Journal of Dental Sciences (2013) 8, 27—30

Available online at www.sciencedirect.com

SciVerse ScienceDirect

journal homepage: www.e-jds.com

ORIGINAL ARTICLE

Comparing the accuracy of four electronic apex locators for determining the minor diameter: An *ex vivo* study

Hale Cimilli [a]*, Seda Aydemir [a], Nevin Kartal [a], Nicholas Chandler [b]

[a] *Department of Restorative Dentistry and Endodontics, Faculty of Dentistry, Marmara University, Istanbul, Turkey*
[b] *Sir John Walsh Research Institute, School of Dentistry, University of Otago, Dunedin, New Zealand*

Received 25 February 2012; Final revision received 11 May 2012
Available online 26 November 2012

KEYWORDS
apex locator;
major foramen;
minor constriction

Abstract *Background/purpose:* The purpose of this study was to assess the accuracy of the minor apical diameter, as measured by the Root ZX II, Raypex 5, Propex, and ATR EndoPlus electronic apex locators (EALs).
Materials and methods: We selected 40 extracted maxillary incisors and used the locator instruments to measure the distance from the coronal reference point to the file tip at the major diameter. We termed this the reference canal length (RCL). Files were stabilized in position with a flowable composite. We then shaved 4 mm from the apical region and took photographs of the canal termination at 64% magnification to visualize the minor diameter. The minor diameter length (MDL) was then calculated.
Results: Measurements with Raypex 5 (15.22 $\pm$ 1.79 mm), Root ZX II (15.24 $\pm$ 1.73 mm), Propex (15.22 $\pm$ 1.76 mm) and ATR EndoPlus (15.27 $\pm$ 1.78 mm) were significantly smaller than the MDL (15.43 $\pm$ 1.75 mm) ($P < 0.05$). When measurements were evaluated to within $\pm$0.5 mm, the MDL determination was 82.5% acceptable for the Root ZX II and the ATR EndoPlus, and was 85% acceptable for the Raypex 5 and the Propex.
Conclusion: The accuracy of these instruments for detecting the minor diameter is acceptable for clinical practice.

* Corresponding author. Marmara University, Faculty of Dentistry, Department of Restorative Dentistry and Endodontics, Buyukciftlik Sokak, Number 6, 34365 Nisantasi, Istanbul, Turkey.
E-mail address: zhcimilli@gmail.com (H. Cimilli).

http://dx.doi.org/10.1016/j.jds.2012.09.015

Introduction

Determining an appropriate working length is a critical part of successful root canal treatment. Canals are ideally prepared and filled to the apical constriction, which is the narrowest part of the root canal and has the smallest diameter of blood supply and best healing potential.[1] From this point, the canal widens as it exits the root at the apical foramen (i.e., the major apical diameter), which is within the cementum. Microscopy shows that the distance from the minor diameter to the major diameter is within a range of 0.5–1.0 mm.[2]

A working length extended beyond the minor diameter may cause periapical inflammation and overfilling of the root canal system, with the likelihood of postoperative pain and delayed healing. By contrast, a working length that is too short may result in inadequate debridement and underfilling of the root canal. Retained infected tissue may cause postoperative pain and inadequate healing.[3]

The minor diameter cannot be accurately detected radiographically.[4] In a radiographic study, Olson et al[5] found that, when placing files in extracted teeth, only 82% appeared to be at the apical foramen.[5] Radiographs also provide a two-dimensional image of a three-dimensional structure and are technique sensitive in exposure and interpretation.[6] Electronic apex locators were designed in part to overcome the drawbacks of radiographs.[7–10] Studies have assessed the accuracy of electronic apex locators *in vivo*.[11–14]

Krajczar et al compared the accuracy of using an EAL versus using the conventional radiographic method to determine the working length; they reported that measurement by EAL was more accurate.[10] The combined use of radiography and EAL is recommended during root canal preparation; however, limited information is available about their accuracy for determining the minor diameter and radiographic working length.[13] The purpose of this study was to assess the accuracy of four EALs for detecting the minor diameter through an *ex vivo* experiment using the Root ZX II (J. Morita, Irvine, CA, USA), Raypex 5 (VDW, Munich, Germany), Propex (Dentsply Maillefer, Ballaigues, Switzerland) and ATR EndoPlus (ATR, Pistoia, Italy).

