ORIGINAL ARTICLE

In vitro comparison of four different electronic apex locators to determine the major foramen using the clearing technique

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Abstract

Objectives: The aim of this study was to evaluate the accuracy of four electronic apex locators (EALs) (DentaPort ZX, Raypex 5, Endo Master and VDW Gold) in detecting the major foramen using the clearing technique.
Materials and Methods: Forty-eight extracted single-rooted extracted teeth with mature apices were used for the study and divided into four groups of 12 teeth each. All teeth were embedded in an alginate model. Electronic measurements were taken using a size 15 K-file attached to the holder. Then, the teeth were cleared and photographed under a stereomicroscope with a digital camera. The distance between the tip of the file and the major foramen was measured by using an image analysis software program. Positive and negative values were recorded when the file tip was beyond or short of the major foramen and zero value when the file tip and the major foramen coincided. Statistical analysis was performed using the Kruskal-Wallis and Chi-square tests at a significance level of 0.05.
Results: Mean distance from the file tip to the major foramen were 0.302 ± 0.202, 0.065 ± 0.293, 0.117 ± 0.475, and 0.258 ± 0.160 mm in the DentaPort ZX, Raype 5, Endo Master, and VDW Gold groups, respectively. There were no statistically significant differences among the devices ($P > 0.05$).
Conclusion: Under the experimental conditions, all EALs showed an acceptable determination of the major foramen.

Key words: Clearing technique, electronic apex locator, major foramen

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Introduction

Accurate determination of working length (WL) is one of the most important steps for successful root canal treatment.[1,2] Short WL measurements, especially in cases of infected necrotic pulps and chronic apical periodontitis, leads to significantly lower success rates compared cases where an accurate WL was achieved.[3] Furthermore, a WL established beyond the apical constriction (AC) may cause apical perforation and overfilling. This may increase postoperative pain and delay or prevent healing.[4] Cementodentinal junction, that is also described as the AC, is the narrowest part of the root canal and recommended end-point for instrumentation and filling.[5] It is located about 0.5-1 mm from the major foramen.[6] The foramen does not always located at the anatomical apex of the tooth. It may be located to one side and at distances of up to 3 mm the anatomical apex.[6,7] For this reason, it is difficult to localize the major foramen and the AC using a radiological approach.[8] Thus, in addition to radiographic measurement, electronic WL determination has become increasingly important.[2]

The development and production of electronic apex locators (EALs) for locating the canal terminus have been

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major innovations in the field of endodontics. Custer[9] was the first to introduce an electrical method of locating the apical foramen. Suzuki[10] discovered that electrical resistance between the periodontal ligament and oral mucosa has a constant value of 6.5 kΩ; this led to the development by Sunada[11] of the first EAL. First and second generations of EALs used a single direct or a single frequency alternating current as the measuring signal. However, these devices provided inaccurate measurements as a result of presence electrically conductive materials in the root canal. Modern EALs determine the WL by measuring impedance with two or more different frequencies and they can work in the presence of an electrolyte.[12] These devices eliminate many of the problems related to radiographic measurements. Their most important advantage over radiography is that they can measure the length of the root canal to the end of the apical foramen, not to the radiographic apex.[13]

Different generations of EALs have been introduced in the market to locate the root apex for measuring the WL such as the DentaPort ZX (Morita, Tokyo, Japan) [Figure 1]. It is a third generation combined device, locate the position of the WL by simultaneous measurement of impedances values in the same canal using two different frequencies (8 and 0.4 kHz).[13] This EAL is based on the same principle as the original Root ZX, which has been investigated in many studies.[14-16] Raypex 5 (VDW, Munich, Germany) is a fourth generation device [Figure 1]. It measures the impedances with the same frequencies (8 and 0.4 kHz) as the DentaPort ZX, but its measurements are based on the root mean square values of the signals.[17] Endo Master (EMS, Nyon, Switzerland) is a combined device with fourth generation apex locator, simultaneously calculates the impedance of three different frequencies (100 Hz, 385 Hz and 8.3 kHz) [Figure 1]. VDW Gold (VDW) is another endomotor with integrated an apex locator, which uses two frequencies, 5.5 kHz and 500 Hz. The EAL reference scale is represented by the row of eight leds of various colors [Figure 1].

