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Electronic determination of root canal working length in primary molar teeth: an *in vivo* and *ex vivo* study

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Abstract

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Aim To evaluate *in vivo* and *ex vivo* the accuracy of an electronic apex locator in primary molar teeth with or without root resorption.

Methodology Fifteen primary molar teeth with 30 root canals were divided into two groups: roots without resorption (n = 13) and roots with resorption (n = 17). Root canals were measured with the Root ZX apex locator *in vivo*, and then after tooth extraction, each canal was measured electronically *ex vivo*. The actual root canal length was measured visually, with the placement of a K-file into the most cervical edge of either apical foramen or resorption. The Student's t-test was applied for statistical analysis at a 5% significance level.

Results The electronic apex locator was precise in 69% and 65% of the cases with and without root resorption, respectively (tolerance = ±0.5 mm), *in vivo* and 69% and 77% *ex vivo*. When the tolerance was ±1 mm, however, these figures increased to 92% and 94% for root canals with and without resorption, respectively, *in vivo* and *ex vivo*. No significant difference was observed between the resorbed and non-resorbed root canals measured using the Root ZX.

Conclusion The Root ZX apex locator was accurate in determining *in vivo* and *ex vivo* the working length ±1 mm in primary molar teeth in over 90% of roots regardless of the presence of root resorption.

Keywords: electronic apex locator, endodontic therapy, primary teeth.

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Introduction

Many dentists recommend the extraction of primary teeth with pulp inflammation because the morphology of their root canals is complex and the permanent tooth germ may be injured (Camp 1998). However, studies have demonstrated the efficacy of endodontic treatment of primary teeth with success rates of 99.5% and 100% (Rabinowitch 1953, Moskovitz *et al.* 2005). When pulp tissue is compromised, root canal treatment of primary teeth is crucial until exfoliation occurs. As a result, adequate growth and development of the stomatognathic system is achieved as well as formation and eruption of the succeeding permanent tooth (Camp 1998).

An important step in root canal treatment is to determine the working length correctly, as this ensures that biomechanical preparation and filling materials are restricted to the canal space and avoids harm to both periradicular tissues and the succeeding permanent tooth germ. The most widely used methods for the measurement of working length are radiographic and electronic, with the former being used more often for primary teeth. Several studies have demonstrated the limitations of radiographs that include image distortion

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(ElAyouti *et al.* 2001, Williams *et al.* 2006), superposition of roots and adjacent anatomical structures (e.g. permanent tooth germ), radiation exposure and patient management (Katz *et al.* 1991). The use of electronic apex locators (EAL) in primary teeth is not accepted universally. Some *ex vivo* studies demonstrated the efficacy of this method in determining the working length of primary teeth, even in the presence of root resorption (Mente *et al.* 2002, Subramaniam *et al.* 2005, Leonardo *et al.* 2008). Kielbassa *et al.* (2003) and Ghaemmaghami *et al.* (2008) conducted *in vivo* studies using EAL and recommended electronic measurement of primary teeth.

The purpose of this study was to evaluate *in vivo* and *ex vivo* the accuracy of the Root ZX apex locator (J. Morita Mfg. Corp.®, Tokyo, Japan) in primary molar teeth with or without root resorption.

Materials and Methods

Sample selection

The study was approved by the Human Research Ethics Committee of the Federal University of Santa Catarina (number 207/08).

Fifteen primary molar teeth (30 root canals) were selected following clinical and radiographic examination. The teeth were scheduled for extraction because of the impossibility of performing endodontic treatment because of difficulty in providing rubber dam isolation, no possibility of restoration after caries excavation or presence of one or more roots with resorption greater than two-thirds. Those canals presenting root obliteration and fracture during extraction were excluded.

In vivo electronic measurement

After anaesthesia, carious tooth tissue was removed, and an access cavity was completed with number 2 carbide bur (SS White®, New Jersey, NJ, USA) under water irrigation; an Endo Z bur (Dentsply Maillefer®, Ballaigues, Switzerland) was used to refine the pulp chamber walls. Relative isolation, using cotton rolls, was performed to control moisture contamination within the pulp chamber. Root canals were then irrigated with physiological saline solution, and the access cavities were dried with cotton pellets before performing the electronic measurement.

