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Accuracy of the iPex multi-frequency electronic apex locator in primary molars: an *ex vivo* study

P. Nelson-Filho, P. C. Romualdo, K. C. Bonifácio, M. R. Leonardo, R. A. B. Silva & L. A. B. Silva

Department of Paediatric, 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 the iPex multi-frequency electronic apex locator (NSK Ltd, Tokyo, Japan) for working length determination in primary molar teeth.

Methodology One calibrated examiner determined the working length in 20 primary molar teeth (total of 33 root canals). Working length was measured both visually, with the placement of a K-file 1 mm short of the apical foramen or the most coronal limit of root resorption, and electronically using the electronic apex locator iPex, according to the manufacturers' instructions. Data were analysed statistically using the intra-class correlation (ICC) test.

Results Comparison of the actual and the electronic measurements revealed high correlation (ICC = 0.99) between the methods, regardless of the presence or absence of physiological root resorption.

Conclusions In this laboratory study, the iPex accurately identified the apical foramen or the apical opening location for working length measurement in primary molar teeth.

Keywords: electronic apex locators, iPex, primary teeth, root canal length.

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Introduction

The determination of working length is one of the most important steps in root canal treatment (Ingle & Bakland 2002). Appropriate microbial disinfection, correct cleaning and shaping, and hermetic sealing of the root canal depend on the accurate determination of working length (Gordon & Chandler 2004). It is especially 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, Leonardo *et al.* 2009). 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 persistence of apical infection (Holan & Fuks 1993, Coll & Sadrian 1996, Mente *et al.* 2002, Angwaravong & Panitvisai 2009).

In clinical practice, radiography has been the method of choice for working length determination (Forsberg 1987, Haffner *et al.* 2005). However, radiographic assessment has limitations due to anatomic variations of the canal system, interference of adjacent anatomic structures or technical errors in projection (Keller *et al.* 1991, Surmont *et al.* 1992, ElAyouti *et al.* 2002, Hoer & Attin 2004). The foramen does not coincide with the anatomical apex; it might be located laterally and at a distance of up to 3 mm from the anatomical apex (Dummer *et al.* 1984). This makes it difficult to localize the foramen and constriction using a radiological approach (Olson *et al.* 1991). Particularly in paediatric

Correspondence: Paulo Nelson-Filho, Departamento de Clínica Infantil, Odontologia Preventiva e Social, Faculdade de Odontologia de Ribeirão Preto, Universidade de São Paulo, Av. do Café, s/n Monte Alegre, 14040-904 Ribeirão Preto, SP, Brazil (Tel.: +55 16 3602 4099; fax: +55 16 3633 0999; e-mail: nelson@forp.usp.br).

dentistry, children's acceptance and cooperation for radiographic examination is usually achieved with difficulty, and so a method that could minimize the need for exposing children to radiation during this part of root canal treatment would be welcomed.

All these factors together have stimulated the development of electronic root canal length measuring device, the so-called electronic apex locators (EALs), which are claimed to accurately locate the position of the minor foramen. The minor foramen marks the transition between the pulpal and periodontal tissue. It is common clinical practice to consider this anatomic landmark to be situated 0.5–1 mm coronally to the major foramen, and it has been stated that it is an ideal point to end instrumentation and filling of the root canal system (Ricucci 1998).

Different types of EALs have been evaluated in the permanent (Haffner *et al.* 2005, Plotino *et al.* 2006) and primary (Angwaravong & Panitvisai 2009, Leonardo *et al.* 2009) dentitions. The high precision rates achieved in these studies have increased their popularity and supported their clinical use.

The iPex multi-frequency EAL (NSK Ltd, Tokyo, Japan) has been investigated in the permanent dentition (de Vasconcelos *et al.* 2010), but it has not yet had its precision evaluated in primary teeth. Therefore, the purpose of this study was to evaluate *ex vivo* the accuracy of iPex for working length determination in primary molar teeth.

Materials and methods

The research project was reviewed by the institutional Research Ethics Committee and the study design was approved (Process number 2009.1.189.58.8).

Tooth selection and preparation

Primary maxillary and mandibular molar teeth were obtained from the Human Tooth Bank of the Ribeirão Preto School of Dentistry, 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. Fifteen primary molars were selected for a total of 33 root canals. The roots were numbered and stored in sterile saline until use.

After endodontic access cavity preparation, a K-file with diameter compatible with that of the canal diameter was passively introduced up to the apical foramen or the most coronal limit of root resorption to verify canal patency. No root canal preparation was performed.

Direct (real) determination of working length

For direct (real) measurement of working 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 most coronal limit of root resorption, 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

Table 1 Direct (real) and electronic (iPex) working length measurements in the 33 root canals of primary molar teeth

Tooth	Root canal	Direct method (mm)	iPex (mm)
1	P	11	11
1	MB	11	11
1	DB	12.5	12.5
2	P	14	15
3	P	14	14
3	MB	13	13
4	P	16.5	16.5
4	DB	14	15
5	P	7	8
5	MB	12	11.5
6	P	16	16
6	MB	14	14
7	MB	9.5	9.5
8	P	12.5	12
8	MB	14	14
9	MB	12	12
10	P	13	13
11	MB	7	7
12	P	13	13.5
12	MB	13	13
12	DB	12	12
13	P	14	14
13	MB	12	12
13	DB	12.5	12.5
14	P	11	11
14	MB	9	9
15	MB	13	13
16	P	14	14
16	MB	12.5	13
16	DB	12	12
17	P	10	10
18	P	14	14
18	MB	13	13

P: palatal; MB: mesiobuccal; DB: distobuccal.

millimetre ruler in order to measure the working length to an accuracy of 0.5 mm.

