrast, CBCT detected obturation voids in 9 mandibular molars, 5 maxillary molars, one mandibular premolar, and two maxillary premolar teeth. Statistically significant differences between the CBCT and RVG were found in all variables. Therefore, it can be concluded that CBCT is more dependable in detecting canal obturation voids, missed canals, obturation extension and periapical radiolucency than the RVG.*

Keywords *- CBCT, Missed canal, Periapical radiolucency, Root canal obturation, , RVG, Void.*

1. Introduction

The radiological examination is an important and necessary part of endodontic management, from the initial diagnostic work-up to monitoring treatment results.[1] Therefore, careful estimation of the root canal system based on high-quality radiography is a prerequisite for all stages of root canal treatment, from initial diagnosis through the monitoring of treatment.[2]

Dental radiographs provide essential information for case diagnosis, treatment planning, and follow-up.[3] In most randomized clinical trials and systematic reviews, methods of assessing success are based on clinical examination and apical radiographs, which generally consist of intraoral radiographs. Conventional periapical radiology has formed the backbone of endodontic therapy for diagnosis, canal configuration, treatment planning, and management. Two-dimensional (2D) imaging remains the most commonly used modality in practice.[4,5]

Root canal filling is an important step in endodontic treatment, as the technical quality of the root canal treatment greatly influences the outcome of the root canal treatment. It has been suggested that apical coverage is important for the success of endodontic therapy.[6] Clinical and epidemiological studies indicate that adequate root filling is an important factor in healing apical infections.[7] It is a constant source of irritation and causes an inflammatory response in the periapical tissue. Both can lead to endodontic failure. [6] The quality of root fillings is usually assessed using radiographs. The most commonly used radiographs are apical radiography (PR and digital radiography.[8-10]

Periapical radiograph (PR) is the most commonly used method to assess the quality of root canal obstruction in clinical practice. However, neither apical strictures nor apical foramen is visible on periapical radiographs. The only measurement points that can be displayed in PR are the anatomical (X-ray) vertices. In general, root canal filling is considered clinically satisfactory and appropriate when the tip of the filling material is 0–2 mm anterior to the radiographic apex on his postoperative radiograph.[7] However, the conventional periapical radiograph has several limitations that can lead to undetected pathology or improper treatment.[11] The intraoral radiographic image results from the compression of three-dimensional (3-D) structures into a two-dimensional view. The tooth and its surrounding tissues are visualized in the mesio-distal plane; studies have, however, shown that important features in the bucco-oral plane may not be revealed.[8] Regardless of the intraoral system used, the two-dimensional nature of images limits the information that can be obtained. Their diagnostic value depends on beam angulations, superimposition of anatomical structures, and patient-related factors.[10] In periapical radiography, especially in the maxillary molar region, the irradiation geometry often cannot become optimal, e.g., owing to a low palatal vault. An irradiation geometry with an x-ray beam coming too much from above results in a superimposition of the maxillary zygomatic process and the zygomatic bone onto the roots and a distorted image of them. When roots diverge, they become displayed with different degrees of distortions in periapical radiographs. When they are close together, they cannot always be separated from each other, even if several radiographs are taken.[12] Upon radiographic evaluation, even an improper root canal treatment with insufficient condensation and adaptation can be assumed appropriate depending on the X-ray beam angulation and tooth position.[10] Furthermore, two-dimensional radiology presents clear limits in periapical lesion diagnoses. Intraoral radiography is the technique commonly used to establish whether the periapical disease is present.[12] A periapical lesion was defined as PA radiolucency in connection with the apical part of the root if the width of the radiolucency exceeded at least twice the width of the periodontal ligament space.[13] Conventional radiographic examinations are of limited diagnostic value. The extent of the lesion must be known, as well as how many roots and root canals there are in an affected tooth and which root or roots are affected. The relation to the maxillary sinus and the mandibular canal is also important whether a lesion at one root is connected to that at another.[12]

Upon radiographic evaluation, depending on the X-ray beam angulations and tooth position, even an improper root canal treatment with insufficient condensation and adaptation can be assumed appropriate.[10] Furthermore, two-dimensional radiology presents clear limits in periapical lesion diagnoses. Intraoral radiography is the technique commonly used to establish whether the periapical disease is present.[12] A periapical lesion was defined as PA radiolucency in connection with the apical part of the root if the width of the radiolucency exceeded at least twice the width of the periodontal ligament space.[13] Conventional radiographic examinations are of limited diagnostic value. The extent of the lesion must be known, as well as how many roots and root canals there are in an affected tooth and which root or roots are affected. The relation to the maxillary sinus and the mandibular canal is also important whether a lesion at one root is connected to that at another.[12]