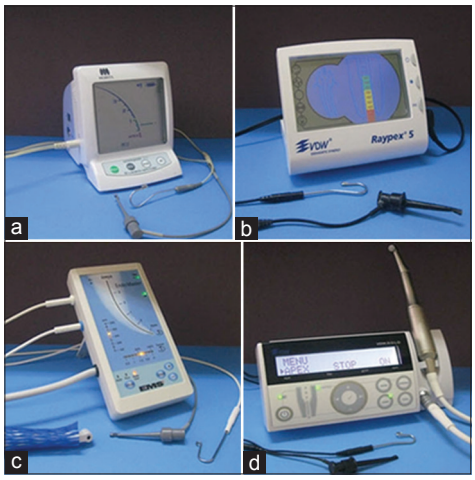

Figure 1: Electronic apex locators tested; (a) DentaPort ZX, (b) Raypex 5, (c) Endo Master, (d) VDW Gold

The purpose of this *in vitro* study was to assess the accuracy of the DentaPort ZX, Raypex 5, Endo Master and VDW Gold in establishing the major foramen using the clearing technique.

Materials and Methods

A total of 48 human single-rooted extracted teeth for unknown reasons were used in this study. Roots with calcification, resorption and open apices were excluded and one apical foramen and mature apices were selected. After extraction, external root surfaces were carefully cleaned of organic residues and all the teeth were stored in a saline solution until required. Crowns of the teeth were removed at the cementoenamel junction with a diamond disc to simplify access to root canal and length measurements. The canal orifices were flared with gates glidden burs (Dentsply Maillefer, Ballaigues, Switzerland). Each root canal was irrigated using 2.5% sodium hypochlorite (NaOCl) solution during the process and a size 10 K-file (Dentsply Maillefer) was used to check the canal patency.

The teeth were randomly divided into four groups of 12 teeth each and then they were placed in the plastic containers that were filled with enough alginate to embed into least half of the roots. DentaPort ZX, Raypex 5, Endo Master and VDW Gold EALs were used according to the manufacturer's instructions for detecting the major foramen. Firstly, root canals were irrigated with 2.5% NaOCl and the tooth surface was gently dried with a cotton pellet. For detecting major foramen, size 15 K-files connected to the EALs were used in all measurements. With the DentaPort ZX, the file was stabilized within the canal when the file was advanced into the canal to just beyond the foramen and withdrawn until the "APEX" bar. With the Raypex 5, the file was advanced to just beyond foramen, and withdrawn until the red bar began flashing. With the Endo Master, the file was advanced until the last red led and withdrawn until the "APEX" led had been reached. With the VDW Gold, the file was advanced until the red led and then withdrawn until the orange led were reached. Then, the files were stabilized within the canals a flow resin composite in all groups.

For clearing the teeth, the specimens were demineralized for 72 h in 5% nitric acid solution at room temperature and the acid was changed daily. They were rinsed in running tap water for 4 h, dehydrated in ascending concentrations of ethanol (80%, 96%, and 100%) for 24 h each and then immersed in methyl salicylate until they became clear. After completion of clearing, the root apexes of the transparent teeth were photographed in a stereomicroscope with a digital camera at × 3 magnification.

The distance between the tip of the file and the major foramen was measured by using an image analysis software program (Image J 1.42q; National Institutes of Health,

Bethesda, Maryland, USA). Positive values were recorded when the file tip was beyond the major foramen [Figure 2a], negative values were recorded when the file tip short of the major foramen and zero values were recorded when the file tip completely at the major foramen [Figure 2b].

Statistical evaluation was performed using SPSS 13.0 (SPSS Inc., Chicago, IL, USA). Differences between the measurements of the groups were analyzed statistically by using the Kruskal-Wallis and Chi-square test. The significance was defined as $P < 0.05$.

Results

Mean distances from the tip of the file to the major foramen and standard deviations for each EAL are shown in Table 1. Table 2 shows that the percentage values of electronic measurements. Within the range of ±0.5 mm, the accuracies were 91.7% for the DentaPort ZX, Raypex 5 and VDW Gold and 75% for the Endo Master groups. The major foramen was detected exactly 25% of the times for the DentaPort ZX, Raypex 5, Endo Master and 16.7% for the VDW Gold. Furthermore, no significant statistical differences were found between the four devices ($P > 0.05$).

