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ACCURACY OF CONE-BEAM COMPUTED TOMOGRAPHY IN DETECTION OF STRIP ROOT CANAL PERFORATIONS USING TWO DIFFERENT VOXEL SIZES IN COMPARISON TO DIGITAL PERIAPICAL RADIOGRAPH WITH A PARALLEL TECHNIQUE, AN IN VITRO STUDY

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ABSTRACT

Background: Detection of strip root canal perforation in obturated teeth depend mainly on radiographic methods. The Periapical radiographs (PR) provide valuable two-dimensional images, while the Cone-Beam Computed Tomography (CBCT) imaging offers a three-dimensional visualization of the tooth and its surrounding structures. The voxel size used for CBCT acquisition has impact on the diagnostic accuracy of those images. This study aimed to compare the diagnostic accuracy of the digital PR and CBCT with 0.2 and 0.3 mm^3 voxel sizes for the strip perforation detection in mandibular root. **Methods:** For this investigation, 48 sound lower first molars were selected and divided into the following groups: (i) without obturation and without strip perforation, (ii) obturation and without strip perforation, (iii) without obturation and strip perforation, (iv) obturation and strip perforation. To obtain the requested radiographic images each tooth was placed in dehydrated human mandible. All images were evaluated by four observers, data was collected, and SPSS software program was used to analyse the data. **Results:** In our study the area under the curves (AUC) values for the CBCT images were highly significance than the value for PR images, there was no significance difference between the two CBCT voxel sizes images for perforation detection in obturated teeth. **Conclusions:** Compared to PR, A significantly higher accuracy for detection of strip root canal perforation was associated to the CBCT images. For non-obturated teeth the 0.2 mm^3 CBCT voxel sizes has a higher significant difference than 0.3 mm^3 CBCT voxel sizes.

KEYWORDS: Strip root perforation, cone-beam computed tomography, periapical radiography, diagnostic accuracy, specificity, sensitivity.

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INTRODUCTION

The success of endodontic treatment can be multifactorial, that may include the anatomical variation of the tooth and expertise of the clinician. Endodontic treatments are most frequently performed on mandibular first molars [1], Because of its anatomical curvature, the mesial root often presents challenges for endodontic procedures and increases the risk of iatrogenic errors. One of these errors is the root perforation during root canal procedure that could occur at the danger zone area which has the thinner wall of dentine thickness. The size of the perforation and the timing of diagnosis are the two most important factors that may have an impact on the prognosis of the root perforation [2], early detection of this errors is very important regarding both deciding the proper treatment plan and avoiding medico-legal actions [3]. Clinically, the root canal perforation could be detected using a variety of instruments and techniques, among these are, a an endoscope[4], dental operative microscope[5], an optical coherence tomography scan[6], and an electronic apex locator [7,8]. However, all these techniques depend on visualizing the empty root canal area to detect the perforation, none of these were able to identify the perforation in roots that had already filled by root canal obturation materials. Radiographic techniques may be applied in these circumstances. The two-dimensional (2D) radiographs, such as periapical and panoramic, provide 2D images of structures that superimposing intraoral anatomical structures, and may obstruct the detection of a perforation.

The CBCT on other hand offers three-dimensional (3D) images for the tooth and surrounding structures, and it is the most effective way to detect perforations [9]. The quality of CBCT pictures is influenced by multiple factors, including the field of view (FOV), voxel size, tube voltage (kaph), and tube current (mA). Voxels are the smallest volumetric features found in 3D images, and they have a big impact on scanning quality and acquisition time [10,11]. To guarantee optimal image quality, the patient should be exposed to the least quantity of radiation possible, in accordance with the as low as reasonably achievable (ALARA). The quality of image is enhanced by using a smaller voxel size and increased radiation dose [12]. Therefore, in order to get the finest image quality with the least amount of radiation exposure, balance should be achieved in compliance with the ALARA recommendation [13]. The goal of this study is to examine the diagnostic accuracy of a digital periapical radiograph (PR) and computed tomography (CBCT) with varying voxel sizes for the diagnosis of root perforation when assessed by different observer specialty.

