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ORIGINAL ARTICLE

Comparison of various current electronic apex locators to determine the working length using the clearing technique

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Abstract

Background: Correct working length determination is an important step for successful endodontic therapy.
Objective: The objective was to compare *in vitro* the accuracy of three electronic apex locators (EALs) (DentaPort ZX [Morita Co., Tokyo, Japan], SIROEndo Pocket [Sirona Dental Systems, NY, USA], and Rootor [Meta Biomed, Cheongwon-gun, Korea]) in detecting the major foramen using the clearing technique.
Materials and Methods: Forty-five human extracted single-rooted teeth with mature apices were used for the study and divided into three groups of 15 teeth each. All teeth were embedded in an alginate model, and the electronic measurements were taken following the manufacturers' orientations. Then, the teeth were cleared and photographed under a stereomicroscope with a digital camera. The distance from the file tip to the major foramen was measured using image analysis software program. Statistical analysis was performed using the Kruskal–Wallis, Mann–Whitney U, and Chi-square tests at a significance level of 0.05.
Results: The mean distances from the file tip to the major foramen were 0.164 ± 0.292, −0.162 ± 0.234, 0.341 ± 0.166 mm in the DentaPort ZX, SIROEndo Pocket, and Rootor groups, respectively. Statistical analysis showed that there was a significant difference between SIROEndo Pocket and Rootor ($P < 0.05$). However, no significant difference was found between DentaPort ZX and other EALs ($P > 0.05$).
Conclusion: DentaPort ZX located the major foramen with 100% accuracy within the range of ± 0.5 mm. However, the accuracy of the SIROEndo Pocket and Rootor in locating the major foramen within ± 0.5 mm was 73.3% and 86.7%, respectively. All EALs showed an acceptable determination of the major foramen within the range of ± 0.5 mm.

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

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Introduction

The removal of all pulp tissue, necrotic debris, and microorganisms from the root canal system is necessary for success following root canal treatment. This may be achieved if the working length (WL) is assessed with accuracy.[1] Short measurements of the WL, especially in cases of infected necrotic pulps and chronic apical periodontitis, led to significantly lower success rates compared to cases where an accurate WL was achieved.[2] 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.[3]

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Radiographs provide a two-dimensional image of a three-dimensional structure, and it is impossible to determine accurately the position of the AC and the apical foramen on the basis of conventional radiographs alone.[3,4] Because the main root canal's apical foramen may be located to one side of the anatomical apex, sometimes at distances of 3 mm. Thus, in addition to radiographic measurements, electronic root canal WL determination has become increasingly important.[1] Electronic apex locators' (EALs) most important advantage over radiography is that they can measure the length of the canal to the end of the apical foramen, not to the radiographic apex.[5]

The first and second generation EALs were unable to give accurate measurements in the presence of irrigation solutions, blood, pus, and pulpal tissue (necrotic or vital).[1] However, recently developed EALs determine the WL by measuring the impedance with two or more different frequencies, and they can work in the presence of various electrolytes.[6] Thus, current EALs have a high reliability and high accuracy in locating the apical foramen.[7]

DentaPort ZX (Morita Co., Tokyo, Japan), SIROEndo Pocket (Sirona Dental Systems, NY, USA), and Rootor (Meta Biomed, Cheongwon-gun, Korea) are some of the modern EALs. DentaPort ZX, a third generation combined device, simultaneously calculates the ratio of two impedances in the same canal using two different frequencies (8 kHz and 0.4 kHz)[8] and works with the same principle as the original Root ZX does,[9] which has been tested in previous studies and has subsequently become a reference in WL evaluation.[10-12]

SIROEndo Pocket is another combined device which uses two frequencies, 0.047 kHz and 0.063 kHz. Rootor is a multiple frequency EAL which uses two frequencies (0.5 kHz and 5 kHz). To our knowledge, there are no published *in vivo* or *in vitro* studies to evaluate the accuracy of SIROEndo Pocket or Rootor.

Thus, the purpose of this *in vitro* study was to evaluate the accuracy of DentaPort ZX, SIROEndo Pocket, and Rootor EALs in establishing the major foramen using the clearing technique.

Materials and Methods

Forty-five maxillary and mandibular human extracted single-rooted teeth with a single, straight canal, and completely formed roots were used. The teeth were stored in a sterile saline after extraction. Calculus and soft tissue were carefully removed from the external root surfaces. The crowns of the teeth were removed at the cementoenamel junction with a diamond disc to simplify access to root canal and length measurements. Gates-Glidden drills of sizes 1–3 (Dentsply Maillefer, Ballaigues, Switzerland) were used to flare the coronal portions of the root canals. Each root canal was irrigated using 2.5% sodium hypochlorite (NaOCl) solution during the process and canal patency was checked with a size 10 K-File (Dentsply Maillefer).

