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ORIGINAL ARTICLE

Accuracy of Conventional Radiography, Digital Radiography and a 4th Generation Apex Locator for Working Length Determination in Primary Posterior Teeth

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ABSTRACT
Working length determination is the first step in pulpectomy of primary teeth similar to permanent teeth. This study sought to compare the accuracy of a 4th generation apex locator, digital radiography and conventional radiography for working length determination in primary posterior teeth.This descriptive analytical study was conducted on 67 root canals of 20 extracted primary posterior teeth with at least two-thirds of their root length remaining. A K file was used to measure the actual root canal length from a coronal reference point to apical foramen or the resorbed apical surface. The teeth were embedded in alginate in order to use DentaPort ZX apex locator. For digital and conventional radiography, the teeth were fixed on a Styrofoam block and radiographs were taken using parallel technique. The obtained values were compared with actual root canal length and analyzed using repeated measures ANOVA.The accuracy of DentaPort ZX, digital radiography and conventional radiography for working length determination within ±0.5 mm of the apical foramen was found to be 77.61%, 64.18% and 62.68%, respectively. No significant differences were noted in the absolute error values among the three methods (P>0.05). Based on the results, apex locator had accuracy close to that of digital radiography and considering its numerous advantages, its use is recommended in pediatric dentistry.

Key words: *Tooth Apex; Radiography, Dental, Digital; Tooth, Deciduous*

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INTRODUCTION

Maintenance, stability and function of primary teeth until their exfoliation and shedding are important issues in pediatric dentistry [1]. For this purpose, endodontic treatment may be required in case of trauma to the primary teeth or extensive carious lesions. Maintenance of infected deciduous teeth is not recommended. Although these teeth may remain asymptomatic for long periods of time, they serve as a source of infection and must undergo endodontic therapy or should be extracted.

Working length determination is the first step in pulpectomy of primary teeth similar to endodontic therapy of permanent teeth. On the other hand, working length must be determined precisely, without passing through the apex in primary teeth in order to minimize the risk of trauma to the periapical tissue and the permanent successor. Moreover, zinc oxide eugenol is commonly used for root canal filling of primary teeth. This material has limited antiseptic property and thus, working length must be thoroughly determined to achieve efficient cleaning. Several methods have been recommended for working length determination in root canals of primary teeth such as the use of mean statistical length of primary root

canals, tactile sense and radiography [2]. Electronic apex locators are also extensively used for this purpose and have several advantages including prevention of unnecessary radiation and easy application in young uncooperative or mentally retarded children since taking radiographs in these patients is extremely difficult, if not impossible.

At present, digital imaging systems have attracted a lot of attention due to having numerous advantages. In these systems, digital X ray sensors have replaced traditional films and bypassed photographic processing. Digital software programs provide enhancement tools, which enable the clinicians to manipulate digital images and use magnification or change the contrast of the whole or part of the image to enhance diagnosis. These tools also allow accurate measurement of lengths and distances. Digital radiographs can be easily archived for efficient storage of patient records or transferred for consultation purposes. Moreover, digital radiography enables immediate capture of images and decreases the patient radiation dose. No concerns with regard to deterioration of film quality after long-term storage times exist for digital radiographs.

This study sought to compare the efficacy and accuracy of a 4th generation electronic apex locator and digital and conventional radiography for working length determination of root canals of primary posterior teeth to find the most efficient technique for use in pediatric patients.

MATERIALS AND METHODS

Twenty primary posterior teeth (67 canals) extracted due to extensive periapical lesions, irreparable crowns or orthodontic treatment was collected. Informed consent was obtained from the parents of children that teeth of them were used in this study. Since pulpectomy is only indicated when two-thirds of the root canal length remain, roots with resorption of more than one-third of the length were excluded. Number of maxillary and mandibular teeth and also Ds and Es was equal. The teeth were thoroughly cleaned of tissue residues and disinfected in diluted sodium hypochlorite solution. Each tooth was coded and stored in saline in a screw-top container until the experiment. Access cavities were prepared using a high-speed hand piece and fissure bur. A reference point was marked on the crown using nail varnish prior to the use of K file. The teeth were randomly divided into two groups. In group one, actual root canal length was first determined as the gold standard and then DentaPort ZX electronic apex locator was used. In group two, first the apex locator was used and then the actual canal length was determined. For measurement of actual root canal length, a K file proportionate to the root canal diameter, which would easily pass the apical foramen, was selected and introduced into the canal until its tip was visible at the apex. Exact location of file tip at the apical foramen was ensured using a magnifier (HAO Ming Glass, θ 60nm) with the

