Detection of vertical root fractures: An investigation on the impact of using orthogonal and dissociated radiographs in conventional and digital systems

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ABSTRACT

Introduction: Intraoral radiographs are an important investigative aid in the detection of endodontic injuries, including vertical root fractures (VRF). **Objective:** The objective of this study was to assess the capacity of orthogonal and angulated conventional as well as digital radiographs to detect VRF in teeth under different root conditions. **Methods:** Sixty teeth were divided into three groups according to the canal condition: non-filled, filled with gutta-percha and filled with gutta-percha and metallic post. Ten teeth in each group were artificially fractured, whereas teeth in the control group were not fractured. Orthogonal and horizontally angulated conventional film (Kodak) and digital phosphor plate (VistaScan Dürr Dental) were used. Three blinded and calibrated observers carried out evaluations at four different time intervals. Modal values were used to calculate sensibility, specificity and accuracy. The area under the ROC curve (aucROC) and confidence intervals (CI) was used to compare the performance between radiographic systems, as well as the influence of combined angulated images. **Results:** Angulated radiographs showed larger aucROC for both conventional and digital images. CI revealed statistically significant differences between conventional orthogonal and digital angulated radiographs (CI: 0.403 – 0.697 and 0.767 – 0.967, respectively). Moreover, when only orthogonal incidences were considered, digital radiographs yielded better results than the conventional ones (CI: 0.403 – 0.697 and 0.622 – 0.878, respectively). **Conclusion:** The strong inclination towards yielding better diagnostic test results provided by digital radiographs suggests that the digital system using angulated projections is more appropriate to investigate VRF than the conventional one.

Keywords: Diagnosis. Endodontics. Dental radiography.

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Introduction

Intraoral radiographs are, in the majority of cases, the first investigative aid in the detection of endodontic injuries, including vertical root fractures (VRF).[1,4] In recent decades, digital radiography has replaced the conventional methods.[5] The digital system has some advantages over the conventional one, namely: ease of processing, storing and exchanging data information, as well as the possibility of image post-processing.[5,6] Regardless of the system, the technique plays an important role in precise diagnosis: radiographic imaging shows a radiolucent line when the central X-ray is directed parallel to the fracture line; therefore, it is recommended that different angles be adopted in order to increase the odds of detecting VRF.[7]

Correct diagnosis of VRF is based on clinical and radiographic findings. With regard to radiographic evaluation, the condition of the root canal (filled or non-filled), the system used for image acquisition (conventional or digital), as well as the number of radiographic images acquired are important and may interfere on the diagnosis. Therefore, this study compared the diagnostic accuracy of digital and conventional images using orthogonal and angulated radiographs to diagnose VRF in teeth under different root canal conditions.

Material and Methods

The Federal University of Rio Grande do Sul Institutional Review Board approved this research. Sixty human single-rooted extracted teeth were cut at the cement–enamel junction. The roots were placed in acrylic resin blocks so as to guarantee fragment stability after fracture. In order to simulate resilience of the periodontal ligament, a thin wax layer was used to cover the teeth. The teeth were randomized and divided into three groups (n = 20) according to the root canal condition: non-filled, endodontically filled with gutta-percha, and endodontically filled with gutta-percha and metallic post. Ten teeth of each group were fractured (test group) by means of a chisel positioned inside the root canal, whereas ten teeth were not fractured (control group). Visual inspection under magnification confirmed the presence or absence of VRF and established the gold standard.

Conventional and digital radiographs were obtained by means of an intraoral dental X-ray unit (Dabi Atlante, Spectro 70X — 127 kV, 7.5 mA and 50/60 Hz). Orthogonal (0°) and horizontal angulated (15° shift, mesial and distal) radiographs were taken, thus totalizing 360 images. Conventional radiographs were taken by means of D-Speed Intraoral dental films (0.4 s; Kodak, Rochester, NY, USA) processed in an automatic loader (DENT-X 9000, Elmsford, NY, USA), whereas digital radiographs were taken by means of VistaScan System phosphor plates (0.3 s; Dürr Dental, Bietigheim-Bissingen, Germany).

Conventional radiographs were inspected in a light box equipped with a dark-mask, in a subdued-lighted room. Digital radiographs were stored and viewed in the DBSWIN 5.3.0 software (Dürr Dental, Bietigheim-Bissingen, Germany) which includes some visualization tools and filters for image post-processing. Figure 1 shows the orthogonal and angulated radiographs of three fractured teeth under different root canal conditions.