The teeth were randomly assigned to three groups of 15 teeth each and then the teeth were embedded in an alginate model that was specially developed to test the EALs [Figure 1-c].[13] DentaPort ZX, SIROEndo Pocket, and Rootor were used according to the manufacturer's instructions for detecting the major foramen. Measurements were taken after the tooth surface was gently dried with a cotton pellet after irrigation with 2.5% NaOCl into the root canal. Size 15 K-files connected to the EALs were used in all measurements. For the DentaPort ZX device, size 15 K-File was stabilized within the canal when the file was advanced into the canal to just beyond the foramen, as indicated by the flashing "APEX" bar and then withdrawn until the last green bar had been reached. For the SIROEndo Pocket, the file was advanced into the canal until an "A" appears on the display. For the Rootor, the file was advanced until the "00" last red led. Then the file was stabilized within the canal with a flowable 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%, 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 (Nikon, SMZ800, New Jersey, USA) at ×6 magnification.

The distance between the tip of the file and the major foramen was measured using image analysis software program (Image J 1.42q, National Institutes of Health, Berklend, Maryland, USA). Positive values indicated that the file tip was beyond the major foramen [Figure 2a], negative values indicated that the file tip was short of the major foramen, and zero values indicated that the file tip was aligned at the major foramen [Figure 2b]. All measurements

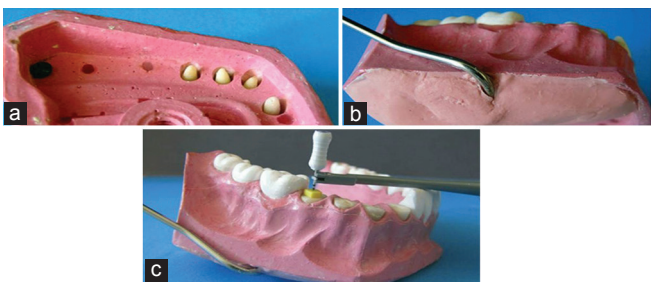


Figure 1: (a) Teeth were inserted into their sockets on the model. (b) Lip clip was inserted into unset alginate. (c) Figure of the test system

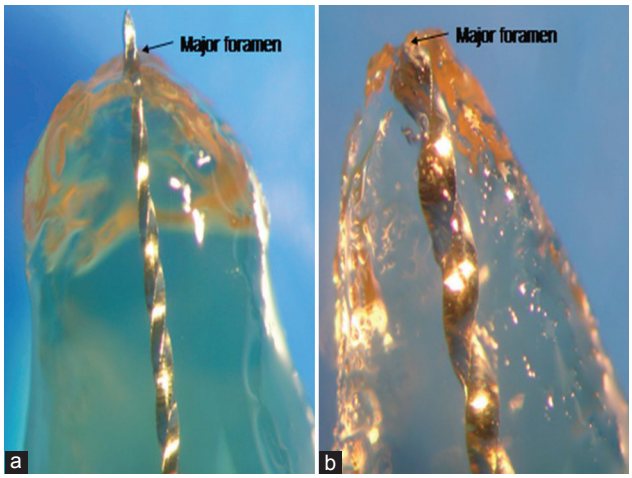


Figure 2: (a) The file tip was beyond the major foramen. (b) The file tip and the major foramen coincided

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

Group	Mean	SD
DentaPort ZX	0.164*	0.292
SIROEndo Pocket	−0.162	0.234
Rootor	0.341*	0.166

χ^2=12.348; *P*=0.002; *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	SIROEndo Pocket	Rootor
>1*	0	0	0
1.0–0.51*	0	0	2 (13.3)
0.5–0.01*	8 (53.3)	5 (33.3)	12 (80)
0	5 (33.3)	5 (33.3)	1 (6.7)
−0.01-−0.5	2 (13.3)	1 (6.7)	0
−0.51-−1.0	0	3 (20)	0
<−1	0	1 (6.67)	0

*Positive values indicate measurements beyond of the major foramen

were carried out by the same operator to reduce the potential for operator variability.

Statistical analysis

Statistical evaluation was performed using SPSS 13.0 (SPSS Inc., Chicago, IL, USA). Kruskal–Wallis, Mann–Whitney U, and Chi-square tests were used to analyze the data. Statistical significance was set at $P < 0.05$.