Conventional radiographic examinations frequently allow the recognition of a periapical lesion only when it is at an advanced stage,[4] and the size of periapical lesions is often underestimated.[12] One factor that highly controls lesion recognition is bone thickness. Certainly, it has been established that, in an intraoral radiogram, the lesions which involve only the bone medullary component may pass unobserved because of the ray angulations,[14] radiographic contrast,[15] location and lesion's shape.[4] These restrictions may guide to an overestimation of the success rate.[4] Moreover, two-dimensional images sometimes do not allow for to detection of the real number of root canals, with consequences in a success rate.[14] With digital radiography, endodontics failed to recognize at least one root canal in 40% of teeth despite taking parallax radiographs.[16]

The ultimate goal of a root canal treatment is to clean and fill the root canal sufficiently in all dimensions as well as retreatment.[17] It may not be possible to detect voids radiographically in root fillings in the bucco-oral dimension, especially in oval or ribbon-shaped canals with the widest extension in the bucco-oral direction. Previous in vitro studies have demonstrated that few root canal fillings completely obturate the root canals and that, especially oval and ribbon-shaped canals with large bucco-oral dimensions, are probable to be improperly filled.[8]

Cone beam computed tomography (CBCT) or digital volume tomography (DVT) utilizes an extraoral imaging scanner, which was urbanized in the late 1990s to produce three-dimensional scans of the maxillo-facial skeleton, acquired the way of a single sweep of the scanner, using a simple, direct relationship between sensor and source, which turn around synchronously through 180°–360° roughly the patient's head. Limited volume CBCT scanners (3D Accuitomo, J Morita Corporation, Osaka, Japan) can detain a 40 mm high by 40-mm diameter volume of data, which is similar in overall elevation and width to a periapical radiograph.[16]

CBCT overcomes several limitations of conventional radiography. Slices can be selected to avoid adjacent anatomical noise. For example, the roots of posterior maxillary teeth and their periapical tissues can be visualized unconnectedly and in all three orthogonal planes without superimposition of the overlying zygomatic buttress, alveolar bone and neighboring roots. The spatial association of the roots of multi-rooted teeth can be visualized in three dimensions. The true size and three-dimensional nature of periapical lesions can also be assessed/Cone beam computed tomography enables radiolucent endodontic lesions to be detected before they would be evident on conventional radiographs. These clinical studies appear to presume that the radiological findings from CBCT symbolize the true status of the periapical tissues, i.e. that CBCT can be used as a gold standard with a sensitivity and specificity of 1.0 to detect the presence or deficiency of periapical disease.[16]

The most stimulating area in which CBCT may be applied to endodontics influences the treatment outcome. CBCT scans should result in a more objective and accurate resolution of the diagnosis of endodontic treatment. CBCT images are geometrically accurate, and the problems of anatomical noise seen with periapical radiographs can be eliminated. Serial sets of linear and volumetric dimensions obtained with CBCT technology could therefore be used to provide a more objective and accurate representation of osseous changes (healing) over time. Therefore, clinical studies must be re-evaluated to measure the presence or absence of missed canals, periapical radiolucency, obturation length and voids.

2. Materials and Methods

This Cross-sectional comparative study was performed in the Department of Conservative Dentistry and Endodontics Faculty of Dentistry, Bangabandhu Sheikh Mujib Medical University Shahbag, Dhaka-1000, Bangladesh, during the period From 18th October 2020 to 17th April 2021.

2.1. Study Population

Patients have received endodontic treatment in the Department of Conservative Dentistry and Endodontics, Bangabandhu Sheikh Mujib Medical University. The inclusion criteria were Endodontically treated teeth maxillary and mandibular premolars and molars and radiographic quality of the images adequate for evaluation of the periapical status of the teeth. The post-obturation assessment of the patients was performed radiologically by radiovisuography (RVG), and Cone-beam computed tomography (CBCT) to determine/observe the presence of missed canals, periapical radiolucency, voids in obturation and the length of termination of the obturation.