rubber stop at the coronal reference point. The file was then retracted from the root canal and its length was measured using an endometer with 0.5mm accuracy and recorded. For use of DentaPort ZX 4th generation apex locator, an amalgam well containing alginate was used for each tooth in order to better simulate the oral environment. Before the setting of alginate in the amalgam well, each tooth was embedded in the alginate to the level of the cementoenamel junction. The metal lip clip of the apex locator was also inserted into the alginate adjacent to the tooth. A file attached to file holder was introduced into each root canal and preceded gently until the monitor of apex locator flashed “APEX” and remained constant for a minimum of five seconds without alarming the apex was passed. The distance from the file tip to the rubber stop was measured by an endometer and recorded. Next, 3-4mm around the teeth apices were covered with a layer of red wax in order to mask the root end when inserting the files (similar to oral clinical setting). A file proportionate to the root canal diameter was inserted into the canal and proceeded until feeling constriction by tactile sense. The rubber stop was adapted to the occlusal reference point. To prevent the interference of rubber stops when placing several files next to one another, the rubber stops were cut into smaller pieces. Cavit was used to fix the files in place during radiography. To provide standard reproducible conditions when taking radiographs, Styrofoam blocks were fabricated for each tooth and coded. The teeth were glued to their respective cubes and subjected to conventional and digital radiography using photostimulable phosphor (PSP) plates in parallel technique. A film holder, fixed with glue to the cube, was used for this purpose. Both conventional and digital radiographs were captured using an intraoral x-ray unit (Soredex, Helsinki, Finland) at 70kVp and 7mA exposure settings. Exposure time was 0.1s for conventional and 0.03s for digital radiography. E-speed size 2 conventional radiographic films (Skydent, Slovakia) and an automatic film processor (Peri-pro,USA) were used in conventional radiography to decrease errors and eliminate the confounding effects of time, concentration and temperature of processing solutions. Films were placed in a cardboard frame and observed in a semi-dark room on a negatoscope. A transparent ruler with 0.5mm accuracy was used for working length measurement. Digital radiographs, displayed on a computer monitor, were observed

in a semi-dark room, and the measure icon of Scanora software was used to determine the working length. In both radiographic techniques, if a significant difference existed between the length of file inside the canal and actual root canal length, the required value was added/subtracted from the file length until the file tip reached radiographic apex and the radiograph was repeated to properly determine the working length. All measurements were made by the same operator twice and the mean values were calculated. The obtained values were analyzed using repeated measures ANOVA and the results were reported.

RESULTS

Of 20 teeth selected, 10 were Ds and 10 were Es. Half the teeth were maxillary and the other half were mandibular teeth (n=5). Maxillary Ds and Es all had three canals of mesial, distal and palatal. Mandibular Es all had four canals of mesiobuccal,

Comment [M1]: Add city of manufacturer

Comment [M2]: Add city and country of manufacturer mesiolingual, distobuccal and distolingual. In three mandibular Ds, three canals of mesiobuccal, mesiolingual and distal existed and two teeth had four canals of mesiobuccal, mesiolingual, distobuccal and distolingual.

The greatest difference between the value shown by apex locator and actual canal length was -2mm, seen in one canal. In 14 canals, the value showed by apex locator was similar to the gold standard; ±0.5mm difference was seen in 21 canals, which was the most frequent difference.

The greatest difference between the value obtained by conventional radiography and actual canal length was -2mm, seen in one canal. In 19 canals, the value measured on conventional radiographs was similar to the gold standard; ±0.5mm difference was seen in 20 canals, which was the most frequent difference.

The greatest difference between the value obtained by digital radiography and actual canal length was -2mm, seen in one canal and +2mm seen in four canals. In 23 canals, the value measured on digital radiographs was similar to the gold standard; ±0.5mm difference was seen in 16 canals, which was the most frequent difference.

The mean error in use of apex locator was -0.0448mm with a standard deviation of 0.67269mm. This value was +0.5075mm with a standard deviation of 0.72557mm in conventional radiography and +0.4403mm with a standard deviation of 0.70990mm in digital radiography. The obtained mean value by use of apex locator was smaller than the gold standard while the values obtained by conventional and digital radiography were greater than the gold standard.

