

ORIGINAL ARTICLE



Diagnostic accuracy of phosphor plate systems and conventional radiography in the detection of simulated internal root resorption

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ABSTRACT

Objective: To evaluate the performance of conventional radiography and photostimulable phosphor (PSP) plate in the detection of simulated internal root resorption (IRR) lesions in early stages.

Materials and methods: Twenty single-rooted teeth were X-rayed before and after having a simulated IRR early lesion. Three imaging systems were used: Kodak InSight dental film and two PSPs digital systems, Digora Optima and VistaScan. The digital images were displayed on a 20.1" LCD monitor using the native software of each system, and the conventional radiographs were evaluated on a masked light box. Two radiologists were asked to indicate the presence or absence of IRR and, after two weeks, all images were re-evaluated. Cohen's kappa coefficient was calculated to assess intra- and interobserver agreement. The three imaging systems were compared using the Kruskal–Wallis test.

Results: For interexaminer agreement, overall kappa values were 0.70, 0.65 and 0.70 for conventional film, Digora Optima and VistaScan, respectively. Both the conventional and digital radiography presented low sensitivity, specificity, accuracy, positive and negative predictive values with no significant difference between imaging systems ($p = .0725$).

Conclusions: The performance of conventional and PSP was similar in the detection of simulated IRR lesions in early stages with low accuracy.

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Introduction

Digital technology has revolutionized professional practice in general, and this is also valid for dentistry, with pronounced application in many dental specialties. In the search for better image quality and diagnostic accuracy, digital radiographic imaging systems have been increasingly widespread for presenting image receptors with greater sensitivity, quality and versatility [1]. In Endodontics, the need for multiple radiographic exposures during the treatment makes digital radiography an important tool to optimize patient care [2]. It makes possible the evaluation of the periapical status and root canals morphology as well as the diagnosis of internal and external root resorption.

Internal root resorption (IRR) presents as an asymptomatic initial lesion, usually diagnosed in routine radiographic examinations. It consists of the internal destruction of tooth structure [3] and, even without having a fully established etiology, most authors consider trauma as the main etiological agent [4–6]. Furthermore, the scientific literature suggests that pulpitis, pulpotomy, tooth autotransplantation, orthodontic and restorative treatments are possible predisposing factors [6–8]. Clinically, in most cases, an enlarged, oval or round pulp chamber with altered shape of the root canal is observed [9]. Treatment and prognosis of IRR are based on the accurate determination of the size and extension of the

lesion, and early diagnosis reduces significant loss of tooth structure and leads to a good prognosis [10].

Many imaging methods can be used to evaluate IRR [11–13]. Since there is no consensus on the most accurate two-dimensional method to diagnose IRR, and significant interactions have been observed between image receptor type and IRR lesions of different size and location, the aim of this study was to evaluate the performance of conventional radiography and photostimulable phosphor (PSP) plate digital radiography in the detection of simulated IRR lesions in early stages.

Materials and methods

After local Institutional Research Ethics Committee approval (protocol 124/2011), 20 extracted human single-rooted teeth were used. They were free of root caries lesions, fractures, root canal treatment and filling materials. All of the teeth were disinfected in 2% glutaraldehyde solution for two hours, kept hydrated in water and sectioned longitudinally in two halves using a metallographic precision cutter (IsoMet 1000, Buehler, Lake Bluff, IL). Standardized cavities of 0.25 mm in diameter and depth were randomly prepared in the cervical or medium thirds of the internal buccal surface of the root canal using a cavity preparation machine developed by

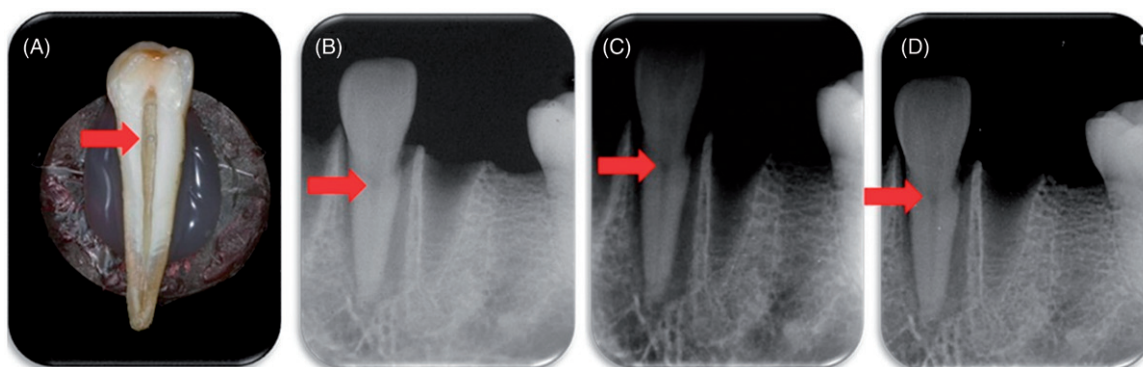


Figure 1. Simulated IRR lesion (arrows): (A) clinical photograph; (B) conventional radiograph; (C) PSP Digora Optime radiograph; (D) VistaScan PSP radiograph.

