The Ability of Two Apex Locators to Locate the Apical Foramen: An In Vitro Study

Fábio Luiz Cunha D´Assunção, DDS, MD, Diana Santana de Albuquerque, DDS, MD, PhD, and Linalda Correia de Queiroz Ferreira, DDS

Abstract

The objective of this study was to compare the accuracy of the Root-ZX and Novapex electronic apex locators (EALs) in locating the apical foramen. Forty extracted human teeth were used. The coronal portion of each canal was flared using Gates Glidden drill. Canals were irrigated with 2.5% sodium hypochlorite. The actual length (AL) and electronic length (EL) measurements were made on each specimen separately with both devices with an aid of a K-type file. The results obtained with each EAL were compared with the corresponding control length. The statistical analysis of the results showed EAL reliability in detecting the apical foramen to 89.7% for the Root-ZX and 82.1% for the Novapex, taking the tolerance of ±0.5 mm into account. A paired sample *t* test showed that there was no statistically significant difference between the accuracy of the devices ($p = 0.4305$). The results of this study indicate that the Root-ZX and Novapex are useful and accurate devices for the apical foramen location. *(J Endod 2006; 32:560–562)*

Key Words

Electronic apex locators, ROOT-ZX, working length

From the Centro Odontológico de Estudos e Pesquisa (COESP)—Endodontics—João Pessoa—Paraíba—Brazil.

Address requests for reprints to Fábio Luiz Cunha D'Assunção, Av. Esperança 1194—Manaíra—João Pessoa Paraíba Brazil—58038281. E-mail address: fabioendo@click21.com.br.

0099-2399/$0 - see front matter

doi:10.1016/j.joen.2005.11.011

Correct working length determination is the main factor leading to success in root canal treatments. Studies have shown the histological results after endodontic treatment to be superior when instrumentation and root filling are limited to the apical narrowing. Therefore, accurate determination of the location of the apical constriction is a key factor in successful root canal therapy (1).

The ideal apical endpoint of endodontic instrumentation and obturation has been determined to be the cemento-dentinal junction. However, it is variable. On average, it occurs 0.50 to 0.75 mm coronal to the apical foramen (2). Although the apical foramen occurs 0.5-mm coronal to the anatomic apex (2), the CDJ may be as far as 2.0 mm from the apical foramen (3). Using these averages, most operators attempt to terminate instrumentation ~1 mm short of the radiographic apex. This technique is accurate and reliable in most situations. In those teeth in which the foramen is not positioned at the average distance from the radiographic apex yet, the canal will be either over or under instrumented. Furthermore, radiographic interpretation of the apices of some teeth (e.g. maxillary molars) may be so difficult that radiographic working length determination is not simple (4).

Electronic apex locators (EAL) are widely used in endodontics to determine the root length during root canal treatment. Introduced by Sunada (5) in 1962, the EAL has become an invaluable tool in modern endodontic practice. These devices, when attached to a file, are able to detect the point at which the file leaves the root canal and enters the periodontal ligament. Early electronic apex locators are relied on the principle that the electrical resistance between the oral mucous membranes and the periodontal ligament remained constantly 6.5 KΩ, regardless of the age of the patient and the type and shape of the tooth. Second-generation electronic apex locators measure impedance, which is a complex function of inductance and capacitance found in any alternating current and is considered generalized resistance (6).

In his study, Huang (7) concludes that when the tip of one file passes through the narrow apical foramen, the physical properties of the foramen produce the electrical resistance gradient. This resistance gradient is not caused by the biological characteristics of the periodontal ligament as it was discussed by Sunada (5). The latest generation of apex locators has many advantages when compared to earlier devices. Unfortunately, many devices are inaccurate in root canals that contain moisture, vital pulp tissue, blood, and other exudates (8).

Kobayashi and Suda (9) have developed an EAL, the Root-ZX (J. Morita CO., Tustin, CA) that is based on the ratio method for measuring canal length. This method 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.

Recently, a new EAL has been developed, the Novapex (Forum Technologies, Rishon Le-zion, Israel), which utilizes voltage difference and operates on the principle that impedance measurement not only differs between two electrodes, depending on the frequencies used, but also differs greatly at an apical constriction region (10). There is lack of literature information about the accuracy of Novapex in determining the correct electronic working length.

Given this, the purpose of the present study was to conduct an in vitro evaluation to compare the accuracy in detecting the apical foramen of two electronic apex locators (EALs): the Root-ZX and Novapex.

Materials and Methods

The research involved 40, extracted, single-rooted, human teeth with mature apices. The teeth were soaked in 2.5% sodium hypochlorite for 6 h and then stored in sterile 0.9% saline until used. The crown was sectioned with diamond disc to allow access to the root canal and establish a level surface to serve as a stable reference for all measurements. Gates Glidden burs #5 and 6 were used to flare the coronal one-third of each canal. Canals were irrigated with sterile saline during the access and flaring, and the patency of the apical foramen was verified using a #20 Flexofile. One cervical plane was prepared with a diamond bur to serve as a fixed coronal reference point for all the measurements.