Electronic measurement of the working length was performed using the Root ZX apex locator according to manufacturer's recommendations. A clip was placed on the patient's lip, and a size 15 K-FlexoFile (Dentsply Maillefer®) of 21 mm length was attached to the EAL. The file was introduced slowly into the root canal until the EAL displayed the '0.0' mark. The rubber stop was shifted to the occlusal reference edge, and the file was then removed. The occlusal reference point was defined and recorded for each canal. The distance between the file tip and rubber stop was measured using a digital calliper with 0.01-mm resolution (Digimess ®, São Paulo, Brazil). This procedure was performed three times for each canal and the measurements obtained, electronic length (EL1), were recorded. Measurements were repeated three times, and the average was calculated and computed.

Following electronic measurement, the tooth was extracted and its roots were analysed with a 5× magnifying glass (Intex ®, São Paulo, Brazil) to verify the presence of perforating root resorption. Two groups were established: roots without resorption (n = 13) and roots with resorption (n = 17).

Ex vivo electronic measurement

The teeth were then inserted into a device made of floral sponge, which had been previously humidified with saline solution. Root canals were then irrigated with physiological saline solution, and the access cavities were dried with cotton pellets before performing the electronic measurement.

The Root ZX apex locator was used according to the manufacturer's recommendations. The labial clip was inserted into the sponge, and a size 15 K-FlexoFile of 21 mm length was adapted to the file holder. The file was introduced slowly into the root canal until the EAL displayed the '0.0' mark. The rubber stop was shifted to the occlusal reference edge, which was recorded previously, and the file was then removed. The distance between file tip and rubber stop was measured using a digital caliper with 0.01-mm resolution. This procedure was performed three times for each canal, and the measurement obtained, the electronic length (EL2), were recorded. Measurements were repeated three times, and the average was calculated and computed.

Direct measurement

Direct measurement was taken using a size 15 K-FlexoFile of 21 mm length. The instrument was introduced into each root canal until its tip reached the most

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cervical edge of either apical foramen or resorption. The rubber stop was tangentially positioned to the occlusal reference edge, which was recorded previously, and the file was then removed.. The distance between the file tip and rubber stop was measured using a digital calliper with 0.01-mm resolution. This procedure was performed three times for each canal, and the measurements obtained, direct length (DL), were recorded. Measurements were repeated three times, and the average was calculated and computed.

Statistical analysis

Data were tabulated in Excel spreadsheets (Microsoft Corp.®, Redmond, WA, USA), and the mean value of the three measurements for each method (EL1, EL2 and DL) was computed. Next, the difference between direct and electronic measurements was calculated for each root canal (DL – EL1; DL – EL2), which were grouped as follows: <−1 mm; between −1 mm and −0.51 mm; between −0.5 mm and +0.5 mm; between +0.51 mm and +1 mm; >+1 mm (Tosun *et al.* 2008). Mean and standard deviations of direct and electronic means were also calculated for each group (with and without root resorption).

To assess whether a significant difference in accuracy of the electronic apex locator existed, for both cases with and without root resorption, the Student's *t*-test was performed at 5% significance, using version 17 SPSS (Chicago, IL, USA).

Results

For the *in vivo* measurements, accuracy of ±0.5 mm was observed in 69% and 65% of the canals in roots without and with resorption, respectively (Table 1). For the *ex vivo* measurements, there was a 69% and 77% accuracy in roots without and with resorption, respectively (Table 2). When the margin of error was ±1 mm, these values were 92% and 94% for roots without and with resorption, respectively, for both the *in vivo* and *ex vivo* measurements.

Mean differences between direct and electronic length *in vivo* were 0.03 ± 0.48 for root canals with no resorption and 0.16 ± 0.57 for root canals with resorption. Mean differences between direct and electronic length *ex vivo* were 0.003 ± 0.507 for root canals with no resorption and 0.065 ± 0.531 for root canals with resorption. No significant difference was observed between the resorbed and non-resorbed root canals measured by the Root ZX ($P > 0–05$).

