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Ex vivo evaluation of the accuracy of two electronic apex locators during root canal length determination in primary teeth

M. R. Leonardo, L. A. B. Silva, P. Nelson-Filho, R. A. B. Silva & M. S. G. G. Raffaini

Department of Pediatric, Preventive and Community Dentistry, Ribeirão Preto School of Dentistry, University of São Paulo, Ribeirão Preto, São Paulo, Brazil

Abstract

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Aim To evaluate *ex vivo* the accuracy of two electronic apex locators during root canal length determination in primary incisor and molar teeth with different stages of physiological root resorption.

Methodology One calibrated examiner determined the root canal length in 17 primary incisors and 16 primary molars (total of 57 root canals) with different stages of root resorption based on the actual canal length and using two electronic apex locators. Root canal length was measured both visually, with the placement of a K-file 1 mm short of the apical foramen or the apical resorption bevel, and electronically using two electronic apex locators (Root ZX II – J. Morita Corp. and Mini Apex Locator – SybronEndo) according to the manufacturers' instructions. Data were analysed statistically using the intraclass correlation (ICC) test.

Results Comparison of the actual root canal length and the electronic root canal length measurements revealed high correlation (ICC = 0.99), regardless of the tooth type (single-rooted and multi-rooted teeth) or the presence/absence of physiological root resorption.

Conclusions Root ZX II and Mini Apex Locator proved useful and accurate for apex foramen location during root canal length measurement in primary incisors and molars.

Keywords: electronic apex locators, Mini Apex Locator, primary teeth, root canal length, root canal length measurement, Root Zx II.

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Introduction

Working length determination is a critical step during root canal treatment. It is particularly critical in primary teeth in order to minimize periapical injury and possible damage to the permanent successor tooth germ (Dandashi *et al.* 1993, Kielbassa *et al.* 2003).

Radiography is traditionally used to obtain information about root canal anatomy, working length and the surrounding apical tissues (Forsberg 1987, Haffner *et al.* 2005). However, the accurate determination of root canal length radiographically is hindered because of anatomical variations, interference of anatomical structures or errors in projection (Keller *et al.* 1991, Surmont *et al.* 1992, El Ayouti *et al.* 2002, Hoer & Attin 2004).

These factors have stimulated the development of electronic root canal length measuring devices (apex locators), which accurately report the foramen or more precisely an area between the minor and major foramen diameter. The first generation of electronic apex locators was based on the electrical resistance

Correspondence: Prof. Dr Mario Roberto Leonardo, Departamento de Clínica Infantil, Odontologia Preventiva e Social, Faculdade de Odontologia de Ribeirão Preto, University of São Paulo, Av. do Café, s/n Monte Alegre, 14040-904 Ribeirão Preto, SP, Brazil (Tel.: +55 16 3602 3984; fax: +55 16 3633 0999; e-mail: lea@forp.usp.br).

existing between the oral mucosa and the periodontal ligament. However, these devices had several shortcomings that restricted their use (Gordon & Chandler 2004, Hoer & Attin 2004, Haffner *et al.* 2005, Venturi & Breschi 2005). The second generation was based on the principle of impedance and the third generation of electronic apex locators, the two-frequency impedance-type devices, was based on different electrical principles (Baldi *et al.* 2007).

Recently, electronic apex locators for root canal length determination have gained popularity. Several studies have reported the precision of these devices as well as their extended measurement capabilities, which include accurate measurements in the presence of electrolytes (Kaufman *et al.* 2002, Haffner *et al.* 2005, Venturi & Breschi 2005, Plotino *et al.* 2006).

However, information regarding the accuracy of electronic root canal length measuring devices in the primary dentition is limited. Therefore, the purpose of this study was to evaluate *ex vivo* the accuracy of two electronic apex locators for root canal length determination in primary teeth.

Materials and methods

The research project was reviewed by the institutional Ethics in Research Committee and the study design was approved (Process #2006.1.859.58.0).