2.2. Steps Occupied in Radiological Measurement

Periapical radiograph (RVG) was taken with the NOMAD Pro 2 System with revelation parameter of 60Kv, 2.5Ma with an exposure time of 0.16 seconds. Cone beam computed tomography was done utilizing an extra oral imaging scanner. A three-dimensional volume of data was acquired during a single sweep of the scanner, which was rotated synchronously through 180° to 360° approximately the patient's head. The cone-shaped X-ray beam will capture a cylindrical or spherical volume of data, described as the field of view. Small FOV units (less than 10 cm) were used to obtain the tooth's dento-alveolar imaging.

2.3. Procedure of CBCT

CBCT is a fairly recent modality in which a pyramidal or cone-shaped X-ray beam is focused at the center of the ROI onto a detector on the opposite side. The X-ray source and detector rotate, and multiple sequential planar projections of the field of view (FOV) are acquired in a complete or partial arc.[9] CBCT uses a cone-shaped X-ray beam centered on a two-dimensional (2D) sensor to scan a 180-degree to 360-degree rotation around the patient's head to acquire a full 3D volume of data.[10.] A single partial or full rotational scan from an x-ray source takes place while a reciprocating area detector moves synchronously with the scan around a fixed fulcrum within the patient's head. During the scan rotation, each projection image is made by the detector's sequential, single-image capture of attenuated x-ray beams.

Once the basis projection frames have been acquired, data is processed to create the volumetric data set. This process is called reconstruction. The volumetric data set is a compilation of all available vowels. Most CBCT devices are presented to the clinician on screen as secondary reconstructed images in three orthogonal planes (axial, sagittal, and coronal), usually at a thickness defaulted to the native resolution.[18] These 2D data are then converted with the help of algorithms into a 3D volume by a computer.[9]

2.4. Blinding of the Assessor/Observer for Analysis of the Radiographic Image

Apart from the principal investigator, the radiographic image was analyzed by one of the teachers of the faculty in a blinded manner. The assessor/examiner was unaware of the experiment's true nature and purpose. The principal investigator and the blinded examiner evaluated each set of images (RVG and CBCT) to reach the final conclusions.

2.5. Data collection and Analysis

Predetermined data collection sheet, filled up by the investigator himself through the interview, supplemented by documentary evidence (CBCT and RVG image after completion, data set was first checked and entered into the computer from numerical codes on the form. After coding and editing, collected data was analyzed using computer-based programming (SPSS, Version –23). The results were presented -in tables, figures or graphs and diagrams as necessary. The result of significance was expressed as a p-value, and Statistical analysis will be performed by Chi-square/ t-test; a value $p<0.05$ was considered statistically significant.

3. Results

The results showed that RVG did not detect any missed canals from 26 endodontically treated teeth, whereas CBCT identified missed canals in 4 mandibular molars and one in a maxillary molar tooth (Table 1). The presence of periapical radiolucency was observed in two mandibular molars by RVG, where CBCT detected periapical radiolucency in 4 mandibular molars, one maxillary molar, and one maxillary premolar (Table 2). Regarding the length of obturation, CBCT did not detect overextension in any tooth but was detected in two mandibular molars and two maxillary molars by RVG (Table 3). RVG did not detect any void in obturation in any 26 teeth. In contrast, CBCT detected obturation voids in 9 mandibular molars, 5 maxillary molars, one mandibular premolar, and two maxillary premolars (Table 4).Statistically significant differences between the CBCT and RVG were found in the missed canal of mandibular molar teeth. Furthermore, regarding void in obturation, the findings between CBCT and RVG were significant between mandibular molar teeth and maxillary premolar and molars teeth.

Table 1. Distribution of missed canals across different tooth types (n=26)

Tooth Name					Pvalue
RVG		CBCT			
		n	%	n	%	
	Mandibular Molar (n=10)				
	Yes		0.0	4	40.0	
	No	10	100.0	6	60.0	<0.05
	Maxillary Molar (n=6)					
	Yes	0	0.0	1	16.7	
	No	6	100.0	5	83.3	>0.05ns
	Mandibular premolar(n=5)					
	Yes	0	0.0	0	0.0	
	No	5	100.0	5	100.0	
	Maxillary Premolar (n=5)					
	Yes	0	0.0	0	0.0	
	No	5	100.0	5	100.0	

s=significant
ns= not significant
P value reached from Z two-sample proportion test