This study aims to examine the diagnostic accuracy of two voxel sizes CBCT images (0.2 and 0.3 mm^3) comparing to a digital PR for the identification of strip root canal perforation for mesial root of the mandibular first molar in presence or absence of root canal obturation when assessed by different observer specialty.

METHODS

This study's protocol was given approval by the scientific research of ethical committee at kafrelsheikh university (no. KFSIRB200-1). This study adhered to the guidelines provided by the Standards for Reporting Diagnostic Accuracy (STARD) [14]. To analyse inter-observer and intra-observer compatibility, four groups (n = 12) with total of 48 sound lower first molars were included in this study. Selected intact teeth extracted from the outpatient clinic at Kafrelsheikh University for periodontal reasons were stored at room temperature in distilled water. Informed consent was obtained from all patients so that future studies using their extracted teeth may be carried out. All selected teeth were examined by PR with a mesial shift and by a magnifying glass, any teeth with internal or external root resorption, fractures, anomalies, cracks, and open apices were excluded from this study. The teeth were cleaned by soaking them for 30 minutes in a 5.25% sodium hypochlorite solution (NaOCl), and if there was any calculus deposited on the surface was removed using sharp curettes.

After endodontic access cavities preparation in all teeth, canal's patency for the mesial roots was verified using a # 10 K-file, The working length was determined to be 1 mm short of the true canal length that was measured after the tip of the patency file just become visible at the apical foramen. The biomechanical preparation for the mesial roots was done using Protaper Next rotary systems up to X2 files (#25, 6%), and 2.5% NaOCl solution was used for irrigation throughout instrumentation, activation of the irrigant solution was done using an Irrisafe 20/21 file, final rinse of the canals was done using 2mL distilled water. The teeth used for the study were remained wet throughout the experiment, and randomly divided into 4 groups with 12 teeth for each group according whether or not there is strip perforation and whether or not there is root obturation as the follows: (i) without obturation and without strip perforation, (ii) obturation and without strip perforation, (iii) without obturation and strip perforation, (iv) obturation and strip perforation. Gates Glidden drill No. 1 was used for making strip root canal perforation in the coronal third of the mesiolingual root canal until the perforation was made at the distal surface of the mesiolingual root, size #20 K-file was used to confirm presence of perforation defect.

The root canal obturation was done using AH plus sealer and gutta-percha points using the lateral condensation technique.

Regarding the radiography methods and evaluation, the teeth were placed into prepared sockets in the posterior region of dehydrated human mandible after filling the socket space with impression material to secure the teeth in their place. Three layers of dental wax were applied to the mandible's buccal and lingual surfaces to mimic soft tissue. A Gendex X-ray unit running at 7 mA, 65 kVp, and 0.2 s exposure time, and GXPS-500 photostimulable phosphor plate (PSP) used with a film holder (Rinn Manufacturing Company, Elgin, IL) were used to take three horizontal angles intraoral digital PRs including direct angle, 10^o distally, and 10^o mesially (Figure 1), the distance between the X-ray cone and tooth was 25 cm. The CBCT images at two distinct voxel sizes 0.2 mm3 (Figure 2) and 0.3 mm3 (Figure 3) were acquired at 1 mA, 96 kVp, with a 55 x 50 mm FOV with exposure times ranging between 12 and 15s using the ProMax® 3D Max CBCT equipment.

The images of CBCT were assessed in three reconstruction planes with 0.1 mm slice thickness. Before interpretation process, a calibration session was carried out with 10 images that were not used in the study. The images of digital PR and CBCT were assessed blindly by four calibrated observers with 10 years of experience: two dentomaxillofacial radiologists, and two endodontists were viewed and examined the image sets separately. The observers were blind to the outcomes of the other imaging technique and did not participate in the preparation of the samples, the observers were not given a time limit for examination. Each image set was viewed separately at 1-week intervals and then evaluated again 1 week later, and if there was any difference between the first and second viewings, a final decision was requested for each observer independently. The observers evaluated the radiographic images using a monitor in a low-lit room and labelled their findings as 'presence or absence of perforation'.