Electronic determination of working length

The electronic working length determination was undertaken using the iPex multi-frequency EAL (NSK Ltd). 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. A low-impedance lip-clip electrode was attached to the sponge and the EAL was used according to the manufacturers' instructions. The file holder was clipped to the metal shaft of the K-file, and the device was adjusted to react when the file advanced into the root canal reached a point 1 mm short of either the root apex or the most coronal limit of root resorption, that is, the point where the 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 (data not shown), which revealed 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 (in mm) of direct and electronic determination of the working length were made by an experienced calibrated examiner (kappa = 0.9), and were recorded in specific charts for further comparison of the methods. Data were analysed statistically using the intraclass correlation coefficient (ICC).

Results

Table 1 presents the working length measurements obtained with direct visualization and iPex EAL in all 33 root canals. The means and standard deviations were 12.4 (2.1) mm and 12.5 (2.1) mm for direct (real) and electronic (iPex) working length measurements, respectively. Figure 1 compares graphically the actual and electronic working length measurements and shows a high intraclass correlation (ICC = 0.99) between the direct and electronic methods.

Discussion

The use of electronic working length determination has increased considerably in recent years, not only in the permanent (Haffner *et al.* 2005, Plotino *et al.* 2006), but also in the primary dentition (Bodur *et al.* 2008, Ghaemmaghami *et al.* 2008, Leonardo *et al.* 2008, 2009, Tosun *et al.* 2008, Angwaravong & Panitvisai 2009, Mello-Moura *et al.* 2010).

The accuracy of the electronic measurements with the iPex was similar to that reported by other authors using various EALs in primary teeth (Subramanian *et al.* 2005, Leonardo *et al.* 2008, 2009, Tosun *et al.* 2008). The excellent results of these *ex vivo* studies with these instruments have supported their indication for clinical use in children.

In the present study, the results of iPex were an almost perfect correlation (ICC = 0.99) with those of the direct method. In the same way, Leonardo *et al.* (2008) and Leonardo *et al.* (2009) found a high correlation (ICC = 0.99 and 0.95, respectively) between the actual working length measurements and those obtained *ex vivo* with different EALs – Root ZX and Mini Apex (Leonardo *et al.* 2008) and DSP (Leonardo *et al.* 2009) in primary incisors and molars with different stages of physiological root resorption. Using different devices, several studies that evaluated the efficacy of apex locators in primary teeth revealed satisfactory results (Mente *et al.* 2002, Leonardo *et al.* 2008, Tosun *et al.* 2008). A recent study (Nelson-Filho

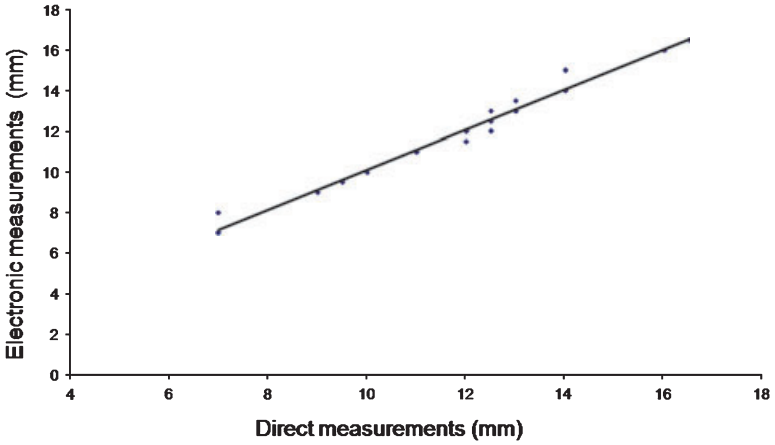

Figure 1 Actual (direct measurement) and electronic (iPex apex locator) root canal length measurements in the primary molar teeth. The intraclass correlation represents the intersection of the two measurements that are indicated on the axes X (direct measurement) and Y (electronic measurement). The dots that coincide with the line represent that the two measurements had the same values. ICC, intraclass correlation coefficient (statistical analyses).

et al. 2010) proposed that the DSP and Propex EALs were able to determine accurately the working length of the root canal in multi-rooted primary teeth, with or without physiological apical resorption.

Conclusion

In this *ex vivo* study, the iPex EAL was able to determine accurately the working length in multi-rooted primary teeth.

References

Angwaravong O, Panitvisai P (2009) Accuracy of an electronic apex locator in primary teeth with root resorption. *International Endodontic Journal* **42**, 115–21.

