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Ex vivo comparison of digital images with conventional radiographs for detection of simulated voids in root canal filling material

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Abstract

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Aim To compare the diagnostic potential of direct digital images with conventional radiographs for the detection of simulated root canal voids.

Methodology The root canals of 80 extracted maxillary incisors with straight root canals were prepared and filled and the specimens divided into two groups: (i) a group of 40 teeth without voids; and, (ii) a group of 40 teeth with voids created in the root filling. Each root was imaged using the paralleling technique with a CCD-based digital system and F-speed film. Totally, there were 240 images: conventional radiographs ($n = 80$), digital images ($n = 80$) and digital zoomed images at 2× magnification ($n = 80$). These were interpreted for voids by a radiologist (without prior knowledge of the distribution of the voids). The reliability of the radiologist was confirmed using Cohen's Kappa Statistic, with the kappa value found to be >0.08. The sensitivity, specificity and predictive values were calculated. The differences in sensitivity and specificity between the imaging systems were then assessed using the Exact McNemar significance probability at the 95% significance level.

Results The sensitivities (95% CI) of conventional radiographs, digital images and zoomed images were 0.68 (0.57–0.78), 0.83 (0.74–0.91) and 0.80 (0.71–0.89), respectively. The specificities of the conventional radiographs, digital and zoomed images were 0.80 (0.71–0.89), 0.83 (0.74–0.91) and 0.83 (0.74–0.91), respectively. The positive predictive values (95% CI) were 0.77 (0.68–0.86), 0.83 (0.74–0.91) and 0.82 (0.74–0.90), respectively. The negative predictive values (95% CI) were 0.71 (0.61–0.81), 0.83 (0.74–0.91) and 0.80 (0.72–0.89), respectively. There were no significant differences between the sensitivity and specificity of digital images and conventional radiographs, and of digital images and zoomed images during the detection of voids in root fillings ($P > 0.05$).

Conclusions Under the conditions of this laboratory study, the diagnostic performance of digital images and conventional radiographs, and between the digital images and digital zoomed images for simulated void detection in root fillings were not significantly different.

Keywords: digital image, film, radiograph, void, zoom.

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Introduction

Complete filling of the root canal is one of the keys to successful root canal treatment (British Endodontic Society 1983). The clinical assessment of root fillings requires the use of radiographs (Gutmann 1992, Smith *et al.* 1993). A root filling is confirmed as acceptable if radiographically, the prepared canal space appears radiopaque along the canal shape and is free of voids (Field *et al.* 2004). Void detection is clinically important because the presence of voids results in the possibility of microorganism and toxin retention, which may be associated with post-treatment

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disease (Nguyen 1994). The incidence of voids is influenced by many factors (Kytridou *et al.* 1999, Metzger *et al.* 2001, Aminoshariae *et al.* 2003) and occurs in various sizes and locations in root fillings (Da Silva *et al.* 2002). To enable the detection of voids in root fillings, the radiograph must provide a high degree of clarity.

Digital imaging has become an alternative to film-based radiography. The performance of digital imaging *versus* film-based radiography has been tested in many dental diagnostic settings and found of comparable utility (Kullendorff *et al.* 1996, White & Yoon 1997, Naitoh *et al.* 1998, Paurazas *et al.* 2000, Wolf *et al.* 2001). However, most studies of root canal imaging compare the performance of digital imaging and conventional radiography for determining root canal length (Cederberg *et al.* 1998, Eikenberg & Vandre 2000, Lamus *et al.* 2001, Lozano *et al.* 2002), or for determining the distance between the file tip and root apex (Cederberg *et al.* 1998, Eikenberg & Vandre 2000, Melius *et al.* 2002).

An advantage of digital imaging is that the presentation of the image can be adjusted by digital processing algorithms to aid diagnostic accuracy (Wenzel & Hintze 1993, Versteeg *et al.* 1997). Processed images are preferred to originals even though the type of processing is task dependent: different dental diagnostic procedures require different detail of interest and software image enhancement offers various image formats. For example, the image should be relatively sharp (edge enhancement) for caries diagnosis in order to detect the boundary between the sound and diseased tissue. The detection of subtle alveolar bone density changes is facilitated when colour conversion of certain grey-levels is performed (Brägger & Pasquali 1989). However, image processing may have limitations in diagnostic accuracy. Svanæs *et al.* (1996) found digital images magnified (×4) had significantly greater accuracy in the detection of approximal caries than nonmagnified images, whereas, Møystad *et al.* (1995) found higher digital image magnification reduced observer performance. Ellingsen *et al.* (1995) compared the original and enhanced digital image with conventional radiography for evaluating the position of an endodontic file tip and found that digital images at standard zoom were superior to E-speed radiographs, although other modes were inferior to conventional film images.

The utility of digital imaging and its function for detection of voids in root fillings has not been reported. The aim of this study was to compare the accuracy of detection of simulated root canal voids by digital imaging with conventional film-based radiography and to assess whether magnification of digital images affects a radiologist's performance in the detection of voids.

Materials and methods

Tooth preparation

Eighty maxillary permanent incisors with single straight root canals and no signs of root resorption were stored following extraction for 48 h in 5% buffered formalin solution.

