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Original

Linear measurements to determine working length of curved canals with fine files: conventional versus digital radiography

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Abstract: **This *in vitro* study compared conventional and digital radiographic linear measurements to determine the working length (WL) of curved canals with fine endodontic files. In total, 30 mesiobuccal root canals in molars were measured with a #06 K-file to a length 1 mm short of the apical foramen (WL1). Teeth were mounted in plastic blocks and standardized periapical radiographs were obtained by conventional and digital (Digora Optime®) radiographic methods with #06, #08 and #10 K-files positioned in WL1. Two independent and calibrated examiners performed the conventional measurements with a millimeter ruler, from the file stop to the file tip (WL2). For the digital images, examiners used the linear measurement tool on the Digora® software, in original mode (WL3). For comparison of WL1, WL2 and WL3, the Wilcoxon test (*P* < 0.05) was applied and the reproducibility of the measurements was assessed. There was no statistically significant difference between Wl2 and Wl3 for #06, #08 and #10 K-files (*P* = 0.341, 0.641 and 0.232, respectively), with an acceptable level of interexaminer agreement. The measurements of Wl2 and Wl3 were significantly (*P* < 0.05) larger than those of WL1. No difference was observed among the linear measures obtained with either radiographic method, which showed higher WL values than the direct measurements. (J Oral Sci 51, 559-564, 2009)**

Keywords: working length; radiography; radiographic image enhancement.

Introduction

In endodontics, conventional film-based radiography is an important resource for diagnosis, transoperative procedures, and treatment control. The digital radiography obtained through intrabuccal sensors rather than radiographic films represents technological progress that allows qualitative and quantitative analyses of all stages of endodontic therapy (1,2). Regarding radiographic estimation of endodontic working length, direct digital imaging provides measurement tools that facilitate the definition of the apical limit of root canal instrumentation (3,4). Moreover, there is substantial reduction in image processing time with the acquisition of digital radiographs (5). Hence, the clinical procedures are performed more quickly, with reduced radiation (6).

However, when using conventional or digital techniques for working length determination, problems can occur when the endodontic treatment is performed in atresic and/or curved root canals. In these situations, frequently, the use of small instruments is required and they are barely perceptible in the radiographic image. It is very difficult to distinguish #06, #08 and #10 endodontic files in the dental structure because their extremities disappear gradually (7-9). Thus, there are difficulties in the accurate determination of endodontic file position in the apical

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third of the root canal which can lead to procedural errors (e.g., ledge, zipping and transportation of apical foramen) during endodontic preparation.

Several authors (10-12) compared the quality of conventional and digital radiographs in the determination of root canal length and showed that the digital method provided the best images for analyzing the distances from files to root apices. In contrast, other studies reported no improved accuracy for endodontic measurements performed on digital radiographs, mainly when using fine endodontic instruments (7,13-15). Notably, in digital radiographs, the application of various image enhancement modalities improves the accuracy of endodontic file lengths (16). Nevertheless, the software programs of digital radiographic systems usually provide a sequence of straight lines for evaluation of root canal working length that can lead to imprecise endodontic measurements in curved canals (4).

The purpose of the present study was to compare conventional and digital radiographic linear measurements performed to determine the working length of curved canals with fine endodontic files. The null hypothesis was that the two radiographic methods are similar for endodontic measurements in the described conditions.

Materials and Methods

Thirty extracted human teeth, without endodontic treatment and with well-preserved coronal and radicular structures, were selected – 15 maxillary molars and 15 mandibular molars. The criteria for tooth selection included the integrity of the dental crowns as well as the degree of root curvature (25 to 40 degrees), as established by the Schneider method (17). Another criterion for selection was the accessibility of the apical foramen with at least a #06 K-file (Dentsply-Maillefer, Ballaigues, Switzerland).

Coronal access to the teeth was initially obtained with a #1557 tapered carbide bur (S.S. White Dental products, Rio de Janeiro, Brazil) at high speed, and refined with an Endo-Z bur (Dentsply-Maillefer). The actual working length was obtained by introducing a #06 K-file (Dentsply-Maillefer) into the mesiobuccal canals until it passed the apical foramen, and then pulling back under pressure onto a smooth metallic surface. At this moment, the cursor was adjusted to the chosen reference point, the file was removed, and a millimeter ruler was used to measure the verified length. From this measurement, 1 mm was subtracted to achieve the actual work length (WL1).

