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Ex vivo comparison of radiographic and electronic root canal length measurements in primary molars

ABSTRACT

Aim *The aim of the study was to evaluate the accuracy of root canal length measurements of primary teeth using an electronic apex locator (EAL) and digital radiography in comparison to stereomicroscopic measurement as gold standard.*

Materials and methods *After preparation of access cavities of twenty extracted primary molars, the teeth were embedded in alginate blocks. Endodontic files were inserted in the root canals and the length was measured using ProPex II (Dentsply, Maillefer). When the reading was stable for 5s a silicone stop was used for reference. The true lengths of the files were then measured using a micrometer. The gold standard was determined by observing the tip of the file at the apical foramen under a stereomicroscope. For radiographic measurements standard images were obtained at 30 cm source-to-object distance, and zero degrees vertical and horizontal angulations. Radiographic images of each experimental tooth were obtained with the Digora Storage Phosphor Plates (SPP) (Soredex, Orion Corporation, Helsinki, Finland) with the x-ray unit operating at 65 kVp and 10 mA for 0.16 seconds (Trophy Radiologie, Vincennes, France). The radiographic root lengths were measured with the measurement tool of the Digora for Windows software. The mean measurements of both methods were compared to the gold standard measurements using Repeated Measure ANOVA test with Bonferroni adjustments to identify the pair-wise differences (p=0.05).*

Results *The mean measurements obtained with the EAL (14.06±1.89 mm) were significantly lower than measurements done with SPP images (14.24±1.98 mm) (p<0.05). However, when both root canal length measurement techniques were compared to stereomicroscopic measurements (gold standard), no statistically significant difference was found.*

Conclusions *The EAL might be safer than digital radiography for the measurement of root canal length in primary teeth.*

Keywords *Digital radiography; Electronic apex locator; Primary molars; Root canal lengt.*

Introduction

The efficacy and high success rates of endodontic treatment of primary teeth are well documented with numerous studies [Rabinowitch, 1953; Moskovitz et al., 2005]. However extraction of primary teeth with pulp inflammation is still common and among dentists it can be frequently preferred to root canal treatment. The preference of extraction rather than root canal treatment was mostly due to the complexity of root canal morphology of primary teeth and the possible risk of harming the underlying permanent tooth germ [Camp, 1998]. However, these drawbacks may be eliminated by accurate determination of working length which ensures the limits of biomechanical preparation and confines filling materials to root canal space [Beltrame et al., 2011].

Traditionally, working length adjustments have been determined with the use of conventional films, a technique which was recently replaced by digital intraoral receptors. Although the development of digital radiography has created new options in dentistry, the problems inherent to 2-dimensional (2D) imaging can still create difficulties in endodontic practice. For instance, determination of the spatial relationship of multiple canals in the same root and/or adjusting the ideal depth of instrumentation is not simple with 2D images. These problems may be particularly prominent in children due to poor cooperation during exposures creating errors in projection and thereby affecting the final quality of the image. In addition to the aforementioned, determination of root canal length may be further problematic and inaccurate in children because of various stages of apical resorption of primary teeth. Recently, new electronic root canal length measuring devices were introduced to the market to overcome these hindrances. According to the manufacturers' claims electronic apex locators (EALs) determine the position of the apical constriction

with 90% accuracy [Akisue et al., 2007; Bernardes et al., 2007; D'Assunção et al., 2007; Herrera et al., 2007; Kim et al., 2008; Plotino et al., 2006; Versiani et al., 2009]. An additional advantage of the use of these devices is elimination of the need to expose the patient to ionising radiation. The efficacy of EALs has been proved even in the presence of root resorption that was frequently encountered in primary teeth [Beltrame et al., 2011; Mello-Moura et al., 2010; Mente et al., 2002]. Currently, accuracy of new generation of EALs has further improved so that root canal length measurements can be done even in the presence of electrolytes. Although there is a study comparing the performance of new generation EALs with images obtained using solid state sensors [Mello-Moura et al., 2010] no study can be found comparing the accuracy of root canal length measurements obtained with EALs and storage phosphor plate images in primary teeth.

Therefore, the aim of this study was to compare the measurements of a new generation of EAL and storage phosphor plate (SPP) images relative to the measurements from stereomicroscopy for determining root canal length of primary molar teeth.

Materials and methods

Twenty extracted primary lower molar teeth were used in the study. One investigator (AAY) performed the technical procedures for all teeth. Standard access cavities were prepared using a water-cooled diamond fissure bur mounted on a high-speed hand piece. After preparation of the access cavities, teeth were embedded in alginate blocks. Endodontic files ISO size 25 attached to the file holder of Propex II (Dentsply, Maillefer, Ballaigues, Switzerland) were inserted in the distal root canals until the display read apex. If the reading was stable for 5 s, a silicone stop was shifted to the occlusal reference edge. The occlusal reference point was defined and recorded for each canal and a total of 20 measurements were taken for the distal roots of 20 primary molars.