Tooth selection and preparation

Primary incisor and molar teeth either without physiological apical resorption or with resorption up to half of the root were obtained from the Human Tooth Bank of the School of Dentistry of Ribeirão Preto, University of São Paulo (Brazil). Tooth extraction was necessary as a result of one of the following reasons: prolonged retention (no spontaneous exfoliation), orthodontic purposes or no possibility of restoration after caries excavation. Preliminary radiographs were taken to evaluate root canal anatomy, identify the radiographic apex and exclude teeth with calcification, whose main canal was not visible radiographically. A total of 33 primary teeth (17 incisors and 16 molars) were selected, giving 57 root canals. The roots were numbered and stored in sterile saline until use.

After endodontic access cavity preparation, canal patency was verified by the introduction of a K-file up to the anatomical apical foramen. The diameter of the endodontic instrument was chosen according to the canal size. No root canal preparation was performed.

Direct determination of root canal length

For direct measurement of root canal length, a reference point was first marked at the most coronal portion of the tooth crown using a fine paint marker. Then a K-file with a silicone stop was passively introduced into the root canal until its tip was visible at either the apical foramen or the apical resorption level and then withdrawn 1 mm. The K-file was held by a needle-holder perpendicular to the edge defined as the reference point and was laid against a millimetre ruler in order to measure the root canal length. The measurements, in millimetres, were made by a calibrated examiner ($\kappa = 0.9$) and were recorded in specific charts.

Electronic determination of root canal length

The electronic root canal length determination was undertaken using two apex locators: Root ZX II (J Morita Corp., Tokyo, Japan) and SybronEndo Mini Apex Locator (Sybron Endo, Sybron Dental, Anaheim, CA, USA). The teeth were fixed in a sponge soaked in saline and the root canals were also filled with saline. Cotton pellets were used to remove excess saline from the pulp chamber. The lip electrode was attached to the sponge and the apex locators were used according to the manufacturers' instructions. The file holder was clipped to the metal shaft of the K-file and was inserted and advanced into the root canal until display read 1. The choice for using the '1' reading on the apex locator's display was based on the results of a pilot study, which showed that this reading presented the best correlation with the actual root canal length measurement (direct method) at 1 mm short of the root apex. The measurements were recorded for further comparison with those obtained by the direct determination of the root canal length.

Statistical analysis

Data were analysed statistically using the intraclass correlation coefficient (ICC).

Results

The actual (direct method) and electronic (apex locators) root canal length measurements for the single-rooted and multi-rooted primary teeth are given in Figs 1 and 2, respectively. Intraclass correlation comparing the electronic measurements with the

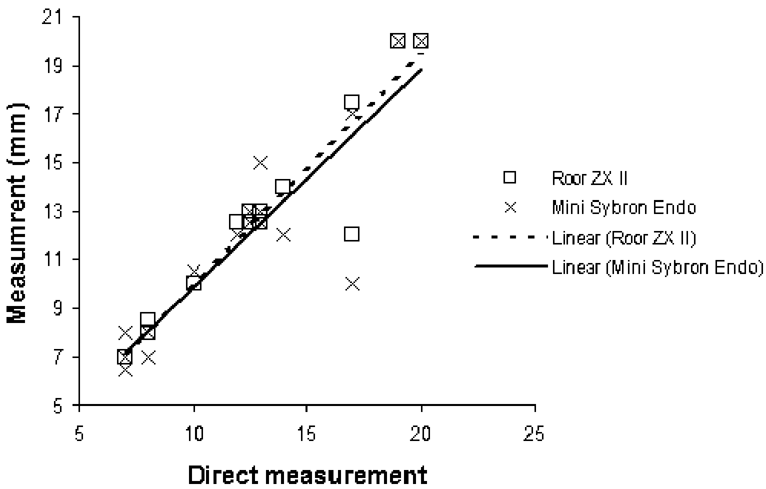

Figure 1 The actual (direct measurement) and electronic (apex locators) root canal length measurements for the single-rooted primary teeth (ICC = 0.99 for both apex locators).