The crown of each tooth was removed at the cemento-enamel junction with a linear precision saw (ISOMET® 4000 Precision Saw, Buehler, IL, USA). The root canal lengths were assessed by placing a size 10 K file (Kerr Manufacturing Co., Romulus, MI, USA) inside the canal until the tip was seen to perforate just through the apical foramen. The instrument was withdrawn 1.0 mm to record the working length. The root canals were instrumented with files up to size 80. No attempt was made to flare the root canal walls. All canals were irrigated with normal saline and dried using paper points. Before being mounted in baseplate wax, each root was marked 6 mm from the apex with a radiopaque marker in order to set the area for void production.

The canals were filled with a single-cone technique, with the size of the cone and the shape of the canal preparation closely matched. The size of the master cone for filling was selected on the basis of 'tugback' being achieved within 1 mm of the working length. An artificial void was made using a blunt needle 0.2 mm in diameter, heated and touched against the cone to produce a void. The position of a void for each cone was set randomly anywhere up to 5 mm from the tip of gutta-percha cone. The voids in the gutta-percha points were subdivided into four equal groups to be set at the buccal, lingual, mesial and distal surfaces of root canals.

One operator then inserted a single cone without sealer into the matched root canal. The filled roots were divided into two groups: resulting in 40 roots with fillings with voids and 40 roots with fillings without voids. The prevalence of voids in this study was 0.5.

Radiographic procedure

Radiographs of each root were obtained in the buccolingual direction using the parallelling technique.

For both conventional and digital radiographs, the receptor and tooth position were kept constant, with a plaster block that was designed to place the film/receptor, tooth block and radiographic tube in a rigid fixed position. All radiographic exposures were completed with a dental X-ray unit (Novelix; Trophy, Beaubourg, France) at 65 kVp and 8 mA. The exposure time for the conventional radiograph *versus* digital radiograph was 0.16 *versus* 0.08 s. The focus-object distance was 23.5 cm and the object to receptor distance 1.5 cm.

Conventional film images were recorded on double-pack, F-speed, size no. 2 periapical films (Insight film; Eastman-Kodak Co., Rochester, NY, USA) and processed automatically (Periomat Plus, Dürr, Germany) for 420 s at 24 °C with Rp X-Omat chemicals (Kodak Australasia; Coburg, Victoria, Australia) as recommended by the manufacturer. The radiodensity of the film was controlled under standard conditions. The digital images were obtained with a RVG-CCD sensor (RVGui; Trophy).

Image evaluation

Prior to image interpretation, a set of 20 conventional radiographs was evaluated by two observers. The second evaluation was performed at least 1 week after the first session. An observer with a kappa value of 0.8 or more was selected as the evaluator: only one observer met this criterion.

The 80 radiographs were numbered, mounted in random order and examined by the single observer. The observer had no prior knowledge of the distribution of the voids. A light box was used to evaluate the films with a magnifying viewer as required. The time for viewing was not limited. The presence or absence of a void on each radiograph was recorded.

A void was considered present when a small round radiolucent area was detected at 5-mm intervals starting at the apex. The viewing distance ranged between 50 and 100 cm. Both the film and digital images were viewed in a darkened room. The same procedure was followed for the digital images and the twofold magnified images, which were displayed using RVG software (Trophy Windows; version 4.1) on a 19-inch SVGA monitor.

Statistical analysis

The number of correct assessments (i.e. void present or absent) was recorded and compared with the baseline data. Diagnostic tests (sensitivity, specificity, positive and negative predictive values) were used to assess the hypothesis that there was no difference between conventional radiographs and digital images, and between digital images and digital zoomed images in the discernment of voids. The difference in sensitivity and specificity between these imaging types was compared using the Exact McNemar significance with probability at the 0.05 significance level. Statistical evaluation in all tests was performed with STATA 7.0 (Intercooled Stata 7.0, Stata corporation, TX, USA).

Results

The numbers of correct void detections using conventional, digital and digital zoomed radiography are presented in Table 1, and the diagnostic values of void detection for different types of images in Table 2.

Sensitivity (95% CI) ranged between 0.68 (0.57–0.78) for the conventional radiograph and 0.83 (0.74–0.91) for the digital image. The specificity (95%) was 0.80 (0.71–0.89) for conventional radiograph, and 0.83 (0.74–0.91) for both the digital image and zoomed image.

The positive predictive values (95% CI) for the conventional radiograph, digital image and zoomed image were 0.77 (0.68–0.86), 0.83 (0.74–0.91), and 0.82 (0.74–0.90), respectively. The negative predictive values (95% CI) for the conventional radiograph, digital image and zoomed image were 0.71 (0.61–0.81), 0.83 (0.74–0.91) and 0.80 (0.72–0.89), respectively.