Materials and methods

We obtained ethical approval to use 40 extracted maxillary incisors from an existing collection. Digital radiographs were taken from the buccolingual and mesiodistal directions using radiovisiography (Dentaline Dentaray RVG, Istanbul, Turkey) with exposures of 50 kV, 9 mA, for 0.1 s. Roots with resorption, fractures, open apices or invisible canals were excluded. The teeth were stored in 5.25% sodium hypochlorite solution for 2 hours to remove periodontal material. They were then decoronated at the cemento-enamel junction to provide a flat horizontal surface for measurements.

A size 15 K-file (Mani Inc, Tochigi, Japan) with a silicone stop was inserted until its tip was visible at the major foramen using a dental operating microscope at 5× magnification (Global, St. Louis, MO, USA). The stop was adjusted to contact the flat coronal root surface and the file was then removed. We measured the distance from file tip to the stop with callipers (at 5× magnification) to the nearest 0.5 mm. This distance was defined as the reference canal length (RCL). We then embedded the middle third of each root in acrylic (Panacrylic, Inci Dental, Istanbul, Turkey) and covered its apical third with alginate (Cavex, Haarlem, The Netherlands).[15] The canals were irrigated with 2.5% sodium hypochlorite.

We made measurements with four EALs. The first measurement was defined as EAL1. From EAL1, we subtracted 0.5 mm. This distance was labeled EAL2 and was the possible minor diameter length (MDL) for the EAL. The instruments were used in accordance with the manufacturers' instructions and within 2 hours[16] (Table 1).

After the EAL recordings, files were reintroduced to the RCL and fixed in position with flowable composite (Prime-Dent Light Cure Flowable Composite, Chicago, IL, USA). We microscopically determined the minor diameter. The apical 4 mm of the canals were longitudinally shaved away with diamond burs until the outline of the canal was visible under a microscope at 64× magnification (Leica Imaging Systems Ltd, Cambridge, England). A digital photograph was taken (Fig. 1).

On the images of each apex, two investigators determined the minor diameter, the major foramen, and the file tip; the investigators worked together to reach a consensus. We then measured the distance from the minor diameter to the file tip with a computer-based system (Leica Interactive Measurements Dialog, Cambridge, England). This distance was subtracted from the RCL and was defined as the MDL. We then compared EAL2

Table 1 The display conditions on the EAL screens for the position of the major foramen.

Device	Display	
Raypex 5	Middle of the yellow bars	
Root ZX II	"0.0'' reading	
Propex	"0.0'' reading	
ATR EndoPlus	"A'' reading	

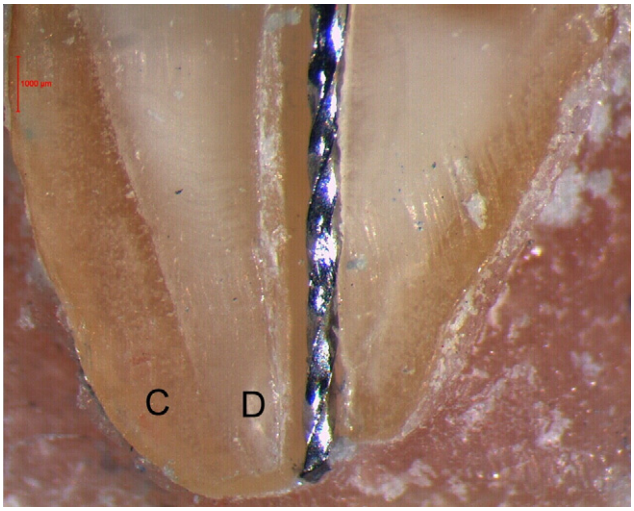

Figure 1 A stereomicroscopic view of 4 mm of the root apex. The file tip is at the major foramen. The letter "C" denotes the cementum and the letter "D" denotes the dentine.

measurement with the MDL. Data were analyzed using the SPSS 11.5 program (SPSS Inc, Chicago, IL). We compared the results of the four apex locators and the MDL and RCL for each tooth by using a paired *t*-test. A P value $\leq$0.05 was accepted as statistically significant.