SPSS software version 17.0 was used analyse the collected data. The intra-observer and inter-observer agreement (difference in measurements made by the same observer and difference in measurements made by different observers respectively) were computed using Cohen's kappa value (k). The following criteria were used to interpret the results of Kappa:

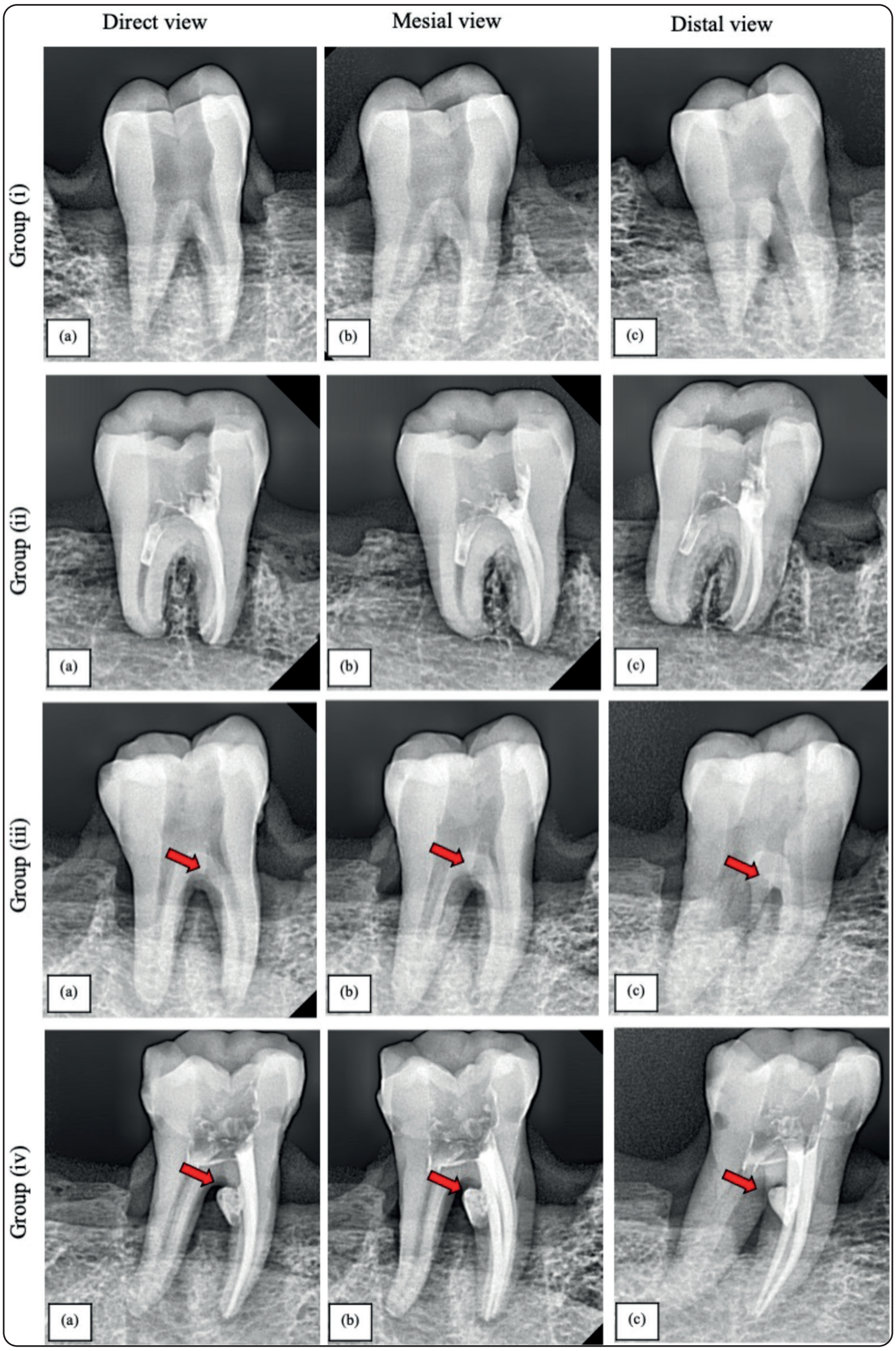

Fig. (1) Periapical radiographic images for detection of root canal perforation using three different angulations: (a) direct view (b) mesial view (c) distal view. Red arrow: area of perforation detection.