Discussion

Electronic apex locators s have been used clinically to determine the apical limit of the instrumentation for more than 50 years. Many studies[12,18-21] evaluated the accuracy of these devices *in vitro* or *in vivo*. Extracted teeth are immersed into electroconductive materials such as agar-agar, alginate, gelatin or a saline solution for testing of apex locators *in vitro*[19,22-24] The alginate model was used to simulate the periodontium in this study. Because, alginate remains around the root, simulates the periodontal ligament with its colloidal consistency and presents a suitable electroconductive property. Furthermore, the easy achievement and preparation, combined with its low cost, make it the medium of choice for use in *ex vivo* evaluations on apex locators.[25] Coronal flaring of the canals before the WL determination with EALs increase the accuracy of the EALs;[14,20] thus, in this study, the canal orifices were flared before measurements.

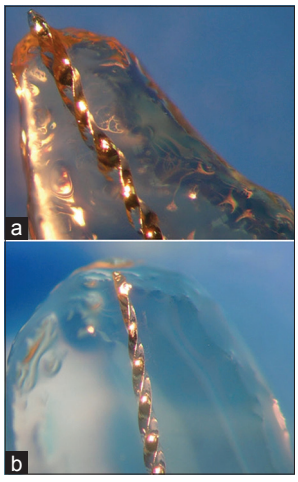

Figure 2: (a) File tip was beyond the major foramen, (b) file tip and major foramen coincided

Studies[15,17,18] were previously researched the precision of EALs in detecting the major foramen or the AC to WL determination. However, the foramen was more reproducible reference point than the AC for accuracy studies.[26] Mayeda *et al.*,[27] had previously concluded that EALs are only capable of detecting the major foramen. For this reason, the major foramen was considered as the reference point to assess the devices in this study. Different error ranges have been used to test the accuracy of the EALs.[15,17] This study's measurements were attained in a target interval of ±0.5 mm to the major foramen. Because this clinical tolerance of ±0.5 mm is considered to be the strictest acceptable and measurements within this minimal tolerance are highly accurate.[28]

Our findings showed that the mean distance between the file tip and the major foramen was 0.302 mm for the Denta Port ZX and 0.065 mm for the Raypex 5. The accuracies were 91.7% for the DentaPort ZX and Raypex 5 within the range of ±0.5 mm. There were no statistically significant differences between the devices. In a previous study of Shabahang *et al.*,[29] had reported that Root ZX located the apical foramen in 96.2% of cases within ±0.5 mm. Pagavino *et al.*,[15] have

Table 1: Mean distances from the tip of the file to the major foramen (mm)

Groups	Mean	SD
Raypex 5	0.065*	0.293
DentaPort ZX	0.302*	0.202
Endo Master	0.117*	0.475
VDW Gold	0.258*	0.160

KW=5.15; P=0.161; P>0.05. *Positive values indicate measurements beyond of the major foramen. SD=Standard deviation

Table 2: Frequency of the distance between the file tip and the major foramen

Distance from major foramen (mm)*	*n* (%)			
	DentaPort ZX	Raypex 5	Endo Master	VDW Gold
>1	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
1.0-0.51	1 (8.3)	0 (0.0)	2 (16.7)	1 (8.3)
0.5-0.01	8 (66.7)	8 (66.7)	5 (41.7)	9 (75.0)
0	3 (25.0)	3 (25)	3 (25.0)	2 (16.7)
−0.01-−0.5	0 (0.0)	0 (0.0)	1 (8.3)	0 (0.0)
−0.51-−1.0	0 (0.0)	1 (8.3)	0 (0.0)	0 (0.0)
<−1	0 (0.0)	0 (0.0)	1 (8.3)	0 (0.0)