Results

Raypex 5 measurements of EAL2 (15.22 $\pm$ 1.79 mm), Root ZX II (15.24 $\pm$ 1.73 mm), Propex (15.22 $\pm$ 1.76 mm), and ATR EndoPlus (15.27 $\pm$ 1.78 mm) were significantly less than the MDL (15.43 $\pm$ 1.75), as evaluated by microscopy (P = 0.001, P = 0.002, P = 0.001, and P = 0.013, respectively) (Table 2). As we predicted, there was a significant difference between the RCL (15.75 $\pm$ 1.74 mm) and the MDL (P = 0.000) (Table 2). When we evaluated measurements within $\pm$0.5 mm, we found the MDL measurement was 82.5% accurate for the Root ZX II and ATR EndoPlus, and 85% for Raypex 5 and Propex, according to EAL2. Raypex 5 measurements of EAL1 (15.72 $\pm$ 1.79 mm), Root ZX II (15.74 $\pm$ 1.73 mm), Propex (15.72 $\pm$ 1.76 mm), and ATR EndoPlus (15.77 $\pm$ 1.78 mm) were almost the same as the measurements for the RCL (P = 0.226, P = 0.401, P = 0.160, and P = 0.160, respectively) (Table 2).

Table 2 Root length measurements, based on EALs and microscopic measurements.

Devices	EAL1 (mm)	EAL2 (mm)
	Mean $\pm$ SD	Mean $\pm$ SD
Raypex 5	15.72 $\pm$ 1.79	15.22 $\pm$ 1.79
Root ZX II	15.74 $\pm$ 1.73	15.24 $\pm$ 1.73
Propex	15.72 $\pm$ 1.76	15.22 $\pm$ 1.76
ATR EndoPlus	15.77 $\pm$ 1.78	15.27 $\pm$ 1.78
Microscope measurements		
Reference canal length[a,b]	15.75 $\pm$ 1.74	—
Minor diameter length*	—	15.43 $\pm$ 1.75

EAL = electronic apex locator; MDL = minor diameter length; RCL = reference canal length; SD = standard deviation.
*MDL-Raypex EAL2, P = 0.001; MDL-Root ZX II EAL2, P = 0.002; MDL-Propex EAL2, P = 0.001; MDL-ATR EndoPlus EAL2, P = 0.013.
[a] RCL-Raypex EAL1, P = 0.226; RCL-Root ZX II EAL1, P = 0.401; RCL-Propex EAL1, P = 0.160; RCL-ATR EndoPlus EAL1, P = 0.160.
[b] RCL-MDL*, P = 0.000.

Discussion

Studies of the accuracy of EALs differ in determining the apical termination position. Some authors measure to the minor diameter,[11,17] but other authors measure to the major foramen.[16,18–21] In our study, we aimed to determine the major and the minor diameters. For the devices in this study, there were no significant differences between the RCL and the measurements of EAL1. However, there were significant differences between the MDL and the EAL2 measurements for all devices. All EALs can determine the RCL, but EALs cannot measure the MDL. However, these differences are not significant in clinical applications.

The aim of root canal treatment is to shape and fill the canal to its minor diameter. A study by Plotino et al.[17] calculated the accuracy of electronic measurements as 100% for Propex and 97.37% for Root ZX (within $\pm$0.5 mm), using 4.5$\times$ magnification. The apical constriction was their landmark. Wrbas et al.[11] report that the Root ZX located the minor diameter with 75% reliability and the Raypex 5 located the minor diameter 80% of the time (within $\pm$0.5 mm) under 36$\times$ magnification *in vivo*. Other studies investigating the reliability of EALs found the Root ZX II was 97.44% accurate within $\pm$0.5 mm[18] and the Root ZX was 84% accurate.[13] In our study, the Root ZX II was able to detect the minor diameter within $\pm$0.5 mm with an 82.5% degree of accuracy. The Raypex 5 and Propex reached an 85% level of accuracy. These percentages are considered acceptable for clinical practice and are in accordance with findings from previous studies; however, significant differences were observed between the measurements of the EAL2 and MDL. Measurements within the $\pm$0.5-mm limit were acceptable in clinical practice.