The absolute error value was 0.5373±0.40183, 0.6567±0.59167 and 0.6045±0.57431 in use of apex locator, conventional radiography and digital radiography, respectively. The absolute error of apex locator was slightly smaller than that of two other methods. The absolute error value of digital radiography was slightly smaller than that of conventional radiography. To compare the accuracy of measurement among the three methods, the absolute error values were subjected to repeated measures ANOVA. Since the sphericity hypothesis was refuted, the Greenhouse Geisser test was used to compare data, according which, the P value was found to be 0.252. In other words, no significant difference existed in absolute error values among the three methods.

Table 1. Comparison of working length determined by apex locator and digital and conventional radiography with the actual root canal length

	Difference between the value obtained by apex locator and actual length					**Difference between the value obtained by digital radiography and actual length**					**Difference between the value obtained by conventional radiography and actual length**				
Deviation from the actual length (mm)	0	0.5	1	1.5	2	0	0.5	1	1.5	2	0	0.5	1	1.5	2
Frequency	14	38	12	2	1	23	20	13	9	2	19	23	15	5	5
Percentage	21	56.5	18	3	1.5	34	30	19.5	13.5	3	28.3	34.3	22.4	7.5	7.5
Cumulative percentage	21	77.5	95.5	98.5	100	34	64	83.5	97	100	28.3	62.6	85	92.5	100

DISCUSSION

Mello-Moura *et al* . [2] evaluated the efficacy of five methods namely tactile sense, conventional radiography, combination of radiography and tactile sense, digital radiography and apex locator for

working length determination. Subramaniam *et al*, [3] also compared tactile sense, conventional radiography, digital radiography and apex locator for working length determination in 20 primary anterior teeth in vitro. Thus, the current study aimed to compare three contemporary methods namely apex locator, digital radiography and conventional radiography for working length determination in primary posterior teeth. Vieyra and Acosta [4] compared four 4th generation apex locators and found no significant difference among them. Thus, the optimal efficacy of 4th generation apex locators for working length determination has been confirmed. Therefore, we used DentaPort ZX 4th generation apex locator in the current study. The mean error in working length determination was -0.0448 mm with an standard deviation of 0.67269mm with apex locator, which shows that apex locator tends to underestimate the working length compared to the actual value; this finding is similar to the results of Pratten and McDonald [5] who assessed the accuracy of Endex apex in permanent teeth and Kaufman *et al* , [6] who assessed the accuracy of Root ZX, Apritt III and Sono Explore and found that all three apex locators underestimated the length by 0.06 to 0.25mm. Katz *et al* . [1] assessed the accuracy of Root ZX apex locator in primary teeth and stated that it tends to underestimate the root canal length. This finding can be justified by the fact that apex locators alarm when the file tip contacts the periapical tissues (*in vivo*) or the alginate (*in vitro*). In most cases, the periapical tissues or the alginate slightly penetrate into the canal space, especially in cases with resorption or open or blunderbuss apices. In our study, the mean error value was +0.5075 with a standard deviation of 0.72557 in conventional radiography and +0.4403 with a standard deviation of 0.70990 in digital radiography. These values show that both methods overestimate the root canal length. This result is in line with the findings of Brito-Junior *et al* , [7], Katz *et al* , [1] and Stein *et al* [8] and is probably attributed to the oblique surface of resorbed apex in primary teeth.

In the current study, the accuracy of DentaPort ZX for working length determination within ±0.5mm of the apical foramen was found to be 77.61%. This rate was higher than the obtained value by Pratten and McDonald [5] using Endex apex locator but lower than the rates obtained by Shabahang *et al* , [9] and Vajrabhaya and

Tepmongkol [10] using Root ZX. Higher accuracy of DentaPort ZX apex locator in our study compared to that of Pratten and McDonald [5] is probably due to the use of a 3rd generation apex locator in their study, which has lower accuracy than 4th generation apex locators.

The current study was conducted on primary teeth and since due to root resorption, alginate had greater contact with intracanal space, it must have penetrated into the canal. This explains the reason behind underestimation of root canal length and greater error compared to the absence of root resorption or presence of a constricted apical foramen (as in permanent teeth). Difference in the types of teeth studied explains the reason behind lower accuracy of apex locator in our study compared to that in studies by Shabahang *et al*, [9] and Vajrabhaya and Tepmongkol [10] since they evaluated permanent teeth. Moreover, Shabahang *et al*. [9] evaluated 26 canals and Vajrabhaya and Tepmongkol (10) assessed 20 canals, which are smaller than our sample size (67 canals). In general, it may be stated that variability in the results of studies may be attributed to assessment of primary teeth (which undergo physiological resorption and exfoliation) compared to permanent teeth, different methodology, accuracy of operators, type of apex locator used and in vivo or in vitro setting of studies.