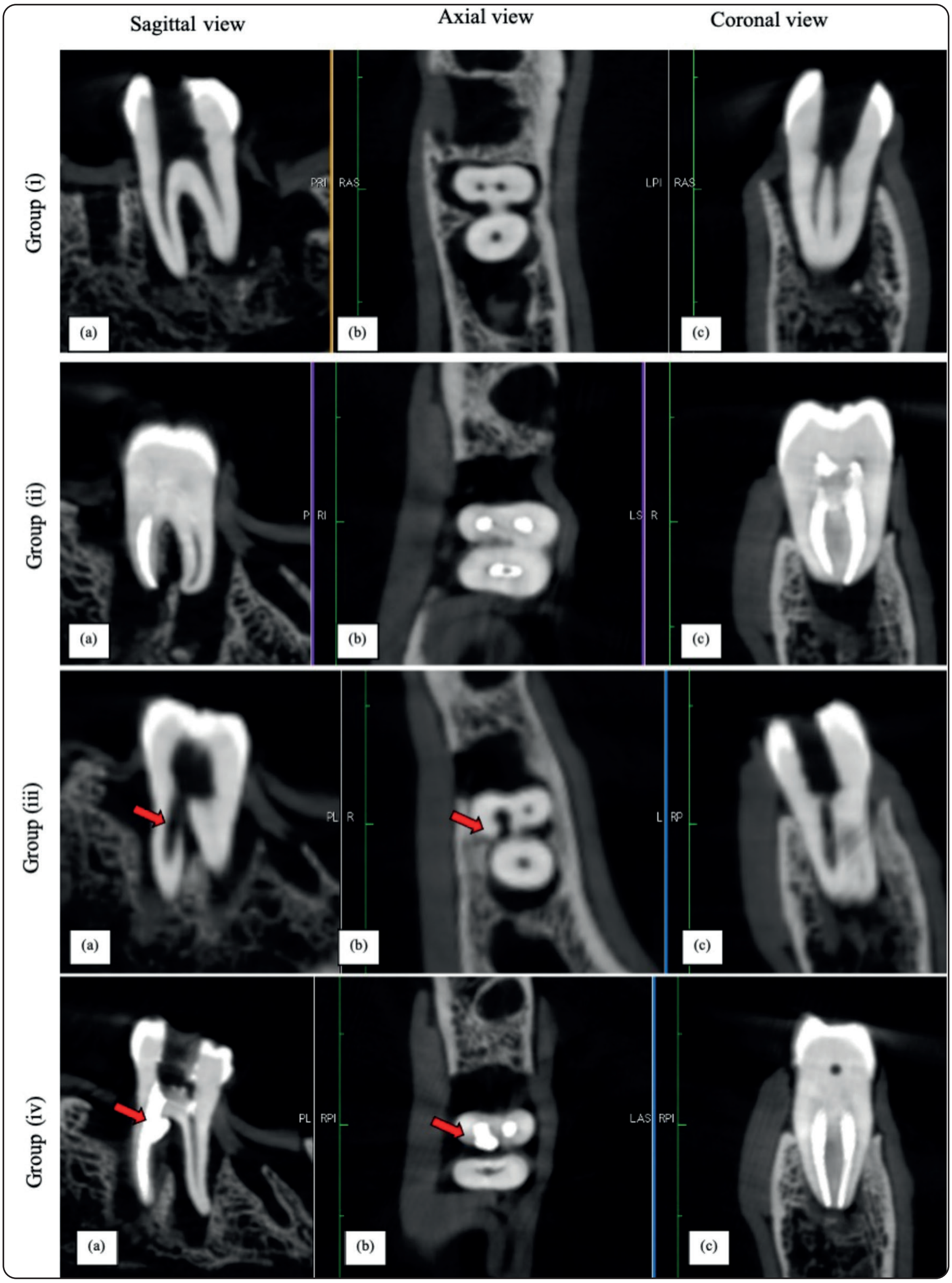

Fig. (2) CBCT images for detection of root canal perforation taken at 0.2 mm3 voxel size (a) sagittal view (b) axial view (c) coronal view. Red arrow: area of perforation detection.