Electronic measurement was achieved using the Novapex and Root-ZX. The teeth were placed in contact with a conductive gel to simulate the periodontium. This gel consisted of alginate. The teeth were kept in position until the alginate had set completely. All measurements were made in an interval of 2 h, with the gel kept sufficiently humid for this time. Measurements were taken after 2-ml irrigation with 2.5% sodium hypochlorite (Biodinâmica, Brazil) into the root canals. Cotton tips were used to dry the tooth surface and eliminate the excess irrigating solution. The electronic and actual lengths were measured by only one boarded endodontist with experience in the use of electronic apex locators, using the size 20 Flexofile (Dentsply, Maillefer) according to the manufacturer's instructions (Novapex Owner's Manual) (10). When the signal reached the '0.0' mark (apical foramen), the measurements were noted. For the Root-ZX the same Flexofile was placed in the canal while attached to the appropriate electrode of Root-ZX apex locator. The other electrode (lip clip) was attached to the conductive gel. The apex locator was operated according to the manufacturer's instructions (11). The termination point used in this study was the red line on the meter designated by the manufacturer as the APEX.

The silicone stop of the instrument was then moved, the file was removed from the canal and measured with a caliper and its length registered as the electronic length (EL).

The actual root canal length (AL) is the distance from the coronal reference plane to the apical foramen. It was measured by inserting a #20 file into the root canal until the file tip was just visible at the level of the apical foramen. This procedure was done under a magnifying glass at a magnification of 5×. After adjusting the silicone stopper to the coronal reference, the file was removed from the root canal, and the distance between the file tip and the stopper representing the actual root canal length was measured to the nearest tenth of a millimeter.

The results obtained (in millimeters) for each EAL were recorded in independent tables. In each case, we subtracted the corresponding reference measurement (i.e. actual length) from the electronically determined distance, recording the result in tabular form as positive form (measurements exceeding the apical foramen), negative (measurements short of the apical foramen), or correct (measurement coinciding with the actual length) with a ±0.5 mm acceptable range. Paired *t* test was used to statistically analyze the significance of the mean differences between EL and AL at 5% confidence level.

Results

One tooth was missed during specimen preparation because the apex formation was incomplete, leaving 39 teeth for analysis. Each tooth served as its own control. Thus, 39 measurements for each EAL were obtained. Statistical results showed no significant difference between Root-ZX and Novapex in their ability to accurately identify the apical foramen. Concerning locating the apical foramen, Root-ZX was accurate 89.7% of the time to ±0.5 mm, whereas Novapex was accurate 82.1% of the time to ±0.5 mm from the apical foramen (Table 1). Statistical analysis showed no significant differences between the two apex locators tested ($p = 0.4305$).

TABLE 1. Position of the file tip relative to the apical foramen as determined by the Root-ZX and the Novapex

Distance from Apical Foramen (mm)	Root-ZX (n = 39)	%	Novapex (n = 39)	%
<−0.5	1	(2.6%)	2	(5.1%)
−0.5 to 0.5*	35	(89.7%)	32	(82.1%)
>0.5	3	(7.7%)	5	(12.8%)

*negative value indicates file position coronal to the apical foramen.

Discussion

The main purpose of this study was to evaluate the accuracy of one EAL most widely used in clinical practice the Root-ZX, and a new brand apex locator the Novapex. An in vitro study was developed in view of the difficulties posed by clinical studies in comparing electronic measurements with a control (12).

Numerous studies have reported on the accuracy of EALs in determining the location of the minor diameter (13, 14, 17). These studies differ in establishing the reference point from which measurement accuracy is determined: some authors measured from the minor diameter, while others measured from the major diameter or apical foramen. In vitro studies have shown the Root-ZX to be 62.7 to 68% accurate to within ±0.5 mm (18).

Several in vitro researches have assessed the accuracy of the Root-ZX (J. Morita Corp., Tokyo, Japan). A study carried out by Shabahang et al. (17) produced values to a precision of 96.2%. Lucena-Martin et al. (12) showed that it gave a precise measure in 85% of the cases. The results of our study are in general agreement with previously reported results. It was not possible to compare Novapex with other existent studies because of the lack of research on this device. However, Goldberg et al. (22), through an in vitro study, evaluated the accuracy of three apex locators in determining working length during the retreatment process. The authors evaluated the ProPex, Novapex, and Root-ZX and they had as results 80, 85, and 95% of accuracy, respectively, for the three devices. No significant differences were detected between the three apex locators, ($p > 0.05$) demonstrating that the electronic apex locators tested have similar accuracy in the retreatment process.

In our research only one operator carried out the electronic and actual working lengths. As it can be seen in other studies, if the locators are used according to the instructions of the manufacturer, no previous experience with these devices is essential to obtain correct measurements. In addition, the important interobserver concordance suggests that electronic root canal measurement is an objective and acceptably reproducible technique (12, 15).

