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Accuracy of two electronic apex locators in primary teeth with and without apical resorption: a laboratory study

G. Tosun[1], A. Erdemir[2], A. U. Eldeniz[3], U. Sermet[1] & Y. Sener[1]

[1]Department of Pediatric Dentistry, Faculty of Dentistry, University of Selcuk, Konya; [2]Department of Endodontics, School of Dentistry, University of Kırıkkale, Kırıkkale; [3]Department of Endodontics, School of Dentistry, University of Selcuk, Konya, Turkey

Abstract

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Aim To evaluate the accuracy of the Root ZX (J Morita Corp., Kyoto, Japan) and Tri Auto ZX (J Morita Corp.) devices for measuring root canal length in primary teeth with and without apical resorption.

Methodology Thirty-four extracted human primary molar teeth with resorption and 19 primary teeth without resorption were collected. After endodontic access preparation, the actual lengths of the teeth were determined. The teeth were then embedded in an alginate model to determine the electronic working length measurement. Statistical evaluation was completed using Student's *t*-tests.

Results For the Root ZX, there was no significant difference between those teeth with root resorption and those without. However, for the Tri Auto ZX, there was a significant difference in the electronic measurements between those teeth with root resorption and those without ($P < 0.05$). Significant differences were found amongst the measurements of the two apex locators ($P < 0.05$). For root canals with resorption, the respective accuracy rates (within ±0.5 mm) of Root ZX and Tri Auto ZX were 83.33% and 89.47%; within ±1 mm, the Root ZX and Tri Auto ZX demonstrated 98.95% and 100% accuracy, respectively. For root canals with no resorption, the percentage of measurements within ±0.5 mm of the apical construction was 89.28% for the Root ZX and 80.35% for the Tri Auto ZX. The accuracy within ±1 mm of the Root ZX and the Tri Auto ZX was 98.22% and 100%, respectively.

Conclusion Within the limitations of this laboratory study, the presence of resorption affected the performance of the Tri Auto ZX more than the Root ZX.

Keywords: electronic apex locators, primary teeth with apical resorption, Root ZX, Tri Auto ZX.

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Introduction

Paedodontic endodontics includes pulpal treatment of primary teeth. Pulpotomy is indicated when caries removal results in pulp exposure in a primary tooth with a healthy pulp or with reversible pulpitis (Camp & Fuks 2002). The objective of this treatment is to maintain the primary tooth by removing the coronal portion of the infected pulp until natural exfoliation occurs (Saltzman *et al.* 2005).

There are two options in the treatment of primary molars with infected or necrotic pulp tissue as a result of caries (Moskovitz *et al.* 2005), pulpectomy being a conservative alternative to extraction (Fuks & Eidelman 1991, Yacobi *et al.* 1991). A number of problems may occur if a primary tooth is lost at an early age, one of which is space closure, which can inhibit the eruption

Correspondence: Dr Gul Tosun, DDS, PhD, Assistant Professor, Selcuk Universitesi, Diş hekimliği Fakültesi, Pedodonti Anabilim Dalı, Kampüs, Konya, Turkey (Tel.: +90 332 223 3483; fax: +90 332 241 0062; e-mail: gultosun@hotmail.com).

of successor permanent teeth (Camp & Fuks 2002). However, several factors must be considered before commencing treatment (Andlaw & Rock 1997), because the various morphological configurations of root canals in primary teeth make mechanical debridement and subsequent filling difficult (Andlaw & Rock 1997, Kielbassa *et al.* 2003).

In addition, the exact location of the canal terminals in a primary tooth apex, particularly for molar teeth, is difficult to predict because primary teeth are resorbed during the eruption of their permanent successors (Mente *et al.* 2002). To minimize periapical injury and possible damage to the successor tooth, the root length should be carefully determined without exceeding the apex in primary teeth (Holan & Fuks 1993, Mente *et al.* 2002, Kielbassa *et al.* 2003).

Although radiography is a traditional method to obtain information on the anatomy of the root canal and surrounding tissue, it can only provide a two-dimensional image and so may give misleading results about the true anatomy. Moreover, radiographic assessment of small areas of resorption may be difficult in cases when resorption occurs on the buccal or lingual aspect of the root. This will often be undetectable radiographically, resulting in an increased risk of overinstrumentation (Mente *et al.* 2002). Recently, overestimation of the working length was demonstrated to occur in more than half of all premolar teeth, although the radiographic working lengths were apically located 0–2 mm short of the radiographic apex (ElAyouti *et al.* 2001).