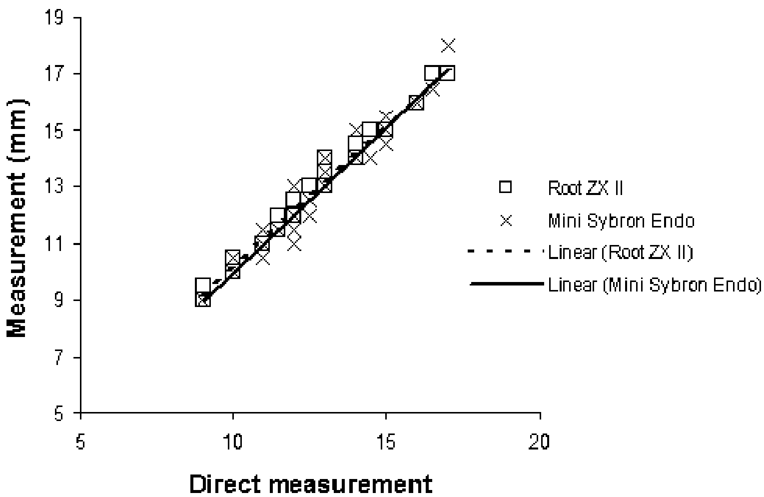

Figure 2 The actual (direct measurement) and electronic (apex locators) root canal length measurements for the multi-rooted primary teeth (ICC = 0.99 for both apex locators).

actual canal length was high (ICC = 0.99) regardless of the tooth type and the presence or absence of root resorption.

Discussion

The establishment and maintenance of the apical limit of instrumentation is undoubtedly an important step for the outcome of root canal treatment. An accurate determination of the working length contributes to a safe and effective instrumentation (Hoer & Attin 2004, Carneiro *et al.* 2006). Unfortunately, root canal preparation is adversely influenced by the highly variable root canal anatomy (Al-Omari *et al.* 1992, Nagy *et al.* 1997, Carneiro *et al.* 2006) and the relative inability of the operator to visualize this anatomy from radiographs (Stropko 1999, Peters *et al.* 2003, Carneiro *et al.* 2006). Specifically, the use of radiographs during paediatric endodontic therapy should be considered carefully. The diagnostic value is often limited and the exposure of children to X-rays should be limited to the least possible (Mente *et al.* 2002). Furthermore, radiographic assessment is difficult, particularly in cases where the physiological resorption in primary teeth occurs on buccal or lingual aspects of the root. This will often not be visible radiographically, resulting in an increased risk of overinstrumentation and/or overfilling (Mente *et al.* 2002). Whilst overinstrumentation and overfilling of a primary tooth can damage the germ of the permanent tooth, underfilling, on the other hand, is also a risk factor that accounts for ongoing disease.

Given that the use of electronic devices for working length determination has increased considerably in recent years (Kim & Lee 2004, Haffner *et al.* 2005, Plotino *et al.* 2006) and taking into account the small number of studies in the primary dentition, the present study evaluated the accuracy of two electronic apex locators (Root ZX II and SybronEndo Mini Apex Locator) in root canal length determination in primary incisors and molars.

The Root ZX apex locator (J. Morita Corp.) was developed by Kobayashi & Suda (1994) in the 1990s. This is an electronic canal length measuring device based on the ratio method, which simultaneously measures impedance values at two frequencies (8 KHz and 0.4 KHz) and calculates a quotient of impedances. This quotient is expressed as a position of the file in the canal. When the minor diameter of the canal is reached, the quotient approaches a value of 0.67. This is a constant value that is reliable in the presence of electrolytes or pulp tissue. The use of this apex locator in primary teeth has been investigated (Katz *et al.* 1996, Kielbassa *et al.* 2003) with results as good as those of the present study, regardless of the stage of root resorption.

In this study, the tested electronic apex locators (Root ZX II and Mini Apex Locator) proved useful and accurate to determine root canal length in single-rooted and multi-rooted primary teeth with and without root resorption, given that there was an almost perfect correlation between the electronic and the actual root canal length measurements. Nevertheless, these results do no imply that radiographs can be replaced by the use of the apex locators. The use of electronic apex locators is a valuable tool for complementing and/or assisting radiographic methods of working length determination, and may reduce the number of radiographs required for determination of root canal length (Gordon & Chandler 2004). Radiographic assessment after electronic root canal measurement confirms the root canal pathway because the image of the file within the canal facilitates the observation of a number of anatomical details.

In addition, it is important to mention that this study was a preliminary *in vitro* experiment, which does not include the errors that may occur whilst measuring root canal length in the mouth under clinical conditions.

Conclusion

The Root ZX II and SybronEndo Mini Apex Locator were able to determine accurately the root canal length in single-rooted and multi-rooted primary teeth with and without physiological root resorption.

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