

Digital *versus* conventional radiography for determination of primary incisor length

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Abstract

Aim: This *in vitro* study evaluated the accuracy of primary incisor lengths determined by digital and conventional radiography compared to the actual tooth length. **Methods:** Twenty extracted primary maxillary incisors were mounted in acrylic blocks. Tooth length was estimated by using a straight-line measurement provided by the distance measurement tool of a digital dental imaging system (Computed Dental Radiography, Schick Technologies Inc.) and conventional E-speed film radiographs by using a digital caliper. Two operators familiar with both radiographic methods performed the estimates. The estimated tooth lengths were compared to the actual tooth lengths measured with the digital caliper. Data were statistically analyzed by Dahlberg's equation, paired *t* test, Pearson's correlation coefficient and ANOVA at 5% significance level. **Results:** There were no statistically significant differences ($p = 0.85$) between tooth length estimated on digital and conventional radiographs. Admitting as clinically acceptable a 0.5-mm discrepancy between the actual tooth lengths and the radiographically estimated lengths, 60% of the radiographic measurements were considered as accurate. When the acceptable difference range was 1.0 mm, the accuracy of the radiographic measurements increased to 100%. **Conclusions:** Digital and conventional radiography provided similar tooth length measurements and were equivalent to the actual tooth lengths.

Keywords: dental radiography, dental digital radiography, primary tooth, odontometry.

Introduction

Radiographic determination of tooth length is one of the critical aspects of pulpectomy in primary teeth because minor degrees of resorption may not be obvious radiographically¹ and an underlying permanent tooth germ can cause image superimposition. Consequently, the root apex is not clearly identified.

In order to establish the correct working length (WL) for instrumentation of the root canal system, the tooth length should be estimated from a preoperative radiograph, an endodontic file should be inserted up to the established length and another radiograph should be taken to check whether the instrument is positioned at the right level. Therefore, accurate tooth length measurements are extremely important to ensure that the file does not pass beyond the apical foramen and causes injuries to the periapical tissues². Overinstrumentation in primary teeth involves the additional risk of damage to the permanent tooth germ^{3,4}.

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The WL is traditionally established based on the examination of conventional intraoral radiographs. The recent technological advances turned the digital radiography into a viable option for the determination of the WL. The reliability of WLs established with use of digital radiography has been described as comparable to or even better than that of conventional radiography⁵⁻¹⁰. Other studies¹¹⁻¹⁴, however, reported that conventional radiography is more accurate in comparison to older digital radiographic systems.

For most digital radiographic systems, image acquisition and manipulation may be performed using the proprietary softwares supplied by the manufacturers or other commercially available graphic softwares. Among the options of digital radiographic systems are the linear measurements between two or more spots localized on the image using the mouse, which produce a numerical measurement, generally in millimeters. Although this method has been used for WL determination in permanent teeth^{6,7,10}, little is known about its reproducibility, consistence and accuracy for tooth length assessment in the primary dentition. The purpose of this study was to compare the accuracy of digital and conventional radiography as well as inter and intra-examiner agreement for determination of the length of primary incisors.

Material and methods

After approval of the research protocol by the Ethics Committee of Faculdade de Odontologia de Araraquara, children from the Pediatric Dentistry clinic with symptomatology and clinical findings of necrosis and radiographic diagnosis of periapical lesion in the primary incisors were invited to participate in this study. The informed consent was obtained from all parents/legal guardians. Twenty primary maxillary incisors with less than 2/3 of root resorption were used in this study. The teeth were stored in 1% thymol solution at room temperature until use.

Each tooth was measured twice with a digital caliper (Mitutoyo Corp., Tokyo, Japan) and the average was recorded as the actual tooth length. The teeth were embedded in acrylic resin blocks and adapted to a custom-made radiograph positioning device that maintained the angle and distance (25 cm) constant between the radiation source and the tooth for both digital and conventional radiographs. A groove was made in the resin block to allow adaptation of the guiding shaft in order to adjust the cylinder of the X-ray equipment, thereby simulating the paralleling radiographic technique.