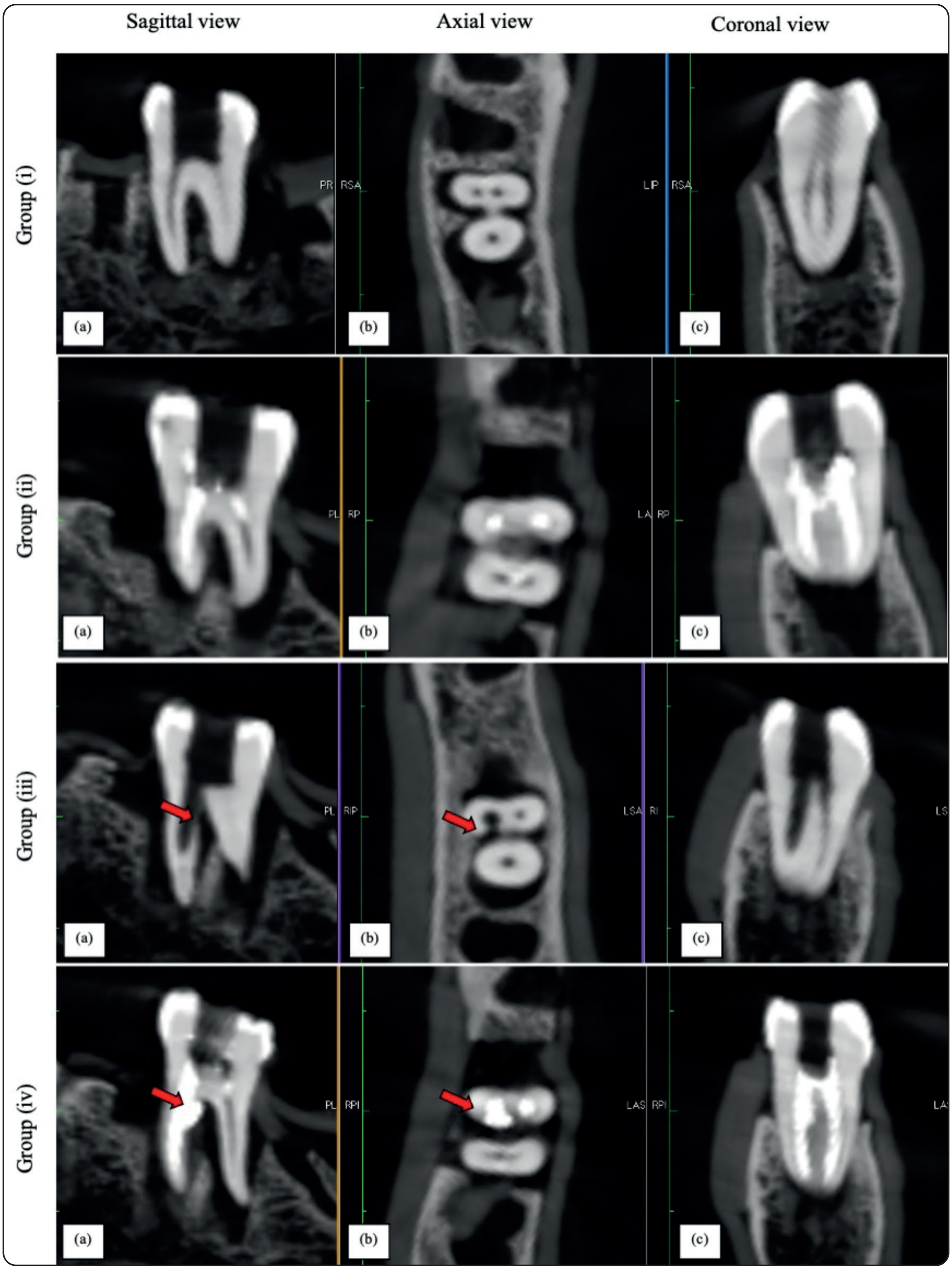

Fig. (3) CBCT images for detection of root canal perforation taken at 0.3 mm3 voxel size (a) sagittal view (b) axial view (c) coronal view. Red arrow: area of perforation detection.

excellent agreement, strong agreement, moderate agreement poor agreement and no agreement when the k value equal 0.81–1.00, 0.61–0.80, 0.41–0.60, 0.10–0.40 and <0.10 respectively [15]. The AUC was determined using the standard error (E) and the 95% confidence interval (CI). AUC values less than 0.5 indicate no discrimination ability, while values of 1 indicate perfect discrimination. Z tests were used to compare the AUC values for each image modality and observer, with a significance level of p = 0.05. The following measurements were also computed: sensitivity (Se), specificity (Sp), negative predictive value (NPV), and positive predictive value (PPV) with a 95% confidence interval (CI) for both PR and CBCT images used to detect the perforations.