The development of electronic apex locators (EALs) has enabled the assessment of the working length to be more accurate and predictable (Plotino *et al.* 2006). The apex locator Root ZX (J Morita Corp., Kyoto, Japan), a third generation electronic device, has reportedly been able to detect the narrowest diameter of the root canal under both wet and dry conditions, and several studies have indicated its high level of reliability (Czerw *et al.* 1995, Shabahang *et al.* 1996, Pagavino *et al.* 1998).

Recently, an engine-driven canal preparation system, Tri Auto ZX (J Morita Corp.), has been introduced. The Tri Auto ZX is a cordless handpiece with an integrated apex locator designed for rotary canal preparation with nickel–titanium instruments. In this system, the file electrode is installed in the head of the handpiece and connected to the Root ZX through the handpiece (Kobayashi 1997, Kobayashi *et al.* 1997, Erdemir *et al.* 2007).

As shown in laboratory (Fouad & Krell 1989, Saito & Yamashita 1990, Fouad *et al.* 1993) and clinical studies (McDonald & Hovland 1990), EALs give accurate readings for 80–90% of root canals. Several factors can affect the electrical measurement of root canal length. One is the presence of root resorption, which occurs physiologically in primary teeth (Mente *et al.* 2002). Measurements appear to be less accurate when the apical foramen is immature or large, which is often the case in primary teeth or young permanent teeth. Although many studies have evaluated the accuracy of electronic devices (Fouad *et al.* 1993, Kaufman & Katz 1993, Vajrabhaya & Tepmongkol 1997) for measuring the permanent teeth, few studies have reported the use of EALs in primary teeth (Mente *et al.* 2002, Kielbassa *et al.* 2003).

The purpose of the present laboratory study was to evaluate the accuracy of Root ZX and Tri Auto ZX apex locators in primary teeth with and without apical resorption.

Materials and methods

Thirty-four extracted human primary molar teeth with resorption and 19 primary teeth without resorption were collected. Two examiners determined the presence of root resorption independently. Teeth with root fractures were excluded. Before the test, the teeth were stored in 10% formalin and placed in 5.25% sodium hypochlorite (NaOCl) solution for 2 h to remove the periodontal ligament (Tinaz *et al.* 2002), and all root surfaces were then cleaned to remove organic debris and deposits.

The cusps were flattened with a tapered diamond bur using a high-speed handpiece under water irrigation to establish a level surface to serve as a stable, unequivocal reference for all measurements. After endodontic access cavity preparation with a high-speed handpiece, a water coolant and a diamond bur, the pulp tissue was removed using barbed broaches (32×480; Verenigte Dentalwerke, Munich, Germany). The canal orifice was widened using Gates-Glidden drills (Mani, Tochigi, Japan) to facilitate file placement. The root canals were irrigated with 5.25% NaOCl and then negotiated with a size 10-K Flexofile (Dentsply Maillefer, Tulsa, OK, USA) to eliminate canal roots having canal obstructions.

On completion of the access preparation, the actual lengths (ALs) were determined with a size 10-K file fitted with a rubber stop and inserted until the tip was just visible at the apical foramen under a 20× stereomicroscope (ZS-TP; Olympus, Tokyo, Japan). The distance from the file tip to the base of the rubber stop was measured with a millimetre scale and to 0.5 mm precision. The reference point was marked on the tooth crown with a felt pen to facilitate accurate reinsertion of the files. The reference points, number of canals and the resorption status of the roots were recorded, and 1 mm was subtracted from the measurement (Kielbassa *et al.* 2003). Each measurement was repeated three times, and the mean value was calculated and recorded for each root canal as the reference length and registered as the AL.

To measure the working length electronically, the teeth were then embedded in an alginate model (Tinaz *et al.* 2002). This was manufactured from plastic dental jaws, natural teeth and alginate impression material. The alginate was prepared according to the manufacturer's instructions and packed into the sockets for immediate tooth insertion. All measurements were performed by the same operator who did not know the resorption status of the teeth.

