CBCT Performance and Endodontic Sealer Influence in the Diagnosis of Vertical Root Fractures

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ORIGINAL RESEARCH

CBCT Performance and Endodontic Sealer Influence in the Diagnosis of Vertical Root Fractures

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Abstract

Aim: To evaluate the performance of three cone beam computed tomography (CBCT) machines in detecting vertical root fractures (VRFs) in teeth filled with different sealers.

Materials and methods: A total of 80 single-rooted premolars were subjected to instrumentation and restoration with gutta-percha + AH Plus sealer, gutta-percha + sealer 26, gutta-percha + fill canal, and gutta-percha without sealer as the control. Half of the samples were randomly subjected to root fracture and all the teeth were scanned by i-CAT (Imaging Sciences International, Hatfield, USA), PreXion (PreXion Inc., San Mateo, USA), and OrthoPhos XG (Sirona Dental System, Bensheim, Germany). Three examiners analyzed the images for the presence of fractures.

Results: The highest accuracy was obtained with the PreXion device, with Az = 0.85, while the i-CAT device provided higher sensitivity (0.93). The specificity values observed ranged between 0.75 and 0.70. Chi-squared tests ($p > 0.05$) demonstrated that the sealers did not exert a significant influence on the diagnosis of VRF.

Conclusion: It may be concluded that endodontic sealers do not influence the detection of VRF. The PreXion device was the most accurate, having the highest specificity value.

Clinical significance: Radiopaque materials might affect the diagnosis of VRFs because they can simulate fracture lines, leading to false-positive results. Moreover, CBCT machines present different specificities that could exert some influence on that.

Keywords: Cone beam computed tomography, Diagnosis, Root canal filling material, Vertical root fracture.

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Introduction

Having a definitive diagnosis of vertical root fractures (VRFs) is a challenge in the clinical scenario. A comprehensive dental history, in conjunction with clinical and radiographic findings, can provide valuable information, suggesting the presence or absence of VRF.[1,2]

Cone beam computed tomography is a superior imaging modality that is a useful adjunct to clinical findings, thereby enabling an accurate diagnosis,[3,4] although several factors, such as voxel size, the field of view (FOV), and the presence of radiopaque materials inside the root, may cause interference in the final image.[5,6] These parameters vary among different CBCT units and different imaging protocols within the same unit.

Although the influence of the type of radiopaque material on the detection of root fractures using CBCT images has been reported, the filling material used has been restricted to gutta-percha.[3,5,6] The results of these studies consistently reveal that gutta-percha cones produce distinct streaking artifacts and beam hardening on CBCT axial slices that might simulate fracture lines, leading to false-positive results.[3,7,8]

Our aim is to verify the performance of three CBCT machines in detecting VRFs in teeth filled with different endodontic sealers.

Materials and Methods

Eighty human premolars were selected by taking into consideration the following inclusion criterion: single rooted on visual inspection. They were subsequently radiographed to suit the exclusion criteria: prior endodontic manipulations, root resorption, lacerations, shape anomalies, teeth with more than one canal, and the presence of posts. The teeth were also analyzed using a stereomicroscope (Tecnival SQF-F, Curitiba, Brazil) with a magnification of up to 40× to confirm the absence of root fractures prior to the experiment.

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Sample Preparation

Coronal access cavities were prepared, and the root canal treatment was done with a ProTaper Rotary System (DENTSPLY, Maillefer, Tulsa, OK, USA) up to size F3.

The samples were divided into 4 groups with 20 teeth per group. The filling materials used per group were gutta-percha without a sealer, gutta-percha + AH Plus (DENTSPLY, Maillefer Tulsa, OK, USA), gutta-percha + sealer 26 (DENTSPLY, Maillefer Tulsa, OK, USA), and gutta-percha + fill canal (TechNew, Rio de Janeiro, Brazil).

Teeth were wrapped in a thin layer of wax no.7 (TechNew, Rio de Janeiro, Brazil) until the region of the cervical collar. The teeth were then embedded in polyvinyl chloride (PVC) tubes containing acrylic resin.

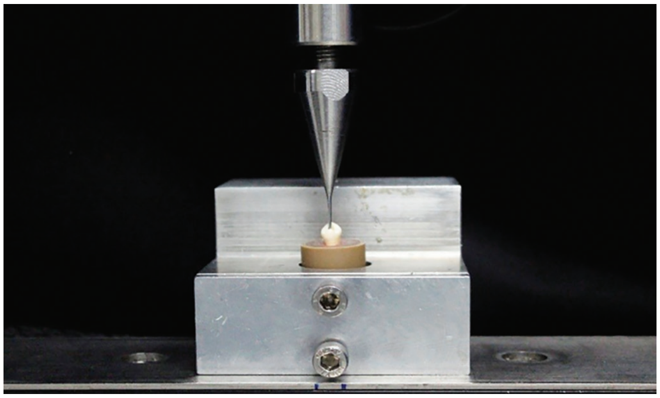


Fig. 1: Positioning of the test specimen in the universal mechanical testing machine