Results

The mean distances from the file tip to the major foramen and standard deviations for each EAL are shown in Table 1. Statistical analysis showed a significant difference between SIROEndo Pocket and Rootor ($P < 0.05$). However, no significant difference was found between DentaPort ZX and the other two EALs ($P > 0.05$). Table 2 shows the percentage values of electronic measurements. Within the range of ± 0.5 mm, the accuracies were 100% for the DentaPort ZX, 73.3% for SIROEndo Pocket and 86.7% for Rootor. The major foramen was detected exactly in 33.3% of the cases with the DentaPort ZX and SIROEndo Pocket and 6.67% with the Rootor.

Discussion

The use of EALs to determine WL and to detect the position of the apical foramen has progressed substantially and gained increasing popularity in recent years.[14] *In vivo* and *in vitro* investigations have previously evaluated the accuracy of these devices.[6,7,9,14] *In vitro* studies used electroconductive materials such as agar-agar, alginate, gelatin, or a saline solution to simulate the clinical situations.[15-18] An alginate model was used to simulate the periodontium in this study as previously described by Tinaz *et al*.,[13] because alginate remains around the root, simulates the periodontal ligament with its colloidal consistency, and presents a suitable electroconductive property.[19]

Preflaring of the root canals before the WL measurements can increase the precision of the EALs;[10,20] thus in the present study, the coronal parts of the canals were preflared before electronic measurements.

The AC is the narrowest part of the root canal and is regarded as the physiological apical limit for instrumentation and filling of the root canal system.[21] However, several investigators have suggested that the precise location of the AC cannot be determined, and there might not always be an AC. However, the major foramen could be located consistently.[22,23] A previous study concluded that EALs are only capable of detecting the major foramen.[15] Thus, in the present study, the major foramen was considered as a reference point to assess the devices.

Radiographs, actual canal length measurements, trimming the apical portion of the root in a longitudinal direction until the file tip and the root canal become visible or clearing technique were used in previous studies to evaluate the performance of different EALs.[23-26] Unlike the radiographic technique, clearing technique gives a three-dimensional view of the root canal which makes it easy to determine the position of the file tip at the root apex and at what level it stops. Furthermore, trimming the apical portion of the root can damage the integrity of the AC and major foramen. Therefore, in the present study, the clearing technique was used in determining of file position.

The results of the present study showed that the mean distance from the file tip to the major foramen was 0.164 mm for the DentaPort ZX, −0.162 mm for the SIROEndo Pocket and 0.341 for the Rootor. Furthermore, many of the measurements (93.3%) of the Rootor were beyond the major foramen. Although no significant difference was found between the DentaPort ZX and the other two devices, there was a statistically significant difference between the SIROEndo Pocket and the Rootor. However, this finding cannot be compared with existing data, because so far, no reports on the accuracy of SIROEndo Pocket and Rootor for determining WL are available.

The Root ZX series EALs showed a tendency to underestimate WL in some previous studies.[24,27-29] These results differ from those obtained in the present study and some previous studies in which long measurements were made rather than short measurements.[11,12,17,30] Furthermore, high standard deviations were observed for the DentaPort ZX and SIROEndo Pocket in the present study. According to Lee *et al.*,[22] 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. If the reading of the device is consistent (low standard deviation) and if the mean distance between the file tip and the major foramen is known, an accurate WL can be obtained by subtracting or adding a predetermined value from the device reading. It is also important that the standard deviation of the values obtained using different EALs should be low. However, high standard deviations were observed in some previous studies[17,28,31] similar to the present study. These results, such as long measurements and the high standard deviations, might be explained by the claim of some authors that the accuracy of an EAL is influenced by some anatomical factors of the root canal such as the diameter of the minor and major foramen and the location of the major foramen.[12,32-35] The diameter of the major foramen is thought to be a major factor that influences the functioning of EALs. Previous studies[33-35] reported that the accuracy of EAL depended on the diameter of the major foramen. However, the diameter of the apical foramen of the specimens was not standardized in the present study. Instead, we used roots with mature apices in order to prevent a large apical foramen problem, and measured all WL with same sized file.

Another factor for long measurements might be manufacturers' instructions to WL determination. The findings of the present study and the previous studies raise the question of whether the WL should be established at the point, where the EAL indicates the major foramen. Hence, some authors have proposed withdrawing the instrument 0.5 or 1 mm when using the EALs to ensure that the file tip does not protrude beyond the WL, avoiding root canal over preparation.[9,12]

Conclusion

Under the *in vitro* conditions of this study, DentaPort ZX located the major foramen with 100% accuracy within the range of ± 0.5 mm. However, the accuracy of the SIROEndo Pocket and Rootor in locating the major foramen within ± 0.5 mm was 73.3% and 86.7%, respectively. All EALs showed acceptable determination of the major foramen within the range of ± 0.5 mm. However, further studies are needed to compare the SIROEndo Pocket and Rootor under both *in vitro* and *in vivo* conditions with other combined devices and EALs.

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