Both EALs were operated according to the manufacturer's instructions. Before electronic measurement, the root canals were irrigated and dried with paper points. To determine all electronic measurements, a size-15 Flexofile connected to the EALs was used, and the devices were then connected to the lip electrode. The devices were used in a random order. When using Root ZX, the file was advanced within the root canal to just beyond the foramen.

The Tri Auto ZX was used according to the manufacturer's instructions. The labial lip was connected to the negative electrode of the device. The file holder was connected to the positive electrode, and an ISO 15 file was attached. The file was inserted into the canal until the indicator 'lights' showed that a reading had been obtained. The stopper was placed at a tangent to the reference point, and the instrument was removed from the canal and measured with callipers, as described previously.

Each tooth was measured three times with each electronic device and the mean value was calculated. Measurements were considered valid if the instrument remained stable for at least 5 s; otherwise, the value was recorded as an unstable measurement because of the inability of the EAL to reveal a constant reading. Unstable measurements were not used to evaluate the accuracy of the measurements provided by the EALs.

After the measurements were completed, the AL was subtracted from the electronically determined distance. Negative values indicated measurements shorter than the AL, positive values were those that exceeded the AL and zero values indicated that the file tip was flush with the apical construction. The ALs ±0.5 and ±1 mm were used to evaluate the accuracy of the two EALs.

The statistical evaluation was completed using Student's *t*-test. The critical value of statistical significance was 5%.

Results

Accuracy was calculated using only stable measurements. There were only two unstable results for both Tri Auto and Root ZX in teeth with root resorption. The corresponding percentage values of the electronic canal measurements are presented in Table 1. For root canals with resorption, the accuracy rate of the Root ZX and that of the Tri Auto ZX were within ±0.5 mm in 83.33% and 89.47% of the root canals, respectively. The Root ZX and Tri Auto ZX produced 98.95% and 100% of the measurements within ±1 mm AL, respectively. For root canals with no resorption, the percentage of measurement within ±0.5 mm of the apical constriction was 89.28% for Root ZX and 80.35% for Tri Auto ZX. The accuracy of AL ±1 mm of Root ZX and Tri Auto ZX was 98.22% and 100%, respectively.

The mean and standard deviations between the differences of the values between each EAL and the AL obtained in millimetres are shown in Table 2. Statistical analysis revealed significant differences between the Root ZX and Tri Auto ZX measurements under all

Table 1 The number and percentages of measurements that were within an acceptable range of ±0.5 and ±1 mm and those that were either short or long

Instrument	< −1 mm *n* (%)	−1.0 to −0.51 *n* (%)	−0.5 to 0.5 *n* (%)	0.51 to 1.0 *n* (%)	1 mm > *n* (%)
Root ZX					
Resorption	1 (1.04)	13 (13.54)	80 (83.33)	2 (2.08)	0 (0)
Nonresorption	1 (1.78)	4 (7.10)	50 (89.28)	1 (1.78)	0 (0)
Tri Auto ZX					
Resorption	0 (0)	9 (9.37)	85 (89.47)	2 (2.08)	0 (0)
Nonresorption	0 (0)	11 (19.64)	45 (80.35)	0 (0)	0 (0)

Table 2 Mean difference between the values obtained with each electronic apex locator and the actual length (mm)

	Mean*	SD
Root ZX		
Resorptive	-0.25^{a}	0.42
Nonresorptive	-0.20^{a}	0.48
Tri Auto ZX		
Resorptive	-0.15^{b}	0.38
Nonresorptive	-0.32^{c}	0.48

Negative values indicate measurements that are short of the AL.
*There was no statistical difference between groups having the same letters ($P > 0.05$).

conditions (that is, in those root canals with resorption and those without) ($P < 0.05$). No significant difference was observed between the resorbed and nonresorbed root canals measured by Root ZX ($P > 0.05$), whereas a significant difference was detected between the two measured by Tri Auto ZX ($P < 0.05$; Table 2).

Overinstrumentation beyond the apical foramen was not observed with either EAL.

Discussion

Root length determination is a crucial factor for a successful root canal treatment (Nekoofar *et al.* 2006), especially in primary teeth (Camp & Fuks 2002). However, the anatomy of primary molars is difficult to predict. It should be remembered that one of the main goals of the paediatric dentist is to avoid damaging the permanent tooth germ. Therefore, to determine the AL in this study, the file was inserted only until it emerged at the root end and 1 mm was subtracted from the measurement.