Bodur H, Odabas M, Tulunoglu O, Tinaz AC (2008) Accuracy of two different apex locators in primary teeth with and without root resorption. *Clinical Oral Investigation* **12**, 137–41.

Coll JA, Sadrian R (1996) Predicting pulpectomy success and its relationship to exfoliation and succedaneous dentition. *Pediatric Dentistry* **18**, 57–63.

Dandashi MB, Nazif MM, Zullo T, Elliott MA, Schneider LG, Czonstkowsky M (1993) An in vitro comparison of three endodontic techniques for primary incisors. *Pediatric Dentistry* **15**, 254–6.

de Vasconcelos BC, do Vale TM, de Menezes AS, Pinheiro-Junior EC, Vivacqua-Gomes N, Bernardes RA, Hungaro Duarte MA (2010) An ex vivo comparison of root canal length determination by three electronic apex locators at positions short of the apical foramen. *Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontics* **110**, e57–61.

Dummer PMH, McGinn JH, Rees DG (1984) The position and topography of the apical canal constriction and apical foramen. *International Endodontic Journal* **17**, 192–8.

ElAyouti A, Weiger R, Lost C (2002) The ability of Root ZX apex locator to reduce the frequency of overestimated radiographic working length. *Journal of Endodontics* **28**, 116–9.

Forsberg J (1987) Radiographic reproduction of endodontic working length comparing the paralleling and the bisecting-angle techniques. *Oral Surgery Oral Medicine Oral Pathology Oral Radiology* **64**, 353–60.

Ghaemmaghami S, Eberle J, Duperon D (2008) Evaluation of the Root ZX apex locator in primary teeth. *Pediatric Dentistry* **30**, 496–8.

Gordon MPJ, Chandler NP (2004) Electronic apex locators. *International Endodontic Journal* **37**, 425–37.

Haffner C, Folwaczny M, Galler K, Hickel R (2005) Accuracy of electronic apex locators in comparison to actual length – an in vivo study. *Journal of Dentistry* **33**, 619–25.

Hoer D, Attin T (2004) The accuracy of electronic working length determination. *International Endodontic Journal* **37**, 125–31.

Holan G, Fuks AB (1993) A comparison of pulpectomies using ZOE and KRI paste in primary molars: a retrospective study. *Pediatric Dentistry* **15**, 403–7.

Ingle JI, Bakland LK (2002) *Endodontics*, 5th edn. London: BC Decker Inc., pp. 510–2.

Keller ME, Brown CE Jr, Newton CW (1991) A clinical evaluation of the Endocater – an electronic apex locator. *Journal of Endodontics* **17**, 271–4.

Kielbassa AM, Muller U, Munz I, Monting JS (2003) Clinical evaluation of the measuring accuracy of Root ZX in primary teeth. *Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontics* **95**, 94–100.

Leonardo MR, da Silva LA, Nelson-Filho P, da Silva RA, Lucisano MP (2009) Ex vivo accuracy of an apex locator using digital signal processing in primary teeth. *Pediatric Dentistry* **31**, 320–2.

Leonardo MR, Silva LA, Nelson-Filho P, Silva RA, Raffaini MS (2008) Ex vivo evaluation of the accuracy of two electronic apex locators during root canal length determination in primary teeth. *International Endodontic Journal* **41**, 317–21.

Mello-Moura AC, Moura-Netto C, Araki AT, Guedes-Pinto AC, Mendes FM (2010) Ex vivo performance of five methods for root canal length determination in primary anterior teeth. *International Endodontic Journal* **43**, 142–7.

Mente J, Seidel J, Buchalla W, Koch MJ (2002) Electronic determination of root canal length in primary teeth with and without root resorption. *International Endodontic Journal* **35**, 447–5.

Nelson-Filho P, Luisano MP, Leonardo MR, Silva RAB, Silva LAB (2010) Electronic working length determination in primary teeth by Propex and Digital Signal Processing. *Australian Endodontic Journal* DOI: 10.1111/j.1747-4477.2009.00185.x

Olson AK, Goerig AC, Cavataio RE, Luciano J (1991) The ability of the radiograph to determine the location of the apical foramen. *International Endodontic Journal* **24**, 28–35.

Plotino G, Grande NM, Brigante L, Lesti B, Somma F (2006) Ex vivo accuracy of three electronic apex locators: Root ZX, Elements Diagnostic Unit and Apex Locator and ProPex. *International Endodontic Journal* **39**, 408–14.

Ricucci D (1998) Apical limit of root canal instrumentation and obturation, part 1: literature review. *International Endodontic Journal* **31**, 384–93.

Subramanian P, Konde S, Mandanna DK (2005) An in vitro comparison of root canal measurement in primary teeth. *Journal of the Indian Society Pedodontics and Preventive Dentistry* **23**, 124–5.

Surmont P, D'Hauwers R, Martens L (1992) Determination of tooth length in endodontics. *Revue Belge de Médecine Dentaire* **47**, 30–8.

Tosun G, Erdemir A, Eldeniz AU, Sermet U, Sener Y (2008) Accuracy of two electronic apex locators in primary teeth with and without apical resorption: a laboratory study. *International Endodontic Journal* **41**, 436–41.