Table 2. Distribution of periapical radiolucency (PARL) across different tooth types (n=26)

Tooth Name					Pvalue
RVG		CBCT			
		n	%	n	%
	Mandibular Molar (n=10)				
	Yes	2	20.0	4	40.0
	No	8	80.0	6	60.0	<0.05
	Maxillary Molar (n=6)				
	Yes	0	0.0	1	16.7
	No	6	100.0	5	83.3	>0.05ns
	Mandibular premolar(n=5)				
	Yes	0	0.0	0	0.0
	No	5	100.0	5	100.0
	Maxillary Premolar (n=5)				
	Yes	0	0.0	1	20.0
	No	5	100	4	80.0

Table 3. Distribution of overextensions in obturation across different tooth types (n=26)

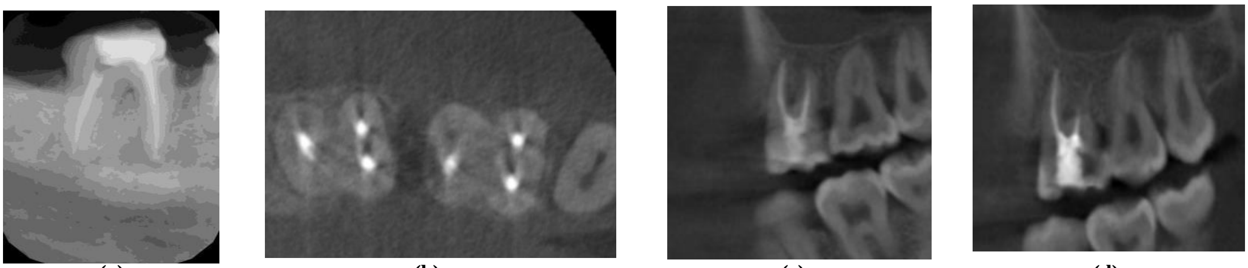
Tooth Name					Pvalue
RVG		CBCT			
		n	%	n	%
	Mandibular Molar (n=10)				
	Yes	2	20.0	0	0.0
	No	8	80.0	10	100.0	<0.05
	Maxillary Molar (n=6)				
	Yes	0	0.0	0	0.0
	No	6	100.0	6	100	>0.05ns
	Mandibular premolar(n=5)				
	Yes	2	40.0	0	0.0
	No	3	60.0	5	100
	Maxillary Premolar (n=5)				
	Yes	0	0.0	0	0.0
	No	5	100.0	5	100.0

ns= not significant
P value reached from Z two-sample proportion test

Table 4. Distribution of voids in obturation across different tooth types (n=26)

Tooth Name						**Pvalue**
RVG		CBCT				
		n	%	n	%	
	Mandibular Molar (n=10)					
	Yes	0	0.0	9	90.0	
	No	10	100.0	1	10.0	
	Maxillary Molar (n=6)					
	Yes	0	0.0	5	83.3	
	No	6	100.0	1	16.7	
	Mandibular premolar(n=5)					
	Yes	0	0.0	1	20.0	
	No	5	100.0	4	80.0	
	Maxillary Premolar (n=5)					
	Yes	0	0.0	2	40.0	
	No	5	100.0	3	60.0	

s=significant
ns= not significant
P value reached from Z two-sample proportion test



(a) (b) (c) (d)

Fig. 1 Representatives photographs of the tooth with RVG and CBCT image (A: RVG, B: Miss canal detected by CBCT in the same tooth of A, C: RVG, D: detected by CBCT in the same tooth of C)

4. Discussion

The endodontic treatment result depends on the successful finding of canal anatomy, including working length for adequate canal preparation and obturation. Generally, intraoral periapical radiographs and RVG are utilized in post-treatment to evaluate the value of root filling to settle on the clinical outcome. The present study compared the quantity of missed canals, periapical radiolucency, length of obturation and voids in obturation by two radiographic techniques RVG and CBCT.

The present study revealed that RVG did not distinguish missed canals from 26 endodontically treated teeth. In contrast, CBCT identified missed canals in 4 mandibular molars and one in a maxillary molar tooth. According to the analysis of 8399 teeth in 32 studies, the incidence of 2 canals in this root was 56.8%. The majority of the missed canals we found were in mandibular molars, which could be due to enlarged awareness among the clinicians regarding the accessory canals in maxillary molars. With respect to the previous research, the present study found more mandibular molars than other teeth, which may have also contributed.