The teeth were radiographed by a single calibrated operator. The exposure times were established in previous evaluations in which radiographs were obtained from extracted teeth with exposure setting ranging from 0.1 to 0.4 seconds. Two experienced radiologists, after a careful comparison of the quality of the images provided by both types of radiographic techniques, chose the most appropriate radiographic density for tooth length determination.

The digital radiographs were obtained using a computed dental radiography system and #2 sensor (CDR-Schick Technologies Inc.,

Long Island City, NY, USA; version 2.6) and X-ray equipment (Gnatus XR 6010; Gnatus, Ribeirão Preto, SP, Brazil), operating at 60 kVp, 7 mA. The digital images were stored in TIFF format for further analysis. The conventional radiographs were taken with E-speed film (Eastman Kodak, Rochester, NY, USA) using the same X-ray equipment. The films were developed by the time/temperature method and mounted on slide frames.

On the conventional radiographs, tooth length was estimated using a digital caliper (Mitutoyo Corp.). The radiographs were viewed on a light box with no magnification. On the digital radiographs, tooth length was measured directly on the screen of a high-resolution 17" monitor with 100% zoom magnification. The measurement method was the electronic ruler of the proprietary CDR system software (version 2.6; Schick Technologies Inc.).

Using the left mouse button, a two-click measurement was performed for tooth length determination: one click at the visible edge of the crown and the other at the root apex. Prior to the measurements, the electronic ruler was calibrated by measuring an object of known length, a #30 Kerr file (Les Fils D'Auguste Maillefer S.A., Switzerland). Enhancement features, such as brightness and contrast, were not used for the on-screen measurements.

Two experienced pediatric dentists with expertise in both radiographic techniques were calibrated ($\kappa = 0.94$) and assessed twice the length of the teeth with a two-month interval.

Intra and inter-observer variability was determined by calculating the error of the method from double measurements using Dahlberg's equation and systematic errors were detected through a paired *t* test¹⁵. The measurements obtained with conventional radiography and digital radiography were compared to the actual tooth lengths and analyzed by ANOVA. A 5% significance level was set for all analyses.

Results

The analysis of intra-examiner agreement showed a high reproducibility of tooth lengths for both examiners when digital and conventional radiographic measurements were performed (**Table 1**). Considering that both examiners presented excellent measurement reproducibility for both types of radiographic method and that there was small variation of tooth lengths and similar standard deviations, the means were used for results analysis.

Inter-examiner agreement was excellent for digital radiographic images; however, measurements in the conventional radiography presented random and systematic error (**Table 1**).

There was no statistically significant difference ($p = 0.85$) between the actual tooth lengths and the tooth lengths for both radiographic image types. However, overestimation of the actual tooth length occurred in 70% of the digital radiographs and in 75% of the conventional radiographs (**Table 2**).

Admitting a 0.5-mm difference between the actual tooth lengths and lengths estimated on the radiographs as a clinically acceptable

Table 1. Tooth length means and standard deviations (mm), random error (Dalberg's equation), systematic error (p) and Pearson's correlation coefficient (r) for intra and inter-examiners (Ex) reliability for digital (Rx D) and conventional (Rx C) images

	Intra-examiners				Inter-examiners	
	Rx D		Rx C		Rx D	Rx C
	Ex 1	Ex 2	Ex 1	Ex 2		
Mean (sd)	11.16 (1.46)	11.26 (1.54)	11.06 (1.55)	11.36 (1.52)	11.21 (1.48)	11.21 (1.53)
Dalberg's	0.06	0.04	0.00	0.01	-0.10	-0.29
p	0,469	0,494	0,959	0,695	0,319	.001*
r	0.95	0.97	0.97	0.98	0.96	0.97

sd: standard deviation; *Diferença estatística.

Table 2. Percentage of overestimated and underestimated radiographic tooth lengths as well as maximum, minimum and mean discrepancies from the actual tooth lengths for each radiographic method

Radiography	Overestimated (%)	Underestimated (%)	Maximun (mm)	Minimun (mm)	Mean (mm)
Digital	70	30	+0.72	- 0.90	0.40
Conventional	75	25	+0.85	-0.90	0.44

discrepancy, 60% of the measurements were considered accurate for both digital and conventional radiography. When the acceptable difference range was 1.0 mm, the accuracy of the radiographic measurements increased to 100%.