Three calibrated examiners (Kappa Index ≥ 0.7) scored the imager for presence or absence of VRF by using a dichotomous scale. The process of analyzing the images was conducted in four steps with a 15-day interval in between: (I) conventional orthogonal radiographs; (II) digital orthogonal radiographs; (III) conventional orthogonal and angulated radiographs, and (IV) digital orthogonal and angulated radiographs. Sensitivity, specificity and accuracy assessments were carried out based on the modal value (the most prevalent score among the three examiners). The area under the ROC curve (aucROC) and the confidence interval (CI) was calculated for each condition and used to compare the performance of the radiographic systems as well as verify the effectiveness of angle variation.

Results

Sensitivity, specificity and accuracy values of each radiographic system and each group of root canal condition, together with the mean aucROC and CI values for each radiographic technique, are shown in Table 1. Combined images improved diagnostic accuracy, regardless of the root canal condition, in both conventional and digital systems. However, accuracy was even higher when teeth with non-filled canals were analyzed.

The analysis of the aucROC and respective CIs revealed that combined images yielded similar good results in both conventional and digital systems. Statistical difference was observed between conventional orthogonal radiographs (CI: 0.403–0.697) and

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Table 1. Mean sensitivity, specificity and accuracy values for conventional and digital systems in each root canal condition; area under the ROC curve (aucROC) and confidence interval (CI).

	Conventional radiography						Digital radiography					
	Orthogonal			Angled			Orthogonal			Angled		
	NF	Fi	MP	NF	Fi	MP	NF	Fi	MP	NF	Fi	MP
Sensitivity	0.4	0.4	0.4	1	0.6	0.4	0.8	0.6	0.5	1	0.5	0.8
Specificity	0.5	0.7	0.9	0.9	0.9	1	0.9	0.8	1	1	0.9	1
Accuracy	0.45	0.55	0.65	0.95	0.75	0.7	0.85	0.7	0.75	1	0.7	0.9
aucROC (CI)	0.550 (0.403 – 0.697)			0.800 (0.682 – 0.918)			0.750 (0.622 – 0.878)			0.867 (0.767 – 0.967)		

NF = non-filled, Fi = filled with gutta-percha, MP = filled with gutta-percha and metallic post.

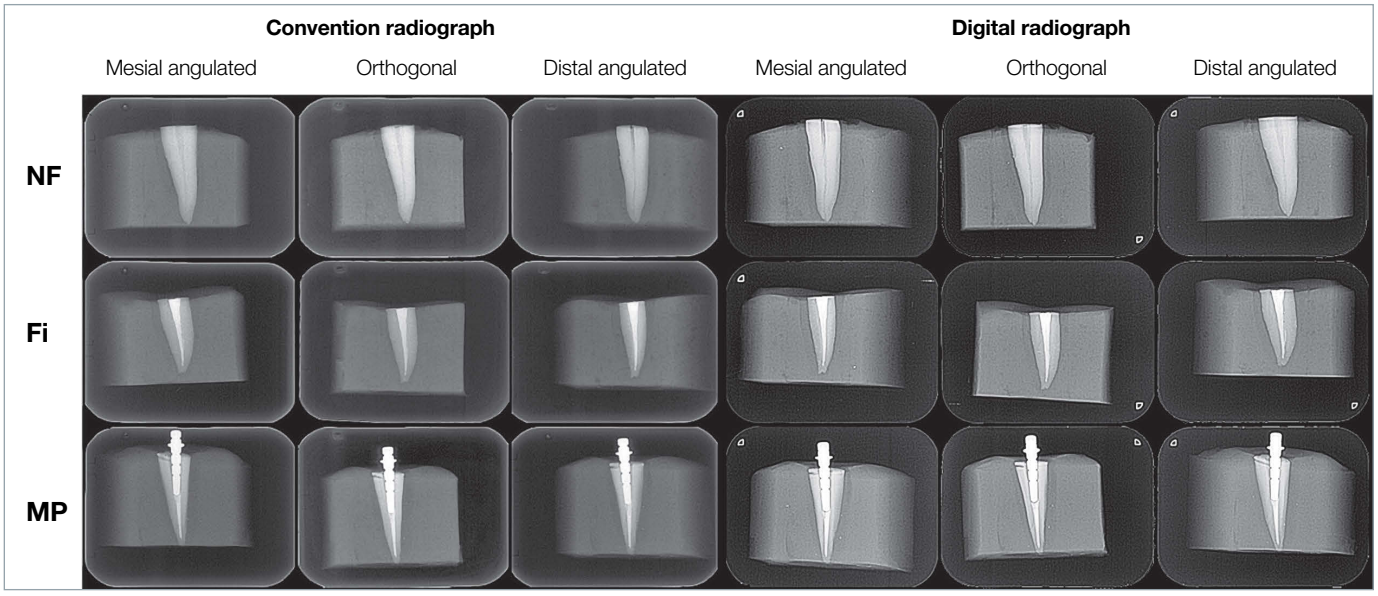

Figure 1. Conventional and digital radiography (orthogonal and angulated) of three teeth with VRF under different root canal conditions. NF = non-filled, Fi = filled with gutta-percha, MP = filled with gutta-percha and metallic post.