The teeth were mounted in plastic blocks, using a type III stone plaster (Herodent, Vigodent, Rio de Janeiro, Brazil) and sawdust mixture (Fig. 1A), in order to simulate

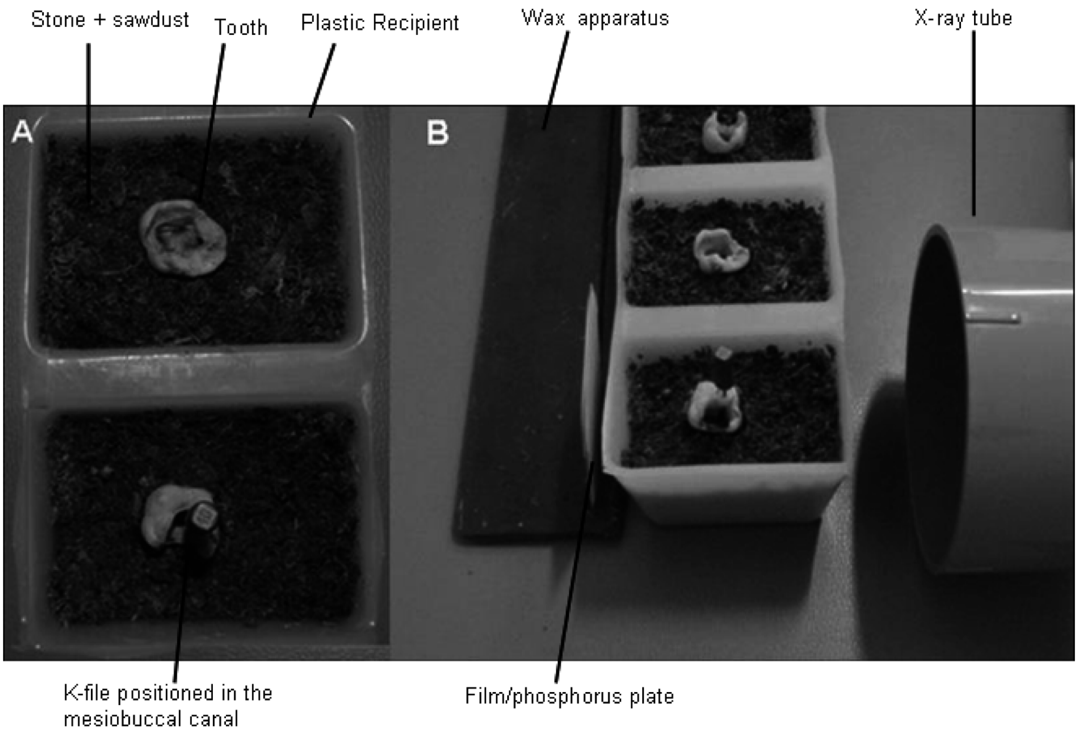

Fig. 1 Methodology for acquisition of radiographs. A: The insertion of tooth in a plastic block containing a type III stone plaster and sawdust mixture, B: Standardization of distance and the angle for conventional and digital radiographs.

alveolar bone tissue, thus simulating clinical conditions. To obtain the conventional periapical radiographs, a 66 KVp and 10 mA radiographic device was employed (Gnatus, Ribeirão Preto, Brazil) at an exposure time of 0.2 s and a focus-object distance of 25 cm. A wax apparatus was constructed, which allowed us to standardize distance and the angle for conventional as well as digital radiographs (Fig. 1B). The film from Group D (Ultra-speed, Kodak Eastman Co. Rochester, New York, USA) was chosen for the conventional radiographs, which were processed using the automatic method (AT 2000, Air Techniques, New York, USA). The digital images were obtained using a phosphorus plate from the Digora Optime® System (Soredex Orion Corporation, Helsinki, Finland) and a high-frequency Kodak 70 kv and 10 mA X-ray machine (300 khz) (Careestream Health, Rochester, New York, USA). The exposure time was 0.12 seconds and the same focus-object distance used to obtain conventional radiographs was applied. In this manner, conventional and digital radiographs were obtained using #06, #08, and #10 K-files (Dentsply-Malleifer), each positioned in the mesiobuccal canals in WL1 (Fig. 2).

Measurements of the conventional radiographic images were performed by two calibrated and independent examiners, specialists in endodontics, with the aid of an endodontic millimeter ruler, a magnifying glass (×5), and a negatoscope. The use of magnifying lens has been suggested for radiographic interpretation of the root canal length, mainly with fine endodontic files (8,14). The measures were taken from the file stop to the file tip. In this manner, the conventional working length (WL2) was determined. The digital radiographic measurements were made with the aid of linear measurements from the Digora® program for Windows in the original mode. The examiners determined the digital working length (WL3) based on the same references used for WL2. For both radiographic methods, the measurements were performed in a closed and dark room.