For root fracture simulation, the created test specimens of each group were mounted on a cylindrical device in a universal mechanical testing machine (EMIC DL 2000; São José dos Pinhais, Brazil). The specimens were then subjected to vertical compression by means of an active tip industrial sewing machine needle made of nickel-plated steel, specially created for this study. The fracture/crack was induced using controlled pressure vertical compression force at a speed of 1 mm/min with a load of 200 kgf, applied by the machine (Fig. 1). All the fractured teeth were inspected after removal of the test specimens by way of a direct visual approach using a stereoscopic magnifier (Tecnival SQF-F; Curitiba, Brazil) at 40× magnification for the confirmation of fracture.

Acquisition and Evaluation of Images

The CBCT devices and their respective evaluation software are shown in Table 1. The image acquisition parameters followed manufacturer's recommendations. Prior to acquisition, the teeth were immersed in an acrylic container filled with water and fixed with utility wax.

Three previously calibrated oral radiologists with at least 8 years of experience in CBCT diagnosis performed the evaluation of the images on a 24-inch LG E 2241 liquid cristal display (LCD) monitor with a matrix resolution of 1920 × 1080. The instructions for CBCT image interpretation and usage of the software were provided and the calibration involved identification of VRFs in images that did not belong to the study. The evaluation was done by performing a dynamic reading of all orthogonal slices (axial, coronal, and sagittal), classifying the images as absence or presence of fracture (Fig. 2). Adjustment of brightness, contrast, and zoom was permitted. The same observation was repeated after a 15-day interval for the evaluation of intra-observer agreement.

Statistical Analyses

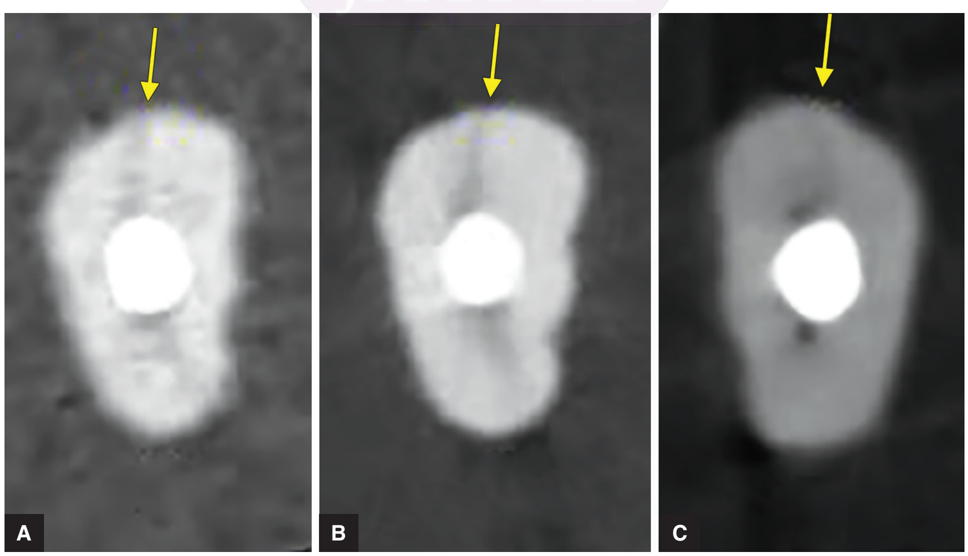
Cohen's κ was used to calculate intra- and inter-observer agreement. The diagnostic values for sensitivity (Sn), specificity (Sp), and accuracy (Ac) were computed for each group. The accuracy was also assessed by the receiver operating characteristic (ROC) analysis, by calculating the area under the ROC curve (Az). The A Chi-squared test was used to verify the influence of root canal sealers on diagnostic accuracy. Data analyses were performed using statistical package for the social sciences (SPSS) 20 (SPSS Inc., Chicago, IL, USA). The level of significance was set at $p < 0.05$.

Results

The data obtained from the calculation of the median of the three examiners were considered. The intra- and inter-observer reproducibility was fair (0.29–0.38).