Recently, electronic methods for determining the root canal length in both permanent and primary teeth have gained popularity amongst dentists because of the hazards of radiation (Katz *et al.* 1991, Brunton *et al.* 2002), the technical problems associated with radiographic techniques (Schaeffer *et al.* 2005) and to avoid overinstrumentation beyond the root canal terminus (ElAyouti *et al.* 2002). In addition, *laboratory* studies have reported superior results using the Root ZX to determine the root length in primary teeth (Katz *et al.* 1996, Kielbassa *et al.* 2003).

In the present study, the experimental model developed by Tinaz *et al.* (2002) was used to simulate clinical conditions. Ibarrola *et al.* (1999) suggested that preflaring the root canals before using an EAL increased the accuracy of the EAL; in the present study, the canals were preflared with Gates-Glidden drills.

Even with magnification, some difficulty was experienced in visualizing the exact location of the tip of the file, particularly in resorbed primary teeth. In addition, the distance between the rubber stop/reference points and rubber stop/calliper was difficult to control visually. To control visualization errors, each measurement was repeated three times and the mean value was calculated.

Ideally, the root canal should be prepared to the cementodentinal junction or the apical constriction (Ricucci 1998, Gordon & Chandler 2004). Studies on the anatomy of root apices have demonstrated that the distance between the apical major foramen and the minor foramen varied from 0.5 to 1 mm for teeth of different ages (Green 1960, Stein *et al.* 1990, Wu *et al.* 2000). Furthermore, root canals do not always terminate with a well-defined apical constriction (Wu *et al.* 2000). In particular, physiological resorption often occurs in the roots of primary teeth. For these reasons, it has been stated that the clinically acceptable error tolerance is ±1 mm (Shabahang *et al.* 1996, Goldberg *et al.* 2002, Kielbassa *et al.* 2003) or ±0.5 mm (Ounsi & Naaman 1999, Kim & Lee 2004, Wrbas *et al.* 2007). Therefore, in the present study, the accuracy of EALs was evaluated using both ALs ±0.5 and ±1 mm.

In previous studies, the accuracy of Root ZX that used AL ±0.5 mm varied greatly from 50% to 100% (Vajrabhaya & Tepmongkol 1997, Ounsi & Naaman 1999) or 64% to 100% AL ±1 mm (Weiger *et al.* 1999, Kielbassa *et al.* 2003). Goldberg *et al.* (2002) evaluated the accuracy of Root ZX on single-rooted teeth with simulated apical root resorption that were inserted into a sponge soaked with normal saline solution. They reported that the accuracy of Root ZX was 63% within 0.5 mm and 94% within 1 mm on permanent teeth.

The accuracy of the Root ZX in the present study was better than that reported by Kielbassa *et al.* (2003), who found that, in the measurements of primary teeth, the Root ZX was accurate within 1 mm in 64% of cases. The reason for the difference between their results and those of the present study might be the differences in the test conditions (clinical versus laboratory).

Several studies have demonstrated that the Tri Auto ZX can accurately determine the working length in root canals with mature apices (Campbell *et al.* 1998, Grimberg *et al.* 2002, Erdemir *et al.* 2007). According to the results obtained in the present study, the Tri Auto ZX measurements were accurately 89.47% and 80.35% of the time within ±0.5 mm for teeth with and without resorption, respectively, and were accurately 100% of the time within ±1 mm for both types of primary teeth. Thus, under the present conditions, the Tri Auto ZX root canal measurement device was accurate within a clinically acceptable range. Similarly, the Root ZX exhibited equal accuracy with resorbed and nonresorbed primary teeth, which concurs with the findings of Kielbassa *et al.* (2003) who found no statistically significant difference between resorbed and nonresorbed primary root canals using the Root ZX device.

Although Mente *et al.* (2002) reported that the presence of resorption in primary teeth did not affect the accuracy of the Tri Auto ZX, in the present study, there was some variability in the root canal length determination using Tri Auto ZX, and it could be claimed that electronic root canal measurement procedures are affected by the areas of root resorption (Grimberg *et al.* 2002).

Conclusion

Both the Root ZX and Tri Auto ZX accurately determined the root canal length in primary teeth. The Root ZX was not affected by the presence of root resorption whereas the Tri Auto ZX was.

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