To verify inter-examiner agreement, the intraclass correlation coefficients (ICC) were used. For comparisons among WL1, WL2, and WL3, the Wilcoxon non-parametric test was used ($P < 0.05$).

Results

Overall agreement between the two examiners was satisfactory. The ICCs were generally high (ICC range: 0.69-0.95) (Table 1).

No significant differences were observed between the

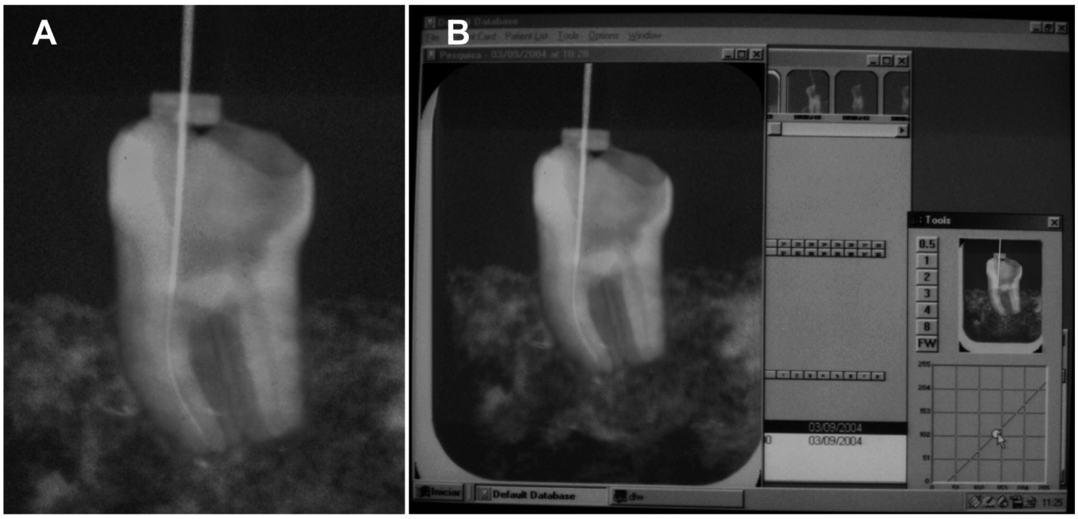

Fig. 2 Examples of radiographic images. A: Conventional radiograph, B: Digital radiograph.

Table 1 Intraclass correlation coefficients for the inter-examiner evaluation

File*	Conventional working length	Digital working length
06	0.8312	0.6911
08	0.9246	0.7551
10	0.9544	0.8193

*File sizes used in determining working lengths.

conventional and digital radiographic linear measurements performed for files #06 ($P = 0.341$), #08 ($P = 0.641$), and #10 ($P = 0.232$). The mean measurements for both radiographic methods independent of the file used were significantly different ($P < 0.05$) from the gold standard for endodontic measurements. These results are displayed in Table 2.

Discussion

The hypothesis of this study was confirmed. The present findings verified that the linear measurements for determining working length of curved canals with fine endodontic files obtained on either conventional or digital radiographs were similar. Radiography is essential for successful endodontic management and plays an important role in achieving accurate and reproducible measurements. The disadvantages associated with conventional films include: the high level of radiation, the need for chemical solutions, the time required to process the radiographs, the need for radiographs which cannot be modified, as well as the control and maintenance of radiographs during and after treatment (2,11). In contrast, digital radiographic systems provide rapid image acquisition, eliminate the chemical process, allow for the manipulation of the image through digital resources, facilitate the filing of images, and allow one to make copies of the images with no new exposure to the patient (4,12,16). Thus, digital technology is gaining importance in the field of endodontics. Though introduced more than 25 years ago, the digital radiograph has not replaced the conventional radiograph in countries such as the Netherlands, Norway, and the USA. The reasons cited by dentists from these countries for not using the digital systems include the complexity of the programs, the need for "hardware", and the additional training required (5).

The length obtained via endodontic measurements is more precise than external root measurement, especially in curved canals, since the apical foramen does not usually coincide with the end of the root apex (15). The length obtained via endodontic measurements was thus established as gold standard in the current study. To obtain a radiographic contrast between the dental root and the structures surrounding the root, much like alveolar bone *in vivo*, the teeth were inserted in a plaster and sawdust mixture, according to the protocol established in a previous study (18). In the acquisition of conventional radiographs, the film from group D was chosen, as it presented high-quality precision for the identification of fine caliber instruments in the determination of working length (9,19,20).