*Negative values indicate measurements short of the major foramen

reported that the file tip was found 0.395 mm beyond the foramen and the position of the foramen can be located with 82.75% accuracy (within ±0.5) when the Root ZX were used. Stoll *et al*.,[23] evaluated the performance of four EALs with different file size and reported that the DentaPort ZX and Raypex 5 located the major foramen with 97.6% and 87.2% accuracy with size 15 file and 97.4% and 82.4% accuracy with size 10 file, respectively. Somma *et al*.,[18] compared the accuracy of the DentaPort ZX, Raypex 5, and Propex II. They reported that there were no significant differences between the devices. Our results were in accordance with these previous studies.[15,18,23,29] Mancini *et al*.,[16] have reported that the mean accuracy of the Root ZX in detecting the foramen within ±0.5 mm was 65.3%, with mean distances of 0.57 mm and the Root ZX showed less performance in comparison with both Endex and Propex II. In this study, the findings were in disagreement with the study of Mancini *et al*.,[16] Different methods and the number and category of teeth may lead to these different results.

In this study, mean distance between the file tip and the major foramen was 0.117 mm for the Endo Master and 0.258 mm for the VDW Gold. Endo Master and VDW Gold located the major foramen with 91.7% and 75% accuracy, respectively. Endo Master detected the foramen in 25% of the cases, while VDW Gold detected in 16.7% of the cases. No, statistically significant difference was found between Endo Master, VDW Gold and the other EALs. There are limited studies evaluating the accuracy of Endo Master and VDW Gold. In a previous study, Barthelemy *et al*.,[22] evaluated to WL determination of three different apex locators and stated that X-Smart Dual indicated significantly shorter lengths than DentaPort ZX or Endo Master. The distance from the file tip to the major foramen was 0.52 mm for X-Smart Dual, 0.24 mm for Endo Master and 0.18 mm for DentaPort ZX. Stavrianos *et al*.,[30] compared the performance of the DentaPort ZX, Raypex 5, Endo Master and Bingo-1020 for determining the WL of endodontically retreated teeth. The accuracy of the DentaPort ZX, Raypex 5 and Endo Master were 100% within ±0.5 mm from the actual length, in the control group while the results was 94% for DentaPort ZX, 72% for Raypex 5 and 81% for Endo Master within ± 0.5 mm, in the experimental group. They reported that the DentaPort ZX and Endo Master more accurate than other EALs in determining WL. Koçak *et al*.,[31] evaluated clinical efficiency of Root ZX mini and VDW Gold and the WL determination of both devices were similar to the conventional radiographic technique, Root ZX mini and VDW Gold showed 87% and 83.5% clinical accuracy (within 0-2 mm from the radiographic apex). In another study,[32] they stated that Tri Auto ZX and VDW Gold can be used reliably to WL determination.

In this study, all devices showed a tendency toward overestimation. These findings was in agreement with results of previous studies.[15,16,33] This could be due to the fact that the EALs were used according to the manufacturer's instructions to WL determination. The findings of this study and the previous studies raise a question of whether the WL should be established at the point where the EAL indicates the major foramen or at some distance coronal to that point. Hence, in order to avoid over preparation, it seems advisable to recommend a withdrawal of the instrument of about 0.5-1 mm from the electronic measurement.[15,34]

According to Lee *et al*.,[26] instead of determining in advance the point at which the EAL should be read, the real factor is to ensure that the electronic measurements can be reproduced reliably. It is also important that the standard deviation values obtained by using different EALs should be low. However, high standard deviations were observed for the Raypex 5 and Endo Master groups, in this study. This result which was observed in some previous studies,[35,36] could be explained by the claim of some authors that the accuracy of an EAL is influenced by the some anatomical factors of the root canal such as the morphology of the minor and major foramen and the location of the major foramen.[15,17,37-39] The diameter of the major foramen is thought to be a major factor that influences the functioning of EALs. A previous study reported that as the diameter of the foramen apicale increased, the distance between the file tip and the apical foramen increased.[37] Similarly, in a study by Huang[39] showed that when the diameter of the major foramen was <0.2 mm, measurements were not influenced, even in the presence of irrigants, but as it increased to above 0.2 mm, the measured distance from the apical foramen increased. The diameter of the apical foramen of the roots was not standardized in this study. Instead, we used the roots with mature apices in order to prevent a large apical foramen problem.

Conclusion

Under the *in vitro* conditions of this study, all EALs showed an acceptable determination of the major foramen within the range of ±0.5 mm.

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