The accuracy of conventional radiography for working length determination within ±0.5mm of the apical foramen was found to be 62.68%; which was higher than the values obtained by Mello-Moura *et al* , [2] and Pratten and McDonald (5). The accuracy of digital radiography for working length determination within ±0.5mm of the apical foramen was found to be 64.18%. Thus, in our study, the accuracy of working length determination by apex locator within ±0.5mm of the apical foramen was slightly higher than that of digital and conventional radiography. The accuracy of digital radiography was also slightly higher than that of conventional radiography. To compare the accuracy of the three methods, the absolute error values were subjected to repeated measures ANOVA, which yielded a P value of 0.252 indicative of an insignificant difference among the three methods. Patino-Marin *et al.* [11] compared the performance of Root ZX apex locator and conventional radiography for working length determination of 60 primary anterior teeth and reported no significant difference; however, the accuracy of apex locator was slightly, but not significantly, higher than that of conventional radiography, which is in line with our findings. Mello-Moura *et al*, [2] in their study on primary anterior teeth reported that electronic apex locator was the most accurate technique followed by tactile sense along with radiography. The least accurate technique was use of tactile sense alone. It should be noted that in their study, intracanal files were not used when taking conventional/digital radiographs and only the distance from the occlusal reference point to the apex was measured on radiographs. In combination of tactile sense and conventional radiography, however, a file was introduced into the canal to the working length determined on a conventional radiograph and until the file tip reached the apical constriction. In our study, tactile sense

was used in both radiographic techniques. Brito-Junior *et al.* [7] compared linear measurements on conventional and digital radiographs for working length determination and found
no significant difference, which is in accordance with our results. However, they evaluated similar canals of permanent teeth (30 mesiobuccal canals of mandibular first molars). This finding is also in agreement with the results of Subramaniam *et al,* [3] who found no significant difference in the accuracy of tactile sense, conventional and digital radiography and apex locator for working length determination of 20 anterior teeth. But, in their study, similar to ours, apex locator, followed by digital radiography yielded values slightly closer to the actual length than conventional radiography. Katz *et al.* [1] Compared Root ZX and conventional radiography for working length determination in primary teeth and reported no significant difference. Almenar Garcia *et al.* [12] compared RVG and conventional radiography for estimation of working length in permanent teeth and found no significant difference. Neena *et al.* [13] compared digital radiography, a 5th generation apex locator and conventional radiography for working length estimation in primary molars in vivo and found no significant difference among the three methods. Wankhade *et al* . (14) assessed root canal length determination by a 5th generation apex locator, radiovisiography, conventional radiography and tactile sense in vivo in single-rooted teeth. Apex locator, radiovisiography, conventional radiography and tactile sense yielded the closest values to the actual length in a descending order of frequency. They concluded that 5th generation apex locator was useful for working length determination of primary teeth with or without physiological resorption. Krishnan and Sreedharan [15] comparatively assessed working length determination in single-rooted primary teeth using a 5th generation apex locator and conventional radiography in vitro and showed higher accuracy of apex locator than conventional radiography for this purpose. Chougule *et al.* [16] compared root canal length determination by conventional radiography and apex locator in primary molars in vivo and showed that apex locator was a reliable alternative to radiography for root length estimation in primary teeth. Saritha *et al,* [17] clinically assessed the accuracy of Root ZXII apex locator in maxillary incisors and compared the results with those of digital radiography. They concluded that apex locator was a reliable tool for working length determination of maxillary incisors. Shahrabi *et al.* [18] evaluated the performance of Raypex® 4 apex locator in vitro and reported its accuracy to be 61.5% versus 63.5% accuracy of radiography. No significant difference was noted between measurements made using apex locator and direct visual observation, but the difference with radiography was significant. The diameter of apical foramen (canal opening) had no effect on the accuracy of apex locator measurements. Shahrabi *et al* ,[19] in their in vivo study evaluated the accuracy of DentaPort ZX apex locator and reported favorable results. Based on their findings, similar to ours, DentaPort ZX can be considered for endodontic treatment of primary teeth.

CONCLUSION

Electronic apex locators can be recommended as the first choice for working length determination in endodontic treatment of primary teeth due to advantages such as easy use especially in children and avoiding unnecessary radiation. Digital radiography is ranked second due to advantages over conventional radiography.

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COMPETING INTEREST

The authors declare that they have no competing interest**.**

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