RESULTS

The intra-observer kappa values between the 1st and 2nd readings for observers who evaluated the non-obturated teeth ranged from strong to excellent (0.604:0.944), and for obturated teeth, they ranged from moderate to excellent (0.444:1). The inter-observer correlation coefficients ranged from strong to excellent for the observers who evaluated the non-obturated and obturated teeth (0.671:1 and 0.713:1, respectively). Regarding the non-obturated teeth, the calculated AUC values for detection of root perforation were ranked ascendingly as 0.771, 0.979, and 1 for PR, CBCT with 0.3mm^3 voxel size, and CBCT with 0.2mm^3 voxel size respectively, with a statistically significant difference between them. The Se for PR was 84.2% and for CBCT was 100% for both voxel sizes, while the Sp was 72.4% for PR, 100% for CBCT with 0.2mm^3 voxel size, and 95% for CBCT with 0.3mm^3 voxel size. For obturated teeth, the AUC value for CBCT images with both voxel sizes was 1, with a statistically significant difference compared to the value for PR images (AUC = 0.875). The Se for all images modality for detecting strip root perforation in obturated teeth was 100%, while the Sp was 100% with both voxel sizes of CBCT images, and it was 75% for PR images (Table 1). There was a statistically significant difference in the detection of strip root perforation in obturated teeth compared to non-obturated teeth using PR and CBCT with 0.3 mm^3 voxel sizes, while CBCT with 0.2 mm^3 voxel sizes showed the same accuracy in the detection of strip root perforation for obturated and non-obturated teeth. There was no significant difference between using 0.2 and 0.3 mm^3 voxel sizes for detection of strip root perforation for obturated teeth.

TABLE (1) AUC values, sensitivity, specificity, PPV, and NPV for all image sets for non-obturated teeth

Image type		AUC values	SEa	Asymptotic sig.b	Asymptotic 95% confidence interval		Se (%)	Sp (%)	PPV (%)	NPV (%)
					Lower bound	Upper bound				
PR	Non-obturated	.771	.071	.001	.632	.910	84.2	72.4	66.78	87.5
	Obturated	.875	.056	.000	.766	.984	100	80	75	100
CBCT-0.2	Non-obturated	1.000	.000	.000	1.000	1.000	100	100	100	100
	Obturated	1.000	.000	.000	1.000	1.000	100	100	100	100
CBCT-0.3	Non-obturated	.979	.024	.000	.932	1.000	100	95	96	1000
	Obturated	1.000	.000	.000	1.000	1.000	100	100	100	100

DISCUSSION

In the this study, all observers assessed the diagnostic accuracy of PR taken by a parallel technique with three horizontal angulation versus CBCT taken in two different voxel sizes (0.2 and 0.3 mm^3) for detection of strip root canal perforation in the mesial root of lower first molars in presence or absence of root canal obturation. To accurately diagnose presence of endodontic problems selecting the appropriate imaging settings is crucial for both decision-making and treatment planning (16). The lower first molar were selected for this study because of their increased morphological diversity and more complicated internal structure (17,18), Berutti et al (19) showed that the thinner part of dentin thickness of the mesial root of the lower first molar was found 1.5 mm under the area of furcation on the distal wall of the root (dangerous zone), this site has a very high incidence of root canal perforation. The selected molars were mounted on a human dehydrated mandible in order to mimic the clinical situation with regard to the presence of cortical and cancellous bone (17). Dental wax was then added to the mandibles buccally and lingually to simulate soft tissue in in vitro experiments (20). In endodontic clinical practice, PR is the imaging modality that is most frequently utilized (21,22), CBCT is one of the imaging modalities that was developed especially to create accurate three-dimensional pictures of the teeth and the tissues surround them (23).