For the radiographic measurements the file was re-inserted in each canal and silicone stop was shifted to the occlusal reference edge which was marked previously. Thereafter, alginate blocks were placed on a supporting post (Pentamix, 3M ESPE, St. Paul, USA) with the x-ray cone to allow exact alignment. In order to keep the receptor (SPP) perpendicular to the x-ray beam at all exposures and to provide consistent and reproducible exposure geometry, a Rinn-Endo-ray film holder (Dentsply/Rinn Corporation, Elgin, III) was used. The standard geometric configuration was fixed at a 30 cm source-to-object distance, and zero degrees vertical and horizontal angulations of the x-ray beam. A 10 mm plexyglass block was inserted between the x-ray tube and the alginate block to simulate the effect of soft tissue during all exposures. The radiographic images of each experimental tooth/canal were obtained with the blue SPPs of Digora Optime system (Soredex, Orion Corporation, Helsinki, Finland) with the x-ray unit operating at 65 kVp and 10 mA for 0.16 sec. (Trophy Radiologie, Vincennes, France). Following the exposures the SPPs were scanned immediately in the Digora Optime scanner and the resulting images were transferred to a personal computer (LiteOn, China) using the Digora for Windows software.

One radiologist and two pedodontists with a mean age of 38 (range 32.0-46.0) and a mean clinical experience of 15 years (range 9-23) acted as evaluators and were asked to measure the length of each file from the apex to the stopper on each SPP image. The measurement sessions were performed in a darkened room to minimise glare. Digital images were displayed on a 17-inch XGA color monitor (1024x768 pixels, LiteOn, China) and the measurements were performed using the distance measurement tool provided by the software.

All measurements taken on the SPP images were calibrated to the true length of the endodontic file using the abovementioned software's distance calibration tool. The file in each canal was removed and the distance from the silicone stop to the file tip was measured using a digital caliper to the nearest 0.01 mm and recorded as the true length. Because each radiographic image has some degree of magnification, the true length served as a reference for the measurement of file lengths and as a calibration control for each image. A mean (from all observers) was calculated for the measurements obtained from each image.

Stereomicroscopic measurements were undertaken using a Hedström file (Dentsply Maillefer) inserted into each distal root canal until its tip was barely visible at the apical foramen at 15x magnification (Leica Application Suite-LAS, Heerbrugg, Switzerland). The silicone stop was tangentially positioned to the occlusal reference edge which was recorded previously, and the file was removed.

The distance between the file tip and silicone stop was measured using a digital caliper to the nearest 0.01 mm. All measurements were carried out three times by the same operator, and the mean was recorded. These measurements were served as the "gold standard" and the mean measurements of all methods were compared to the gold standard measurements.

Statistical analyses were conducted using SPSS version 17 for Windows (SPSS, Chicago, IL). Repeated measure ANOVA was performed to determine the differences between three measurement methods. Post-hoc comparisons with Bonferroni adjustments were used to identify the pair-wise differences ($p=0.05$).

Results

The mean measurements obtained from 20 teeth with three different methods (electronic apex locator, SPP radiography, stereomicroscopy) are shown in Table 1. Table 2 shows the means and standard deviations of the measurements obtained with the three methods. The mean root canal length measurements obtained with stereomicroscopy and regarded as gold standard were 14.11 mm (Table 2). The mean measurements obtained with the electronic apex locator (Propex II) were 14.06 mm, while mean measurements obtained with SPP images were 14.24 mm (Table 2). Root canal lengths measured with the apex locator were significantly lower than the root canal measurements done using SPP images ($p=0.039$). However, no significant difference could be found between stereoscopy measurements (gold standard) and measurements taken with the other two methods used in the present study ($p>0.05$).

Discussion

Radiography is widely used for root canal length measurements. However, because of the well-known hazards of ionizing radiation as well the limitations of the two-dimensional imaging of three-dimensional structures, electronic methods for determining the root canal length both in permanent and primary teeth have recently gained popularity. Electronic devices to determine the position of the apical foramen and thus determine the length of the root canal have progressed tremendously, and have been increasingly integrated into the modern clinical practice in endodontics. Several *in vivo* and *in vitro* studies have been conducted to assess the accuracy and consistency of commercially available electronic apex locators, with a reported accuracy of approximately 90% to 96% [Stoll et al., 2010]. Accordingly its use has been particularly recommended in paediatric practice to minimise the risks of radiation to children.

Number of canals	Electronic apex locator (EAL)	Storage phosphor radiography	Stereomicroscopy
1	15.3	15.31	15.29
2	14.9	15.2	14.8
3	16	16.16	15.9
4	16.2	16.46	16.3
5	11.1	11.26	11.17
6	15.2	15.46	15.26
7	14	14.16	14.12
8	11.5	11.54	11.51
9	14.5	14.67	14.61
10	14.1	14.17	14.11
11	12.4	12.58	12.42
12	14	14	14.09
13	16	16.06	15.98
14	12.9	12.98	13.18
15	9	9.14	9.21
16	15.2	15.19	15.27
17	13.2	13.2	13.22
18	14.8	14.94	14.88
19	14.9	14.99	14.89
20	16	17.39	16.02

TABLE 1 Mean measurements obtained with electronic apex locator, direct digital radiography and by means of stereomicroscopy.