combined digital orthogonal and angulated radiographs (CI: 0.767–0.967). Moreover, a strong inclination towards better results produced by the digital images was observed when only orthogonal radiographs were analyzed (CI for conventional radiographs: 0.403–0.697; CI for digital radiographs: 0.622–0.878).

Discussion

This study assessed two radiographic systems used to detect VRF in teeth under different root canal conditions. Despite the limitation of *in vitro* studies, characterized by the impossibility of assessing the clinical conditions that help to achieve correct diagnosis, the methodology used herein aimed at reproducing the circumstances observed in clinical dental alveoli. Thus, the resilience of the periodontal ligament, the vertical fractures randomly oriented and the stability of tooth fragments were observed. Additionally, image assessment was performed in a stepwise sequence: first, orthogonal and then the combined images; thus reproducing what should be performed in daily practice. Therefore, the benefit of adding images could be estimated.

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The literature cannot yet reach an agreement on the diagnostic ability of digital images in comparison to the conventional system among different tasks in Dentistry.[8-11] When post-processing tools for digital image processing are analyzed, some studies have suggested that the accuracy of digital systems for some diagnostic tasks may be improved.[9,12-14] This study showed higher values of specificity, sensitivity and accuracy when digital radiographs were used, although without statistic difference, regardless of the root canal condition. The best results produced by the digital system may be related to image post-processing, since the examiners were allowed to use the available tools as they wished. Nevertheless, other studies comparing digital and conventional images used to detect VRF found similar results.[15-17]

It is known that endodontic materials or metallic post may affect the correct diagnosis of VRF, since they may simulate or hide the fracture line.[17] Higher sensitivity was observed in teeth with non-filled root canals, which corroborates other studies.[18,19] Specificity was similar among the analyzed systems, regardless of the root canal condition. These facts suggest that, when in doubt, examiners tend to give a negative diagnosis, therefore increasing specificity values.

The values of aucROC and CI suggest that combined radiographs better diagnose VRF, regardless of the radiographic system. An *in vivo* study investigating the diagnosis of VRF found a mean sensitivity of 0.23 — a considerably low value.[20] For this reason, it is possible to deduce that this might have occurred because the authors used only one radiographic incidence for the diagnosis. In an attempt to increase the diagnostic capacity of intraoral images, other studies also performed three intraoral incidences.[15,17,18] Kambungton et al[15] compared the scores obtained with orthogonal and combined radiographs. However, in their study, all three images were viewed at the same time, what may have increased the accuracy for the orthogonal projection. The present study also compared the performance in assessing one or three images at a time, but with a stepwise approach, which is believed to be more consistent with what is supposed to happen in the dental clinic. Therefore, if a radiographic image does not show the fracture line, giving no conclusive diagnosis, a second one (mesially or distally angulated) should be carried out. Moreover, if the doubt persists, a third radiographic image must be taken from the opposite angle in order to fully explore the radiographic method.

In an attempt to overcome the drawbacks imposed by radiography, especially with regard to the overlapping of structures, the development of cone beam computed tomography (CBCT) substantially increased the request for tridimensional images, including cases of VRF diagnosis. Some *in vitro* studies reported better values of sensitivity for CBCT assessment of teeth with unfilled root canals,[15,18,21-23] which is rare in the case of gutta-percha or metallic post-filled teeth.[18,21] When specificity values are analyzed, the results among methods proved to be similar.[15,23] In addition to that, it is important to have in mind that as important as the diagnosis of the pathology per se, is how the other type of exam will change the treatment plan for the patient,[24,25] especially when there is a significant increase in the radiation dose received by this patient.[26,27] This attitude reinforces the radiographic indication for VRF searching and shows that the technique must not be limited to orthogonal radiography, thus revealing the importance of horizontally angulated incidences as a diagnostic tool. Furthermore, when digital and conventional systems are compared, the lower radiation dose obtained with the digital method should be seen as an important advantage.[28,29]

Conclusion

Digital radiograph using orthogonal and horizontally angulated projections proved to be suitable to diagnose VRF, given that it provides higher values of accuracy in comparison to the conventional system.

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