According to anatomical studies the minor diameter is located 0.5–1 mm short of the major foramen.[2] Investigators have therefore subtracted 0.5 mm from the measurement at the major foramen and used this for their EAL studies. They define this measurement as the actual canal length.[11,17–19,22–25] However, this distance may vary because of anatomical or pathological variation. We used maxillary incisors with straight and wide canals in our study to reduce problems presented by more complicated canal anatomy and, to simulate periapical conditions, we immersed the apices in alginate when taking the electronic measurements.[15,26]

The presence of electrolytes, differences in canal diameter, technical differences between microscopes, and variation among EALs are important factors in this type of research.[18,19,22–25,27] Fan et al found that electrolytes in glass tubules and an increase of tubule diameter could

decrease the accuracy of apex locators.[23] In that study, the Root ZX was 91.7% accurate and Propex in dry tubules was 100% accurate. The accuracy of Propex decreased with large glass tubule diameters and in the presence of electrolytes, whereas the Root ZX remained accurate. Venturi and Breschi reported that the diameter of the apices affected the accuracy of EALs and that the Root ZX could be inaccurate or unstable in a low conductive situation.[19]

Measurements with electronic apex locators may be inaccurate in the presence of a wide apical foramen and a small size file.[24,28] Herrera et al found that the Root ZX measurements were more accurate when the foramen was 0.25 mm than when the foramen was between 0.45 and 0.70 mm.[24] For this reason, we used in our study teeth with a small diameter in which 15 files could pass through the foramen for standardization.

Our study used a 2.5% sodium hypochlorite solution to simulate clinical conditions. There is agreement in the literature that irrigating solutions have little influence on the accuracy of modern EALs.[22,23,27] Ozsezer et al evaluated the performance of the Propex in different irrigation solutions *in vivo* by using 2.5% NaOCl, 0.9% NaCl, and 0.2% chlorhexidine gluconate solutions.[12] They reported that the chlorhexidine group gave the most accurate results and saline gave the worst.

Within the limits of this study, all four electronic apex locators—the Root ZX II, Raypex 5, Propex, and ATR EndoPlus—were able to determine the minor diameter within $\pm$0.5 mm with at least 82.5% accuracy. All four EALs are therefore likely to provide clinically acceptable measurements. The ATR EndoPlus is moreover a new instrument that has yet to be described in the literature. Our accuracy data (82.5% at $\pm$0.5 mm) presents new information and suggests that it is a valuable clinical device.

Acknowledgments

This study was supported by Marmara University Scientific Research Projects Committee, SAG-D-010710-0218.