Discussion

The results of this study showed no significant difference between the primary tooth lengths obtained with digital and conventional radiographs, suggesting that digital radiography was effective in the assessment of primary anterior tooth length. These findings are compliant with those of similar studies that compared the accuracy of digital images and conventional radiographs for determination of the length primary teeth *in vivo*¹⁶, extracted primary teeth *in vitro*¹⁷ and extracted permanent teeth^{6,7,10}.

The reproducibility of the measurements after a 2-month interval was excellent for both examiners using either types of radiographic image (**Table 1**). An excellent correlation between digital and conventional radiography has also been found for estimation of canal length in permanent teeth with a two-week interval between image acquisition¹⁸ as well as for assessment of endodontic WLs in permanent molars obtained from human cadaver maxilla^{19,20}.

The findings of the present study revealed excellent agreement between the examiners for digital radiographic images measured directly on the screen monitor with 100% zoom magnification. However, the performance of the examiners for conventional image presented random error (Dalberg's error = 0.29) and systematic error ($p = 0.01$), probably influenced by the radiographs view with no magnification and difficulty to identify the root apex when the root resorption was irregular. The results of the present study do not agree with those of Ellingsen et al.¹¹, who found high inter-examiner agreement in both radiovisiography and conventional radiography for determining the position of the tips of small-sized files relative to the radiographic apex in extracted permanent teeth.

Accepting clinically a 0.5-mm discrepancy between the actual tooth length and lengths estimated on the radiographs, 60% of the measurements obtained with either types of radiographic image were considered equivalent to the actual tooth lengths. These findings are consistent with those of Martinez-Martinez-Lozano et al.⁶, who radiographically compared estimate and actual tooth lengths admitting as acceptable a 0.5-mm difference range, and found that conventional and digital radiological methods were satisfactory in 50.6 and 61.4% of cases, respectively. Leddy et al.¹⁹ compared RadioVisioGraphy imaging and conventional film-based radiography in determining endodontic file length adjustment and reported a 50% increase in length adjustment estimates when a 0.5-mm difference between radiographic and actual measurements were considered as satisfactory.

In the present study, when the acceptable difference range was 1.0 mm, the accuracy of the radiographic measurements increased to 100%. This result corroborates the findings of Larheim and Eggen²¹, who observed that, for conventional radiography, 95% of the sample presented WL estimates equivalent to the actual WLs, admitting a 1.0-mm variation.

Most tooth length measurements were overestimated in less than 1 mm for both digital and conventional film-based radiographs. This discrepancy could be considered as clinically acceptable because, in order to determine the WL, a radiograph is taken with an endodontic file placed inside the canal 2 mm short of the tooth length. The 1 mm overestimated measurements observed in this study did not allow the file to extend beyond the actual tooth length and past the apical foramen. Slightly overestimated root lengths have also been observed in digital radiographs of extracted permanent teeth^{7,18,22} and dry mandibular jaw sections²³.

This study controlled possible sources of error in radiographic images, such as the distance from the tooth to the radiation source and to the film or sensor, as well as the vertical and horizontal cone angulation. A custom-made positioning device allowed holding the specimen, the X-ray equipment cone and the film and maintaining the sensor in a fixed position. It was, therefore, possible to simulate the paralleling radiographic technique, in which the estimated tooth length is closer to the actual length²¹.

Digital image calibration was performed before each tooth length determination using the on-screen calibration tool to measure the image of an endodontic file of a known length. It was done because it has been shown that calibrated digital measurements are more accurate than uncalibrated measurements²⁴.

In conclusion, digital and conventional radiography provided similar tooth length measurements and were equivalent to the actual tooth lengths, which validates both techniques for endodontic image acquisition in primary teeth. The null hypothesis is therefore accepted. It must be emphasized, however, that in this study the radiographic images were obtained under well controlled and standardized conditions, which is very difficult to be reproduced in a clinical setting, especially with pediatric patients. Notwithstanding, some characteristics of the digital images, such as reduced patient exposure to radiation, possibility of producing instant images and elimination of the chemical solutions used for image processing, make them a valuable alternative for endodontic length measurements in primary teeth.

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