The digital radiographic system used in the present investigation was introduced to the market in the mid-1990s and is characterized as a phosphor storage system (9,21). In this technology, there is no formation of instantaneous

Table 2 Linear measurements in the conventional and digital radiographic images obtained by the two examiners and canal lengths obtained via endodontic measurements

	Groups	*n*	Minimum	Maximum	Mean*	Standard Deviation
	WL1	30	15.5	21.5	18.517 a	1.534
Examiner 1	WL2/file 06	30	16.0	23.0	19.467 b	1.553
	WL2/file 08	30	17.0	23.0	19.750 b	1.701
	WL2/file 10	30	17.0	23.0	19.917 b	1.603
	WL3/file 06	30	16.0	24.0	19.650 b	2.150
	WL3/file 08	30	16.0	23.5	20.133 b	1.857
	WL3/file 10	30	17.0	23.5	20.167 b	1.663
Examiner 2	WL2/file 06	30	16.5	23.5	20.100 b	1.759
	WL2/file 08	30	17.0	23.5	20.217 b	1.715
	WL2/file 10	30	17.0	23.5	20.217 b	1.622
	WL3/file 06	30	16.0	23.5	20.133 b	1.857
	WL3/file 08	30	16.5	23.5	20.033 b	1.857
	WL3/file 10	30	15.0	23.5	20.183 b	2.053

*Means followed by different letters are statistically different (Wilcoxon test, $P < 0.05$).
WL1 = Actual working length; WL2 = Conventional working length; WL3 = Digital working length.

images. The X-ray beam coincides with the optical plate, made up of phosphor particles, which are converted into visible light X-rays, forming a latent image. This plate is taken to the machine and is processed with the aid of a scanner. The plate is hit by a beam of light, which is then captured by a photo-detector and transformed into electrical signals, which are then sent to the respective software to process the digital image. The optical plate is similar in size and thickness to the standard periapical film. The Digora® has already been investigated in many previous studies which presented high-quality image resolution with this system (22), in addition to resources that are sufficient to identify the endodontic working length (9).

The specialists who were responsible for obtaining the linear measures for the current study received prior training regarding the proper use of the program; both initially showed little familiarity with the digital system. In the beginning stages, the measurements were slow, as the examiners carried out the post-processing of the image using tools such as zoom, inversion, and changes in brightness and contrast, in order to obtain the best view of the endodontic instrument. At the end of the calibration, both examiners demonstrated great interest in the diverse applications and facilities that this digital system could offer and performed the measurements in the original mode representing the focus of this study. In order to avoid the effects of ambient light, we selected dark conditions to improve the accuracy of endodontic file positioning (23).

Nevertheless, the measurements obtained by the two examiners presented some variations, mainly with instrument #06 in the digital system. However, this discrepancy did not interfere with the findings since it was possible to verify satisfactory interexaminer agreement with regard to the endodontic measurements. Thus, upon comparing the working lengths obtained with the conventional and digital radiographs, no significant differences could be observed, regardless of the instrument used. Both methods appeared to be similar with regard to the definition of working length in curved canals. This finding is in accordance with the literature (10,19). However, other studies (9,14) have observed the superiority of the digital system when using larger instruments such as file #15, as well as in uniradicular teeth in laboratory or clinical studies (8,22). On the other hand, several authors (9,13,14) have confirmed the superiority of the conventional radiograph when working length was determined with instruments of smaller caliber. A detailed assessment of these findings is difficult due to the variation with regard to the digital system used in each work. However, it is important to emphasize that the digital systems which are currently available present high-quality images, so long as researchers respect the appropriate parameters of radiographic exposure (3,21,22).

This study also showed higher values with conventional and digital radiographic methods as compared to direct measurements. The differences among the mean measures of true canal length and radiographic techniques ranged from 1 to 1.7 mm. Previous studies have already demonstrated the overestimation of true canal length in curved root canals when using conventional and direct digital images (10,19). Nevertheless, the current study did not exploit all the resources available with the Digora software, such as: the increased image, the negative-positive conversion, zoom, and the negative to positive zoom. A recent investigation (23) demonstrated that the inverted digital image from a storage phosphor system increased the accuracy of file length measurements in uniradicular teeth. Thus, new research is necessary to analyze all the resources offered by the existing digital systems, such as: filters, number of line pairs, quantity of shades of gray, and software tools to view important details including the contours of fine instruments and apical limits of roots, especially in morphologically complex teeth. It is important to highlight the speed at which software and sensors launched by the industry have evolved, as well as the rapidly improving quality of monitors to present these images. These advances improve the contrast and simplify the post-processing of the image (2).

Considering the experimental conditions adopted in this study, it can be concluded that the linear measurements obtained with a phosphor-plate digital system presented, in the original mode, similar efficacy to that of the conventional radiograph with regard to the working length determination of curved canals, using fine caliber instruments.

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