References

1. Ricucci D, Langeland K. Apical limit of root canal instrumentation and obturation, part 2. A histological study. *Int Endod J* 1998;31:394—409.
2. Kuttler Y. Microscopic investigation of root apexes. *J Am Dent Assoc* 1955;50:544—52.
3. Ingle JI, Bakland LK, Peters DL, Buchanan S, Mullaney TP. Endodontic cavity preparation. In: Ingle JI, Bakland LK, eds. *Endodontics*, 4th ed. Baltimore, MD: Williams & Wilkins, 1994: 92—227.
4. Stein TJ, Corcoran JF. Radiographic "working length" revisited. *Oral Surg Oral Med Oral Pathol* 1992;74:796—800.
5. Olson AK, Goerig AC, Cavataio RE, Luciano J. The ability of the radiograph to determine the location of the apical foramen. *Int Endod J* 1991;24:28—35.
6. Cox VS, Brown Jr CE, Bricker SL, Newton CV. Radiographic interpretation of endodontic file length. *Oral Surg Oral Med Oral Pathol* 1991;72:340—4.
7. Suzuki K. Experimental study on iontophoresis. *Jap J Stomatol* 1942;16:4—11.
8. Sunada I. New method for measuring the length of the root canal. *J Dent Res* 1962;41:375—87.
9. Hoer D, Attin T. The accuracy of electronic working length determination. *Int Endod J* 2004;37:125—31.
10. Krajczar K, Marada G, Gyulai G, Toth V. Comparison of radiographic and electronical working length determination on palatal and mesio-buccal root canals of extracted upper molars. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2008;106:e90—3.
11. Wrbas KT, Ziegler AA, Altenburger MJ, Schirrmeister JF. *In vivo* comparison of working length determination with two apex locators. *Int Endod J* 2007;40:133—8.
12. Ozsezer E, Inan U, Aydýn U. *In vivo* evaluation of Propex electronic apex locator. *J Endod* 2007;33:974—7.
13. Kim E, Marmo M, Lee CY, Oh NS, Kim IK. An *in vivo* comparison of working length determination by only Root-ZX apex locator versus combining Root-ZX apex locator with radiographs using a new impression technique. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2008;105:e79—83.
14. Welk AR, Baumgartner JC, Marshall JG. An *in vivo* comparison of two frequency based electronic apex locators. *J Endod* 2008;29:497—500.
15. Tinaz AC, Alacam T, Topuz O. A simple model to demonstrate the electronic apex locator. *Int Endod J* 2002;35:940—5.
16. Lucena-Martin C, Robles-Gijon V, Ferrer-Luque CM, Navajas Rodriguez de Mondelo JM. *In vitro* evaluation of the accuracy of three apex locators. *J Endod* 2004;30:231—3.
17. Plotino G, Grande NM, Brigante L, Lesti B, Soma F. *Ex vivo* accuracy of three electronic apex locators: Root ZX, elements diagnostic unit and apex locator and Propex. *Int Endod J* 2006; 39:408—14.
18. D'Assunçao FL, de Albuquerque DS, Salazar-Silva JR, de Queiroz Ferreira LC, Bezerra PM. The accuracy of root canal measurements using the Mini Apex Locator and Root ZXII: an evaluation *in vitro*. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2007;104:e50—3.
19. Venturi M, Breschi L. A comparison between two electronic apex locators: an *ex vivo* investigation. *Int Endod J* 2007;40: 362—73.
20. Thomas AS, Hartwell GR, Moon PC. The accuracy of the Root ZX electronic apex locator using stainless-steel and nickel titanium files. *J Endod* 2003;29:662—3.
21. Bernardes RA, Duarte MAH, Vasconcelos BC, et al. Evaluation of precision of length determination with 3 electronic apex locators: Root ZX, Elements Diagnostic Unit and Apex Locator, and RomiAPEX D-30. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2007;104:e91—4.
22. Kaufman AY, Keila S, Yoshpe M. Accuracy a new apex locator: an *in vitro* study. *Int Endod J* 2002;35:186—92.
23. Fan W, Fan B, Gutmann JL, Bian Z, Fam MW. Evaluation of the accuracy of three electronic apex locators using glass tubules. *Int Endod J* 2006;39:127—35.
24. Herrera M, Abalos C, Planas AJ, Llamas R. Influence of apical constriction diameter on Root ZX apex locator precision. *J Endod* 2007;33:995—7.
25. Vatkar N, Suathe S, Hegde V. *In vitro* evaluation of the efficacy of five apex locators. *Endodontology* 2008;20:36—42.
26. Campbell D, Friedman S, Nguyen HQ, Kaufman A, Keila S. Apical extent of rotary canal instrumentation with an apex locating handpiece *in vitro*. *Oral Surg Oral Med Oral Pathol* 1998;85:319—24.
27. Kang JA, Kim SK. Accuracies of seven different apex locators under various conditions. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2008;106:e57—62.
28. Ebrahim AK, Wadachi R, Suda H. *Ex vivo* evaluation of the ability of four different apex locators to determine the working length in teeth with various foramen diameters. *Aust Dent J* 2006;51:258—62.