Soares et al. [14]. This machine is composed of a spherical carbide burr (KG Sorensen, Cotia, Brazil) in a high-speed handpiece coupled to a metallic connecting rod and a dial indicator, and enables accurate control of the vertical and horizontal movement of the burr. In an endeavour to simulate lesions in early stages of IRR (difficult diagnosis), the other surfaces of the root canal were not (Figure 1). After, the two halves of the teeth were put together with cyanoacrylate adhesive (Scotch Super Glue, 3M, Maplewood, MN) and all teeth were individually inserted into the same tooth socket of a dry human mandible.

The 20 teeth were X-rayed before and after the lesion simulation by using the Kodak InSight dental film (Eastman Kodak Company, Rochester, NY) and two PSPs digital systems – Digora Optime (Soredex, Helsinki, Finland) and VistaScan (Dürr Dental, Beitigheim-Bissingen, Germany) – with the GE 1000[®] dental X-ray unit (General Electric Company, Milwaukee, WI), operating at 65 kVp and 10 mA for 0.32 s, 0.26 s and 0.16 s on conventional film, Digora Optime and VistaScan image receptors, respectively. The exposure time was determined in a pilot study as the shortest time that produced an acceptable image in terms of brightness and contrast (principle of ALADA – ‘As low as diagnostically acceptable’) [15]. Exposure geometry was standardized with the aid of an apparatus (Figure 2) in which the paralleling technique was obtained with the mandible in a fixed position and the vertical angle of the X-ray beam at 90° to both the long axis of the tooth and the centre of the image receptor. The source-to-image receptor distance was fixed at 40 cm and an acrylic plate (2.5 cm thick) was placed between the X-ray tube and the mandible to simulate soft tissue scatter.

Two radiologists with more than four years of clinical experience, who were not involved in the preparation of the cavities, were trained and calibrated in a single session with the purpose of explaining the method of evaluation. Then, they were asked to indicate the presence or absence of IRR of a maximum of 20 images per session to avoid visual fatigue. Under reduced lighting conditions, the digital radiographic images were displayed on a 20.1" LCD monitor (FlexScan S2000, EIZO, Hakusan, Japan) using the native software of each imaging system, and the conventional radiographs were evaluated on a masked light box. The observers were allowed to adjust digital brightness, contrast and magnification as well as to use magnifying glasses to assess conventional radiographs to simulate a clinical condition. After



Figure 2. Apparatus used to standardize exposure geometry according to the paralleling technique with an acrylic plate (2.5 cm thick) placed between the X-ray tube and the mandible to simulate soft tissue scatter.

two weeks, all images were re-evaluated by the same two observers and under the same conditions to assess the reproducibility of the method.

Data were analysed using SigmaStat Statistical Software (version 3.5, Systat Software Inc., San Jose, CA). Cohen's kappa coefficient was calculated to assess intra- and interobserver agreement [16]. Accuracy, sensitivity, specificity, positive and negative predictive values were obtained and, subsequently, the Kruskal-Wallis test compared all these values to indicate significant differences between the imaging systems, with a level of significance of 5% ($\alpha = 0.05$).

Results

Kappa values for intra-observer agreement were 0.80 and 0.75 for conventional radiographic film, 0.77 and 0.87 for Digora Optime and 0.87 and 0.85 for VistaScan images system. For interobserver agreement, overall kappa values were 0.70 for conventional film, 0.65 for Digora Optime and 0.70 for VistaScan images system.

Sensitivity, specificity, accuracy, positive-predictive value (PPV) and negative-predictive value (NPV) of the three imaging systems are presented in Table 1. The results indicate that both the conventional and digital radiography presented low sensitivity, specificity and accuracy. In addition, low negative and positive predictive values were found for all imaging systems (negative predictive values ranging from 0.52 to 0.65 and positive predictive values ranging from 0.52

Table 1. Sensitivity, specificity, accuracy, positive-predictive value (PPV) and negative-predictive value (NPV) for each imaging system.

Imaging system	Sensitivity	Specificity	Accuracy	PPV	NPV
Conventional	0.45	0.60	0.55	0.52	0.52
Digora Optime	0.47	0.67	0.57	0.56	0.59
VistaScan	0.65	0.65	0.65	0.65	0.55

The Kruskal–Wallis test indicated no significant differences between imaging systems ($p = .0725$).

to 0.69). The Kruskal–Wallis test showed no significant difference between imaging systems ($p = .0725$).

Discussion

In this study, simulated IRR lesions of hemispherical shape were mechanically created. Recently, Da Silveira et al. [17] introduced an accurate method to simulate IRR with acid demineralization and suggested that the use of dental drills facilitates the diagnosis because of the round and well-demarcated shape. Although acid demineralization produces a more realistic defect, these lesions cannot be standardized in size and shape. Therefore, lesions were simulated in the present study with the aid of a spherical carbide burr to standardize and reproduce the radiographic characteristics of IRR: well-defined rounded or oval symmetrical radiolucency with sharp edges [6–9]. In addition, the lesions were performed only on the internal buccal surface of the root canal to avoid excessive demarcation of IRR.