Discussion

The determination of an accurate working length during root canal treatment of primary teeth is necessary to promote complete cleaning and disinfection of the root canals as well as to avoid damage to the permanent tooth germ (Camp 1998). The use of electronic apex locators overcomes several limitations inherent with radiographic methods, such as

Table 1 Frequency of electronic apex locators measurements *in vivo* at different distances from the apical foramen/resorption

	Interval in mm				
Roots	<−1 *N* (%)	−1 to −0.51 *N* (%)	−0.50 to +0.50 *N* (%)	+0.51 to +1 *N* (%)	>+1 *N* (%)
Without resorption	1 (7.7%)	1 (7.7%)	9 (69.2%)	2 (15.4%)	0 (0.0%)
With resorption	1 (5.9%)	2 (11.8%)	11 (64.7%)	3 (17.6%)	0 (0.0%)
Total	2 (6.7%)	3 (10.0%)	20 (66.6%)	5 (16.7%)	0 (0.0%)

Intervals with positive values are within the canal, and those with negative values are beyond apical foramen/resorption.

Table 2 Frequency of electronic apex locators measurements *ex vivo* at different distances from the apical foramen/resorption

	Interval (mm)				
Roots	<−1 *N* (%)	−1 to −0.51 *N* (%)	−0.50 to +0.50 *N* (%)	+0.51 to +1 *N* (%)	>+1 *N* (%)
Without resorption	0 (0.0%)	2 (15.4%)	9 (69.2%)	1 (7.7%)	1 (7.7%)
With resorption	1 (5.9%)	1 (5.9%)	13 (76.4%)	2 (11.8%)	0 (0.0%)
Total	1 (3.3%)	3 (10.0%)	22 (73.4%)	3 (10.0%)	1 (3.3%)

Intervals with positive values are within the canal, and those with negative values are beyond apical foramen/resorption.

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superposition of images and difficulty in visualizing root resorptions (Katz *et al.* 1996, Mente *et al.* 2002, Subramaniam *et al.* 2005). In addition, EALs are quicker and safer, thus reducing the number of radiographs (Brunton *et al.* 2002).

The apical end-point of root canals in primary teeth is often uncertain as they do not always have a well-defined apical constriction (Wu *et al.* 2000) and physiological and pathological resorptions occur (Bolan & Rocha 2007). Owing to those inherent problems when using EALs, many authors consider it acceptable for the measurement to be ±0.5 mm between the working length obtained directly and that obtained electronically (Ounsi & Naaman 1999, Angwaravong & Panitvisai 2009), whereas others have quoted a difference of ±1 mm (Kielbassa *et al.* 2003, Bodur *et al.* 2008, Mello-Moura *et al.* 2010). In the present study, the accuracy of the EAL was assessed by taking into account both differences (±0.5 mm and ±1 mm).

Based on the difference of ±0.5 mm between direct and electronic measurements, the present study revealed *in vivo* an accuracy of 69% and 65% and *ex vivo* an accuracy of 69% and 77% for roots without and with resorption, respectively. In fact, a great variation in the accuracy of EALs for this difference is observed in the literature: *ex vivo* studies reported 89% and 83% for roots without and with resorption, respectively (Tosun *et al.* 2008), and 97% for roots with resorption (Angwaravong & Panitvisai 2009). In an *in vivo* study, the EAL accuracy was 81% for primary incisors (Ghaemmaghami *et al.* 2008).

On the other hand, considering a difference of ±1 mm between direct and electronic measurements, the EAL accuracy was 92% and 94% for roots without and with resorption, respectively. These findings were similar to those reported by Tosun *et al.* (2008), whose results were 99% and 98% for roots without and with resorption, respectively, and Ghaemmaghami *et al.* (2008), who found a 96% accuracy.

The presence of root resorption did not interfere with the accuracy of the EAL being tested, a finding also corroborated previously (Katz *et al.* 1996, Mente *et al.* 2002, Kielbassa *et al.* 2003). Two *ex vivo* studies conducted by Leonardo *et al.* (2008, 2009), who assessed the accuracy of Root ZX II locator and Digital Signal Processing, respectively, revealed no significant difference between single-rooted or multirooted teeth as well also between roots with resorption and roots without resorption.

The results support the use of electronic apex locators for canal length measurement in primary teeth, thus corroborating other *ex vivo* (Tosun *et al.* 2008, Leonardo *et al.* 2009, Mello-Moura *et al.* 2010) and *in vivo* studies (Kielbassa *et al.* 2003, Ghaemmaghami *et al.* 2008). The use of EALs is safe, comfortable, rapid and accurate.

Conclusion

The Root ZX apex locator accurately determined *in vivo* and *ex vivo* the working length ±1 mm in primary molars, regardless of the presence of root resorption.

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