Table 1 Two-by-two table showing the number of voids correctly and incorrectly detected from conventional radiograph, digital image and digital zoomed image ($n = 80$)

	Actual		
Method	Voids	No voids	Total
Conventional radiograph			
Voids	27	8	35
No voids	13	32	45
Digital image			
Voids	33	7	40
No voids	7	33	40
Digital zoomed image			
Voids	32	7	39
No voids	8	33	41
Total number of teeth tested per radiographic method	40	40	80

Table 2 Sensitivity, specificity and predictive values for the conventional radiograph, digital image and digital zoomed image

Diagnostic tests (95% CI)	Image type		
	Conventional radiograph	Digital image	Digital zoomed image
Sensitivity	0.68 (0.57–0.78)	0.83 (0.74–0.91)	0.80 (0.71–0.89)
Specificity	0.80 (0.71–0.89)	0.83 (0.74–0.91)	0.83 (0.74–0.91)
Positive predictive value	0.77 (0.68–0.86)	0.83 (0.74–0.91)	0.82 (0.74–0.90)
Negative predictive value	0.71 (0.61–0.81)	0.83 (0.74–0.91)	0.80 (0.72–0.89)

Table 3 *P*-value of sensitivity and specificity comparing paired imaging methods using Exact McNemar significance probability

Type of images	Sensitivity	Specificity
Film and digital	0.18	1.00
Digital and zoomed image	1.00	1.00

Digital imaging had higher diagnostic value than the two other imaging types although its specificities were comparable with those of the digital zoomed images. The differences in sensitivity and specificity between the conventional radiograph and the digital image and between the digital image and the zoomed image were not statistically significant ($P > 0.05$) (Table 3).

Discussion

The primary aim of this study was to discover what type of image had sufficient detail to reveal small areas of void. The diagnostic accuracy of digital images and conventional radiographs was compared and it was noted that digital images had the highest diagnostic value according to the sensitivity, specificity, with positive and negative predictive values. However, no significant difference was found between conventional radiographs and digital image, and between digital images and digital zoomed images in the detection of simulated voids in root filling.

The methodology in this study was designed to reduce the factors which affect image interpretation as much as possible. Single cone technique without sealer was used for two reasons. First, this technique is simple. Secondly, the gutta-percha cone would fit tightly to the apical portion of the root canal, which is the area of interest. This methodology made it possible to produce a simulated void for each cone, avoiding multiple voids that may occur in other filling methods. The simulated void represented the radiographic appearance of air space.

In clinical practice, the number, location and size of voids depends on techniques, the skill of the operator, and the material used for filling the root canal. The occurrence of voids in a reported study of root fillings completed by lateral condensation, Thermafil and Thermafil for backfilling was betweeen zero and two per canal (Da Silva *et al.* 2002).

The site of voids in the root filling significantly influences the survival time of the root canal treatment: the teeth with voids at the apical or middle third of the root filling have been found to have a significantly lower mean survival time than those with voids in the coronal third or no void at all (i.e. 69.3 months in the apical third and 78.8 months in middle third) (Cheung 2002).

The present study, therefore, concentrated on void detection in the apical third of root fillings. To assess the effect of superimposition on image interpretation, voids were distributed equally on the buccal, lingual, mesial and distal side of the canal. The results suggested that an observer was more likely to produce false negative diagnoses of buccal and lingual voids than mesial or distal voids. Mean percentages of false negative calculated from the bucco-lingual voids and mesio-distal voids were 7.5% and 4.2%, respectively.

To interpret voids by radiography in clinical practice could still be influenced by factors such as size and site of the void(s), which may occur in the sealer, the selection of the optimal exposure time, effects of scattered radiation, superimposition of trabecular bone and roots, and density of the root filling material. Experience of image display interpretation also influences diagnostic accuracy. The present study limited the number and area of void appearance on radiographs to simplified image interpretation.

The use of zoomed digital images would be expected to enable clinicians to detect small changes more readily. One study of magnification used for the detection of dental caries reported a significant increase in diagnostic accuracy (Svanæs *et al.* 1996), while Møystad *et al.* (1995) reported a limitation of the magnified image for caries detection; however, study of magnified images for void detection is limited and the radiographic appearance of voids is different from dental caries.

The present study tested the utilization of the zoom function in detecting the small areas of void. The size of simulated voids was 0.2 mm, while Da Silva *et al.* (2002) found the average total length of voids (±SD) per canal was 0.9 ± 0.6 mm for the lateral condensation technique and 0.6 ± 0.3 for the Thermafil with backfilling group. The present study showed the performance of digital images was close to twofold magnified digital images in the detection of voids with a size of 0.2 mm: the larger the size of the void, the easier its detection.

The discovery of voids by means of radiographs is important for the evaluation of root fillings. Youngson *et al.* (1995) and Aminoshariae *et al.* (2003) found the percentage of voids detected by radiographs was not significantly different from a microscopic evaluation or tooth sections. The improvement of radiographic quality will benefit endodontic evaluation in clinical practice. In the study of Youngson *et al.* (1995), the mean percentages of voids based on the bucco-lingual radiographs and mesio-distal radiographs were compared and no significant difference between the radiographic views was found. As the present study compared only original and zoomed images, the performance of other digital enhanced images for void detection should be investigated before implementing either technique in clinical practice.

Conclusion

Zoomed digital images are comparable with both original digital and conventional film for the diagnosis of artificial voids in root fillings.

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