Depending on the location, IRR may extend to the coronal/cervical, middle or apical root portions. Scientific studies are contradictory in terms of the most prevalent location of IRR, since it has been described as being mostly located in the coronal and cervical regions by Gunraj [9] and in the middle root by Gabor et al. [18]. Based on such disagreement, the present methodology simulated IRR lesions in the cervical and medium thirds of the root canals, but no difference was observed in the detection of the resorptions between these two regions.

Early diagnosis is a crucial factor in the prognosis of IRR. Thus, the present study considered only simulated lesions of reduced diameter (0.25 mm) to assess the ability of different imaging methods to exhibit such small lesions; this may justify the low accuracy observed. Kamburoğlu et al. [11] and Madani et al. [19] evaluated the radiographic detectability of IRR lesions of three different sizes (0.8, 1.2 and 1.6 mm, and 0.6, 0.8 and 1.2 mm, respectively), and observed that lesions of greater size are more easily detected. Studies using CBCT to evaluate IRR showed high diagnostic values, even for relatively small lesions with diameters of 0.5 mm and 0.6 mm [18,19], probably due to the absence of image superimposition as observed in radiographic techniques.

With the advent of digital radiology, methods for image enhancement to improve diagnostic accuracy have also been studied in the scientific literature. Previous studies have demonstrated that digital subtraction radiography may be useful in the detection of IRR lesions [11,20,21]. However, the simulated IRR lesions were bigger than those of the present study, with diameters starting at 0.5 mm [21], 0.6 mm [11] and 0.8 mm [20]. Moreover, Stephanopoulos et al. [21] made

use of radiographs obtained at different angulations (Clark's technique), which could justify the increased diagnostic accuracy. Considering that our purpose was to evaluate IRR lesions in early stages and bearing in mind that the patient is exposed to ionizing radiation-related risks during radiographic exams, the use of orthogonal radiography after a clinical examination is very important for the clinician to indicate the need for additional images at varying angles.

Periapical radiography is commonly used for IRR diagnosis during clinical practice for being an accessible and inexpensive technique, exposing patients to low doses of radiation, and being the exam of choice for the initial evaluation of patients. Nevertheless, studies that assessed the ability of CBCT under different acquisition parameters to detect IRR lesions [22] or compared CBCT with periapical radiography [12,19,23,24] have pointed out that CBCT is superior to plain radiography for providing relevant information on the location of IRR and identifying perforations in the external surface of the root [23]. Furthermore, the additional information provided by CBCT may modify treatment planning and increase accuracy in the diagnosis of these lesions [23,24]. However, when larger IRR lesions are evaluated, periapical radiography and CBCT have similar diagnostic accuracy [19]. These results show that CBCT is an important method to diagnose and plan the treatment of IRR, without excluding the relevance of periapical radiography.

Kappa values obtained in this study showed excellent and good intra- and interobserver agreement, respectively. These evidences evaluations of high reliability, even with simulated IRR lesions in early stages. An *in vivo* study assessing the accuracy of CBCT and periapical radiography in the diagnosis of IRR revealed excellent values for both intra- and interobserver agreement [24], which also indicates good reliability in the evaluations of IRR under clinical conditions.

A relatively high accuracy rate was found for the three imaging modalities (55% for the film, 57% for Digora Optime and 65% for the VistaScan), with no significant differences, even considering that the IRR lesions were made without any involvement of the surrounding internal walls, which makes the diagnostic process more challenging. This is in agreement with the findings of Kamburoğlu et al. [11], who found no difference between conventional and digital radiography in the detection of IRR lesions larger than those of the present study. In contrast, high values of diagnostic accuracy (90.8%) for a digital radiographic system were found in an *in vivo* study with a non-standardized sample (IRR cases of different progression stages) [24]; however, this important methodological difference makes inappropriate a direct comparison with our results.

The present study was carried out mainly because conventional and digital radiography present different spatial resolution and image formation process, and an investigation of their performance in the diagnosis of IRR would be of great clinical value. Interestingly, similar performance was observed on the three imaging systems, which is in agreement with previous studies in the diagnosis of caries lesions [25], external root resorption [26] and periodontal defects [27]. This makes us believe that such differences were not enough to significantly influence the detection of IRR lesions in early stages.

Being an *in vitro* study, there were some limitations on the present methodology related to the assessment of images without considering clinical parameters such as pulp sensitivity or trauma report, which could have helped in the diagnosis of IRR. Additionally, the scientific literature has shown a great number of studies that aimed to find the most appropriate material to mimic human tissues, such as water, wax, acrylic resin, paraffin and polyethylene [28–34], but no consensus was observed. The acrylic resin used in this study has been validated in previous studies [33,34]. However, an important limitation should be considered when using soft tissue equivalent materials because they might not represent the inhomogeneity in composition and shape of the anatomical structures.

In conclusion, within the limitations of the current study, conventional and PSP plate digital radiography presented low accuracy in the detection of simulated IRR lesions in early stages. This highlights the importance of clinical information in the diagnostic process to determine the need for additional imaging exams.

Disclosure statement

No potential conflict of interest was reported by the authors.

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