Table 1: CBCT devices, software, and specifications of acquisition protocols used

CBCT devices	*Software*	*Specifications*
i-CAT (Imaging Sciences International, Hatfield, PA, USA)	Xoran i-CAT	FOV 6 × 6 cm, voxel 0.2 mm, 120 kV, 5 mA, 40 s—MaxRes
ORTHOPHOS XG (Sirona Dental System, Bensheim, Germany)	Galileus XG	FOV 5 × 5 cm, voxel 0.16 mm, 85 kV, 6 mA, Hi-Res
PreXion 3D (PreXion Inc., San Mateo, USA)	PreXion 3D Viewer	FOV 5 × 5 cm, voxel 0.075 mm, 90 kV, 4 mA, 37 s, HI-res/HI-density



Figs 2A to C: Axial images showing the fracture lines (arrows) and the artifacts in the (A) i-CAT; (B) PreXion; and (C) OrthoPhos images

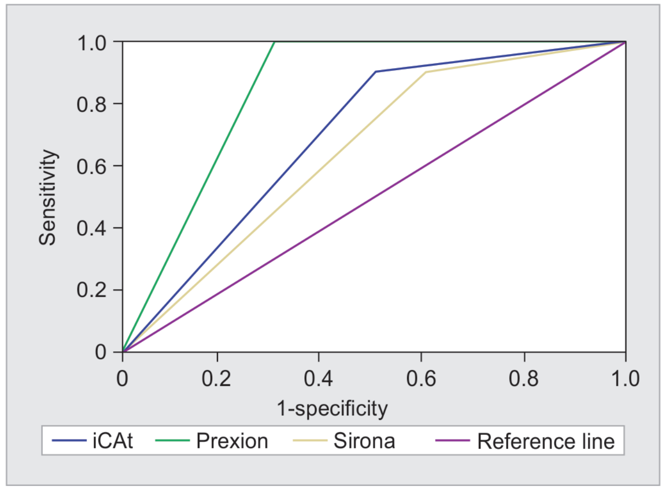
Table 2: Sensitivity, specificity, false-negative and false-positive error rates, and positive and negative predictive values for the detection of root fractures, according to the CBCT device used

Validity measure	*i-CAT*	*PreXion*	*OrthoPhos XG*
Sensitivity	0.93	0.88	0.73
Specificity	0.70	0.75	0.73
False-negative error rate	0.07	0.12	0.27
False-positive error rate	0.30	0.25	0.27
Positive predictive value	0.76	0.78	0.73
Negative predictive value	0.90	0.86	0.73

The results in Table 2 showed that the highest sensitivity (0.93) was detected for the i-CAT device, while the lowest sensitivity was found for the OrthoPhos XG device. The specificity values observed in the three systems ranged from 0.70 to 0.75. The positive predictive values ranged from 0.78 to 0.73. As far as the negative predictive values were concerned, there was better performance by the i-CAT machine (0.99) when compared to the OrthoPhos XG machine (0.73).

The Chi-squared test demonstrated that the endodontic sealers did not significantly affect the diagnosis of root fractures, regardless of the system used (Table 3). Specifically, no difference was observed ($p > 0.05$) in the proportion of teeth with detected root fractures, when any of the endodontic sealers were used. This was an observation made by considering all the systems employed in this study.

Graph 1 represents the ROC curve relating to the diagnosis of root fracture in teeth filled with endodontic sealers + gutta-percha (regardless of the endodontic sealer used) and demonstrates that the greatest accuracy was obtained by using the PreXion device, with Az = 0.85. The accuracy of i-CAT and OrthoPhos XG devices was 0.70 and 0.65, indicating normal and poor performance, respectively.



Graph 1: ROC curve showing the accuracy of the devices employed

Discussion

CBCT imaging is the technique indicated for VRF diagnosis when 2D images do not provide adequate information, especially in endodontically treated teeth.[9,10] Growing interest exists in elucidating the influence of root fillings on the detection of VRFs using CBCT images, although the filling material used has been restricted to only gutta-percha.[3,5] The accuracy of CBCT images in VRF detection is higher in unfilled teeth than in root-filled teeth.[1,3,11,12] However, several studies have reported that root canal filling did not have any influence on VRF diagnosis,[3,13–15] which is confirmed in our experiment.

The endodontic sealers may be classified according to composition as: zinc oxide and eugenol, calcium hydroxide, glass ionomer, resin, silicone-based cements, and mineral trioxide aggregate (MTA)-based sealers. The presence of radiopacifiers and other chemical substances in the formulations (bismuth oxide, bismuth subcarbonate, barium sulfate, and zinc oxide) of the various available sealers can lead to differences in density. The CBCT images show that sealers induce a greater number of artifacts that appear as hypodense lines that simulate fractures.[8,16,17] The different radiopacity of the sealers was found to be insufficient to exert any influence on the diagnosis of VRF ($p > 0.05$) (Table 3), certainly because the volume of gutta-percha inside the canal is too high.

The dark artifact along gutta-percha simulates a fracture line[17] and impairs the ability to identify "true root fractures" in CBCT images;[5,7,9,13–16,18,19] however, three studies did not report a significant decrease in the diagnostic ability.[6,13,15] Different from the artifact appearance, the hypodense fracture line can be visualized at multiple planes in a fine slice reconstruction.[10] Elsaltani et al.[6] and Hassan et al.[7] stated that the axial section of the root is the most suitable for the detection of VRFs.