Ibarrola et al. (16) suggested that preflaring root canals before using the Root-ZX led to an increased accuracy of the electronic apex locator. For this reason, the canals were carefully preflared with Gates Glidden in the present study. A literature search revealed no in vitro studies evaluating the accuracy of the Novapex EAL. In this research the '0.0' mark in the Novapex and Root-ZX displays was used as an apical endpoint.

Several studies have demonstrated that EALs can accurately determine the working length in between 75 to 96.5% of the root canals with mature apices (17, 18). The best results have been reached with the latest generation devices, such as Root-ZX (17, 19). Dunlap et al. (20)

reported that 82% of electronic values recorded with the Root-ZX model were accurate to ±0.5 mm of the apical constriction when 2.5% NAOCL was used.

The apical limit used was the apical foramen. The measurements with Root-ZX and Novapex were, respectively, 89.7% and 82.1% from the apical foramen. It is important to point out that although the electronic measures have been in the average of other studies, in three opportunities for Root-ZX and in five for Novapex, the file tips surpassed the apical foramen and this situation can lead to imprecise measures. According to Lee et al. (21) more important than where to read is the question of how the measurements can be consistently reproduced. If the device indication is consistent, if we know where we are, and if we know the average distance between the file tip and the true CDJ, then we can obtain an accurate length, by subtracting the average distance from the device reading. The authors encountered measurements were 97% for the apical foramen and they showed that measurements from the major foramen were more consistent than from the CDJ. Shabahang et al. (17) showed that the Root-ZX was able to locate the foramen within a range of ±0.5 mm in 96.2%.

In this laboratory study, there were no statistically significant differences related between the two devices. Consequently, the Root-ZX and the Novapex were able to determine the position of the apical foramen accurately. Last but not least, the latest generation of apex locators provides an accurate and useful adjunct for the determination of the root canal length.

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. Green D. A stereomicroscopic study of 700 root apices of maxillary and mandibular posterior teeth. Oral Surg 1960;13:728–33.
4. Tamse A, Kaffe I, Fishel D. Zygomatic arch interference with correct radiographic diagnosis in maxillary molar endodontics. Oral Surg 1980;50:563–5.
5. Sunada I. New method for measuring the length of the root canal. J Dent Res 1962;41:375–87.
6. Mears WA, Steiman HR. The influence of sodium hipochlorite irrigation on the accuracy of the Root ZX electronic apex locator. J Endod 2002;28:595–8.
7. Huang L. An experimental study of the principle of electronic root canal measurement. J Endod 1987;13:60–4.
8. Oishi A, Yoshioka T, Kobayashi C, Suda H. Electronic detection of root canal constrictions. J Endod 2002;28:361–4.
9. Kobayashi C, Suda H. New electronic canal measuring device based on the ratio method. J Endod 1994;20:111–4.
10. Forum technologies. Novapex Sales Manual, 2003.
11. J. Morita Corp. Fully automatic root canal measuring device. Root ZX operation instructions. Tustin CA. 2004:4–7.
12. Lucena-Martín C, Robles-Gijón V, Ferrer-Luque CM, Mondelo JMM. In vitro evaluation of the accuracy of three electronic apex locators. J Endod 2004;30:231–3.
13. Tselnik M, Baumgartner JC, Marshall JG. An evaluation of Root ZX and Elements Diagnostic apex locators. J Endod 2005;31:507–9.
14. Welk AR, Baumgartner JC, Marshall JG. An in vivo comparison of two frequency-based electronic apex locators. J Endod 2003;29:497–500.
15. Tinaz AC, Madem M, Aydin C, Türköz CA. The accuracy of three different electronic root canal measuring devices: an *in vitro* evaluation. J Oral Sci 2002;44:91–5.
16. Ibarrola JL, Chapman BL, Howard JH, Knowles KI, Ludlow MO. Effect of pre-flaring on Root ZX apex locators. J Endod 1999;25:625–6.
17. Shabahang S, Goon WWY, Gluskin AH. An in vivo evaluation of Root ZX electronic apex locator. J Endod 1996;22:616–8.
18. Goldberg F, de Sílvio AC, Mantré S, Nastri N. In vitro measurement accuracy of an electronic apex locator in teeth with simulated apical root resorption. J Endod 2002;28:461–3.
19. Goldberg F. Evaluación Clínica del Root ZX em determinación de la conductometria. Rev Asoc Odontol Arg 1995;83:180–2.
20. Dunlap CA, Remeikis NA, BeGole EA, Rauschenberger CR. An in vivo evaluation of an electronic apex locator that uses the ratio method in vital and necrotic canals. J Endod 1998;24:48–50.
21. Lee SJ, Nam KC, Kim YJ, Kim DW. Clinical Accuracy of a new apex locator with an automatic compensation circuit. J Endod 2002;28:706–9.
22. Goldberg F, Marroquín BB, Frajlich S, Dreyer C. In vitro evaluation of the ability of three apex locators to determine the working length during retreatment. J Endod 2005;31:676–8.