Under the circumstances of this in vitro study, our results showed higher accuracy for the CBCT images compared to PR images for the detection of strip root perforation in non-obturated and obturated teeth. Filling material seeping into the perforation defect could be partly responsible for the higher detection rates of strip perforations in obturated teeth seen in our investigation (24), this result is in agreement with previous studies (25–27) that had showed that the CBCT images had better accuracy than PR images in detection of root perforation in obturated teeth, while Adel et al (9) and Haghanifar et al (28) reported that the accuracy and sensitivity of CBCT were significantly reduced in obturated root canals, they explain that by the artefacts defect that caused by the presence of radiopaque filling materials (sealer and gutta-percha), they also showed that the CBCT had better accuracy than PR in detecting root canal perforation in non-obturated teeth, which come in agreement with our results, this could be explained by the fact that many approaches have been proposed to improve the capabilities of traditional radiography in light of the limits of two-dimensional images, which limit information on the extension, size, and location of defects and cause geometric distortion (29). One of the key variables that influences the CBCT's diagnostic characteristics is voxel size, in our study, the CBCT with 0.2 mm^3 voxel size perform better than CBCT with 0.3 mm^3 voxel size in identification of strip root perforation for non-obturated teeth, this came in agreement with the results obtained by Venskutonis et al (22), while this was different from results obtained by Kamburoglu et al (30) who compare between four different CBCT voxel sizes (0.1, 0.15, 0.2, and 0.3 mm^3) for identification of furcal root perforation. Koç et al (16) reported no difference between 0.075, 0.1 and 0.2 mm^3 voxel sizes for detection of stip root perforation in non-obturated teeth, and another study reported by Afkhami et al (17) who compared between voxel sizes of 0.2 and 0.3 mm^3 showed the same results. Size and location of perforation defect, number of observers and their specilaity, and the type CBCT systems used in the research may attributed to the difference of the obtained results. Our results did not show a significance difference between the two voxel sizes in detection of perforation in obturated teeth, and this may be explained by penetration the filling materials through the perforation defect could facilitate detection of perforation. The selection of the voxel size that require the least radiation dose with no effect on the resolution and accuracy of the CBCT is very important. The ALARA and radiation exposure should be regarded when performing CBCT scan, (31,32). Clinically, the diagnostic accuracy of CBCT scanning for detection of perforation might be less than what this in vitro investigation found. In this study there were several concerns including mimic the presence of the soft tissue, dehydrated human mandibles, and use of artificially created root defects, that did not yield radiographic images with the same level of quality as those obtained in a clinical situation. Detection of perforation in this in vitro study my be increased by presence of several characteristics features as there was no movement of the patient, no beam-hardening artifacts that may be caused by presence of other radiopaque filling materials that might be present in the surrounding structures [22,33].

Our findings could have clinical advantages as in cases of there is a risk of root canal perforation, the injection of radiopaque intracanal medication material into the canal may increase the detection of perforation incidence by PR and CBCT, the voxel size of 0.3 mm^3 could be used equally to 0.2mm^3 voxel size in the presence of root canal filling materials, and this help in decrease the radiation dose of CBCT.

Future study to evaluate the accuracy of different observers specialty to detect the perforation defect, effect of peroration size on the detection of perforation in obturated canals, and clinical trials study using of PR and low dose CBCT in detection of root perforation in the presence and absences of root canals filling materials or intracanal medication material should be performed.

CONCLUSION

The CBCT images is more effective than PR for detection of strip root canal perforation in the context of this in vitro study. A 0.2 and 0.3 mm^3 voxel size are equally effective for detecting perforation in obturated teeth. The reduced radiation dose can therefore be employed to minimize radiation exposure to patients in light of our findings and the ALARA rule.

List of abbreviations

PR	Periapical radiographs
CBCT	Cone-beam computed tomography
AUC	Area under the curves
FOV	Field of view
ALARA	As low as reasonably achievable
NaOCl	Sodium hypochlorite solution
Se	Sensitivity
Sp	Specificity
NPV	negative predictive value
PPV	positive predictive value

Declarations

Ethics approval: Written ethical approval was obtained from the scientific research ethical committee of Kafrelsheikh university (no. kfsirb200-1). Informed consent was obtained from all patients to conduct future research on their extracted teeth.

Consent for publication: Not applicable

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