Despite the numerous efforts to calibrate the examiners and certify that the images could be viewed in a standardized manner,[20] problems with reproducibility and large intra-observer variations have already been reported,[3,6,7,16,17,19,20] especially with intracanal materials.[9,21,22] This may be attributed to the length of professional experience, familiarity with the tool software, prior training, and, most importantly, to the subjective nature of image interpretation. In this study, all the three observers first viewed the axial and then the coronal and sagittal sections, which agrees with other studies.[4,7]

Table 2 shows that the i-CAT device had the highest sensitivity (0.93), corroborating with some authors,[6,7,23] and different than Edlund et al.[2] In the present study, the highest specificity was observed in the PreXion device, which had a value of 0.75, although higher specificity values were reported.[2,3,6,23]

Table 3: Absolute (*n*) and relative (%) frequencies of the presence of root fractures in filled teeth by CBCT devices

	i-CAT		*PreXion*		*OrthoPhos XG*	
Filling material	*Present*	*Absent*	*Present*	*Absent*	*Present*	*Absent*
Gutta-percha	14 (70%)	6 (30%)	13 (65%)	7 (35%)	15 (75%)	5 (25%)
AH Plus + gutta-percha	11 (55%)	9 (45%)	11 (55%)	9 (45%)	8 (40%)	12 (60%)
Fill canal + gutta-percha	11 (55%)	9 (45%)	9 (45%)	11 (55%)	9 (45%)	11 (55%)
Sealer 26 + gutta-percha	13 (65%)	7 (35%)	12 (60%)	8 (40%)	8 (40%)	12 (60%)
Chi-square	$p = 0.700$		$p = 0.620$		$p = 0.079$	

($p < 0.05$)

According to the ROC curve, the system demonstrating a greatest accuracy was the PreXion device, with the highest proportion of true-positives and true-negatives regarding the true diagnosis, and with the area under the curve of 0.85 (good performance). It was followed by i-CAT and then OrthoPhos XG, with normal and poor performances, respectively. The good performance of the PreXion device may be attributable to its reduced voxel size[10,14] and lowest focal point of 0.2 mm, among the devices involved in the study. The focal point of i-CAT is 0.5 mm and that of OrthoPhos XG is 0.4 mm.

Some CBCT devices have incorporated an algorithm to reduce the effect of metal artifacts (MARs) on image reconstructions,[11,24] like OrthoPhos XG used in this study. Our results demonstrated the lowest accuracy and sensitive values, corroborating with other authors.[11,12,18] Also, Queiroz et al.[25] reported that MARs are not useful during the assessment of the teeth filled with gutta-percha, as there is no improvement in the image quality and the reconstruction time is prolonged. Therefore, more studies on this algorithm are necessary.

Voxel size is related to the contrast and resolution of CBCT images. It has been reported that small FOV provides better image quality and fewer artifacts when compared with large FOV.[18] A small voxel size also improves the CBCT image quality due to higher spatial resolution.[26] A recent study[10] reported the good performance of high-resolution protocols and highlighted the necessity for consideration of the exposure dose of radiation. The effective dose of the PreXion device is 189 and 388 μSv for standard exposure (19 seconds) and high resolution (37 seconds), respectively.[27] We agree with Brito-Júnior et al.,[8] who concluded that all root canal sealers produce streaking artifacts, mainly when large voxel sizes are used. Thus, the use of smaller voxel size is preferable to reduce the presence of artifacts and to improve the diagnostic accuracy of root fractures in root-filled teeth. Moreover, as suggested by Hekmatian et al.,[28] it is recommended to remove those materials from root canals before imaging to improve the diagnostic potential of CBCT.

A combination of clinical and radiological signs and symptoms is pathognomonic of VRF. However, in certain instances, the diagnosis is not straightforward.[16] A systematic review assessing the clinical features of VRFs concluded that there was a lack of evidence-based data regarding the diagnostic accuracy of VRFs.[22] It is particularly true that incomplete fractures are not associated with specific patterns of periradicular bone loss. Most of the currently used tests are subjective in nature, which are both patient and operator dependent.[29] We can be very confident with the positive test results obtained by CBCT images; however, we should be very cautious with negative test results. For patients with negative results, a closer follow-up is required.

Conclusion

It may be concluded that endodontic sealers do not influence the detection of VRFs. The PreXion device was the most accurate, having the highest specificity value.

Clinical Significance

Radiopaque materials might affect the diagnosis of VRFs, because they can simulate fracture lines leading to false-positive results. Moreover, CBCT machines present different specificities that could exert some influence on that.

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