The results of periapical radiolucency showed higher periapical radiolucency was achieved with CBCT compared to RVG, which indicated a reduced clinical success rate. A study in Beirut also detected more periapical lesions and observed a reduced clinical success rate (due to higher lesions) with CBCT compared to digital intraoral radiography.[14] The end goal of endodontic treatment is to fill the root canal adequately in all dimensions to minimize the scope of periapical lesions or re-infections.

Another key aspect of endodontic treatment involves working length determination.[19] However, the present study did not see any difference in identifying the overextension in canal obturation between the two radiographic methods. Earlier studies reported significantly higher detection of strip perforation with CBCT compared to periapical imaging but did not find a significant difference in identifying root perforations.[20-21] The present study did not find any strip perforation that did not match the previous study. Regarding voids in obturation, the present study showed significantly higher detection of canal obturation voids inmandibular molars and both maxillary molars and premolars with CBCT compared to RVG. The reason for the differences might be due to the image achieved by CBCT and TVG. Previous studies have indicated that CBCT can identify the voids of obturation because the three-dimensional image (sagital, coronal and axial plane) achieved by CBCT gives additional information than that of RVG image, which is a two-dimensional mesio-destal plane and does not cover the bucco-oral plane.

Based on the present study, it can be considered that the results of missed canal periapical radiolucency and obturation quality (length and void) are superior to RVG. However, RVG detected some root-filling overextensions, which were not seen in CBCT and could be false positives. Overall, CBCT exhibited superior diagnostic accuracy over RVG in identifying canal obturation voids, missed canals, and periapical radiolucency to ascertain endodontic treatment outcomes.

CBCT permits a detailed three-dimensional analysis of tooth and surrounding anatomical structures that yield more precise canal measurements, which can help attain a better clinical outcome. We detected more missed canals and voids in canal obturation using CBCT than RVG, which suggests that CBCT often detected atypical canals (due to anatomic variations) that can be otherwise missed during endodontic treatment, contributing to failure. A retrospective study in Colombia also reported a higher number of periapical lesions, missed canals, and root fillings with voids using CBCT compared to both periapical film radiographs and digital periapical radiographs.[22] Thus, utilizing CBCT in endodontic treatment may help avoid inadequate or incomplete root filling resulting in superior treatment success.

The results found in the present study were well-aligned with current studies, which also supported CBCT as a more valuable diagnostic tool than conventional film or digital periapical radiographs.[22-23] There are several reasons for this, as explained by Lofthag-Hansen et al.[12] (2007). CBCT slices greatly reduce the problem of superimposition of unrelated structures onto the features of interest decreases compared to periapical radiographs in which an entire volume of images is compressed into a two-dimensional image.[12] Some major drawbacks of periapical radiographs include the two-dimensional image, frequent anatomical noise and geometric deformation.

The irradiation geometry often cannot become optimal, especially in the maxillary molar region, e.g., owing to a low palatal vault. Irradiation geometry with the x-ray beam coming too much from above results in a superimposition of the maxillary zygomatic process and the zygomatic bone onto the roots and a distorted image of them. When roots diverge, they become displayed with different degrees of distortions in periapical radiographs. When they are close together, they cannot always be separated from each other, even if several radiographs are taken.

In contrast, CBCT yields more significant information than periapical images and eliminates the superimposition of anatomical structures.[14] When using appropriate CBCT techniques, it is possible to look at each root separately. Slice angles can be chosen so that the frontal and sagittal slices, respectively, become parallel with the longitudinal axis of the root and, therefore, the axial slices perpendicular to it. These factors clearly underscore the superiority of high-quality CBCT techniques over conventional radiography.[12]

The follow-up duration of the present study was relatively brief as it conducted the radiological examinations immediately after the endodontic treatment. The earlier studies recommended follow-up period should be long enough to allow the complete process of wound healing. The more recent retrospective study in the Thai and Egyptian population recommended more than 24 months of follow-up period to avoid false negative results.[24,25]

Conclusion

It can be concluded that CBCT was more reliable in detecting canal obturation voids, missed canals, obturation extention and periapical radiolucency compared with periaical digital radiographs (RVG) to determine the endodontic treatment success

Ethical issue

This study was performed after taking ethical clearance from IRB, Bangabandhu Sheikh Mujib Medical University.

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