	Electronic apex locator (EAL)	Storage phosphor radiography	Stereomicroscopy
Mean root canal length ± SD	14.06 ± 1.89	14.24 ± 1.98*	14.11 ± 1.85

TABLE 2 Mean root canal length measurements ± standard deviation (SD) obtained with the three different methods.

According to the results of the present study, measurements with the apex locator provided lower mean root canal length measurements than SPP images. However, no significant difference was found between stereomicroscopic measurements (gold standard) and measurements taken with the other two methods used in the present study. The EAL might be safer than the digital radiography method for measurement of root canal length in primary teeth. The present study used an *ex vivo* model to assess the accuracy of electronic apex locators, however, comparison of our results with clinical studies done in primary teeth also provided compatible results.

Although no statistical differences were found between electronic, radiographic and actual tooth length measurements, the radiographic measurements were longer than the electronic ones in a study of Katz et al. [1996] and Subramaniam et al. [2005]. Santos-Pinto et al. [2007] evaluated the accuracy of primary incisor length determined by direct digital radiography and measurement of the actual tooth length are similar to our results, and no statistically significant differences were found between two methods. Kielbassa et al. [2003) compared electronic device measurements with actual root canal lengths *in vivo* and the usage of the EAL was strongly recommended for clinical implementation of endodontics in primary teeth.

Most research that has investigated the root canal lengths with radiography preferred either conventional films or solid state sensors. There is only one study that compared the file length measurements using several image receptors including storage phosphor plates [Athar et al. 2008]. Nevertheless, they did not measure the canal lengths of primary teeth. Accordingly, this study is the first for the comparison of root canal lengths in primary molar teeth using storage phosphor plates as the radiographic receptor.

The main difference in the quality of the resultant digital image and accordingly the discrimination of file tips stems from the image receptor technology. Solid state sensors either charge-coupled device (CCD) or complementary metal oxide semiconductors (CMOS) provide a direct and instant image that can be viewed immediately after exposure that makes both endodontists and paedodontists prefer these sensors. However, the narrow active surface area, the thick structures of the sensor as well as the connected wires of the system makes it impracticable for paedodontic clinics.

Digora Optime system uses photostimulable phosphor technology to capture x-rays striking on image receptor. Blue storage phosphor plates have been introduced together with the Digora Optime system having a larger pixel size (64 μm) than most of the solid state sensors. The overestimation of root canal lengths obtained in the present study using SPP images may be attributed to the high pixel size of the blue plates since pixel size varies inversely with the resolution [Couture 2003]. In addition, there is evidence that visibility of radiopaque areas in digital systems is inferior [Yoshiura et al. 1999]. Due to this disadvantage the exact location of the file tip and accordingly the measurement of the file length may not be accurate on SPP images.

In the present study the simulation of the clinical situation has been done using electroconductive alginate to determine the root canal length with Propex II and this model was found to be accurate and shown to be reliable in previous studies [Angwaravong and Panitvisai, 2009; Mello-Moura et al., 2010].

The electronic apex locator used in this study is a fifth generation apex locator (ProPex II). Recent studies demonstrated high accuracy of the apex locator ProPex on the determination of the apical constriction in permanent teeth [Ozsezer et al., 2007] and on the determination of the file length in primary teeth [Nelson-Filho et al., 2010]. The apical zone in Propex II has extended from 0.9 mm to 0.0 mm so we think that it is more sensitive in determining the working length. However, since there are no studies up to date addressing the accuracy of Propex II either in permanent or in primary teeth we cannot compare the presented results.

Within the limitations of the present study, both SPP images and EAL showed comparable performance for the determination of the root canal length in primary molars as compared to stereomicroscopic measurements. However, SPP images were found to give significantly higher root canal measurements than the EAL measurements. Therefore, it is possible to state that in a clinical situation, root canal length determination using a SPP system may cause a risk of over-instrumentation and/or overfilling of a primary molar canal. This may cause serious damage to the permanent tooth germ. Hence, EAL might be safer than digital radiography for the measurement of root canal length in primary teeth. Nevertheless, it should be kept in mind that this study was conducted using only one type of SPP system and an EAL. Therefore; further studies with different brands of the similar materials are needed to generalise these results.

Conclusion

The tested EAL seems safer than digital radiography for the measurement of root canal length in primary teeth, and the use of EAL is appears very practical for paedodontic clinics. The benefits over other methods are namely quickness and comfort. Although questions still exist on whether the accuracy of apex locators can be affected by different types of electrolytes, foramen size, pulp vitality and resorptions their use should be further evaluated and certainly warrants more clinical studies.

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