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Original Article

Evaluation of the accuracy of two apex locators in endodontic treatment and retreatments: an ex vivo study

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Abstract

Introduction: Working length determination is important in successful endodontic treatment and retreatment. This study evaluated the accuracy of two electronic apex locators Root ZX and Raypex®6 (EALs) in determining the electronic working length (EWL) of the root canals in endodontic treatment and retreatment.

Materials &Methods: Access cavities were prepared on forty extracted, single-rooted human teeth and the actual working length (AWL) of the canals was determined. In the first phase of the study, primary EWL of un-instrumented teeth was measured and compared between two EALs. In phase II, all of the teeth were pre-flared and divided into the control (n=10) and the retreatment groups (n=30). Canals in the retreatment group were obturated by the lateral condensation technique using Gutta percha and sealer. After 15 days, gutta-percha was removed, and then the secondary EWL was recorded and compared between the two devices, in treatment and retreatment groups. Data were analysed by paired t-test and t-test.

Results: Significant differences were found between both EALs in treatment and retreatment phases of the study ($p<0.001$). Both EALs showed increased accuracy in retreatment group ($p<0.001$). However, no statistically significant differences were found between the control and retreatment groups in the second phase of the study for Root ZX ($p=0.929$), and Raypex®6 ($p=0.937$).

Conclusion: Accuracy of the two EALs was similar and acceptable. EWLs determined by Root ZX were closer to the AWL. The EWL determination after pre-flaring improved the accuracy of EALs and root canal obturation remnant materials did not have any clear effect on the accuracy of these EALs.

Keywords: Endodontics, Gutta-percha, Retreatment, Root canal

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ارزیابی دقت دو آپکس یاب در درمان های ریشه و مجدد ریشه، یک مطالعه آزمایشگاهی

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چکیده

مقدمه: تعیین طول کارکرد در درمان موفق ریشه و درمان مجدد مهم می باشد. این مطالعه به ارزیابی دقت دو آپکس یاب الکترونیکی (Electronic Apex Locator=EAL, Root ZX & Raypex6)، در تعیین طول کارکرد الکترونیکی (Electronic Working Length=EWL) کانال در درمان ریشه و در درمان مجدد ریشه، پرداخته است.

مواد و روش ها: از ۴۰ دندان تک ریشه کشیده شده انسان، استفاده شد و پس از تهیه حفره دسترسی، طول کارکرد واقعی (Actual Working Length=AWL) کانالها تعیین شد. در مرحله اول، قبل از اینسترومنتیشن کانالها، EWL اولیه برای همه دندانها تعیین و بین EALs مقایسه شد. در مرحله دوم، دندانها پس از آماده سازی کانالها، به دو گروه کنترل (n=10) و گروه درمان مجدد (n=30) تقسیم شدند و کانالها در گروه درمان مجدد، با استفاده از گوتا پرکا و سیلر به روش تراکم جانبی پر شدند و پس از ۱۵ روز گوتا پرکا حذف، و سپس EWL ثانویه، ثبت و بین دو دستگاه در گروههای درمان اولیه و مجدد مقایسه شد. داده ها با استفاده از آزمونهای Paired t-test، t-test مورد ارزیابی قرار گرفتند.

یافته ها: از لحاظ آماری اختلاف معناداری بین گروههای درمان اولیه و مجدد در مطالعه، بین هر دو آپکس لوکیتور (p<0.001) مشاهده شد ولی اختلاف آماری معناداری بین گروههای کنترل و درمان مجدد در مرحله دوم، برای Root ZX (P=0.929) و Raypex6 (P=0.937) مشاهده نشد.

نتیجه گیری: در هردو مرحله، دقت EALs مشابه و قابل قبول بود، EWLs تعیین شده توسط Root ZX به AWL نزدیکتر بود. تعیین EWL پس از آماده سازی (Pre flaring)، سبب بهبود دقت EALs میشود. باقیمانده مواد پر کننده کانال تاثیر محسوسی بر دقت EALs نداشتند.

واژگان کلیدی: معالجه ریشه، گوتاپرکا، درمان ریشه مجدد، کانال ریشه

Introduction

Determination of the appropriate working length (WL) of the canal is important in providing a successful endodontic treatment. Along with limiting the preparation and filing of the canal within this length this first step toward favorable prognosis is important in endodontic treatment and retreatment. Apical constriction is the best landmark at which endodontic procedure should preferably end. The complete removal of necrotic tissue or inflamed pulp is important to reestablish healthy periapical tissues. [1] Accurate detection of working length is critical. Because of distortion, magnification and superimposition, radiography is not an ideal method in many situations. [2,3] These factors have led to the introduction of electronic devices as auxiliary tools to determine WL, often in conjunction with radiography. Compared to radiography, one of the advantages of EALs is that they measure root canal length up to the apical constriction rather than the radiographic apex. [4] EALs of the third generation were introduced in 1990 to overcome the shortcomings of the first and second generations. [5] Rootzx (J.morita corp.,Tokyo,Japan) is an example of this generation and is considered as a gold standard to evaluate the newer devices.[6,7] Recently, some multi-frequency devices were introduced in order to compete with the third generation. [7] Raypex®6 (VDW, Munich, Germany) is an example of a multi-frequency electronic device that is capable of automatic calibration. This device already has proven clinically successful by assessing Raypex®4 and 5.[8,9] Previous studies found that a large number of factors may affect the accuracy of EALs in determining the exact WL in endodontic treatment, and EAL measurements are not always 100% accurate. Some of these factors are: the anatomy of the root canal and tooth type, pulp's electrical conductivity, obstruction of the root canal, location of the apical

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foramen, apical foramen size, pre-flaring of the canal, the presence or absence of canal irrigation solutions, the type and size of the measurement file, gutta-percha (GP) solvents, residual GP and sealer, and the type of experimental medium. [10-13]

Since few studies have been conducted on the topic of accuracy of EALs (Root ZX and Raypex®6) in endodontic retreatments, the purpose of this experimental study was to evaluate the accuracy of two EALs (Root ZX and Raypex®6) in determining the WL of canals in endodontic treatment, before canal preparation and after the removal of the root canal obturation materials.

Materials&Methods

Teeth selection: Prior to conducting the study, the research protocol was approved by the Institutional Ethics Committee (Ref. No. 9338418). Forty extracted, single-rooted human teeth without caries or restoration that had been extracted for periodontal reasons were stored in 0.5% chloramine in water at 4°C until further use. Before the study, the teeth were disinfected with 2.5% sodium hypochlorite solution for 3 h, and subsequently, soft tissue and calculus were removed from the root surface with a scaler. Teeth were examined carefully at 4× magnification to check the complete formation of the apical foramen and were replaced in the event of finding any radicular fracture or immature apex. Teeth with wide and narrow apical foramen were also replaced.

To determine the root canal anatomy, radiographic images were taken from mesiodistal and buccolingual directions, and teeth with more than one canal or calcified canals and any internal and external resorption of the root were replaced with new teeth. Then, the teeth were stored in normal saline solution. Standard access cavity was prepared using a high-speed diamond fissure bur (Mani, Inc.; Tochigi, Japan) under water coolant. To provide a stable and reliable reference point for all of the measurements, the occlusal surface of all teeth was ground lightly with diamond discs (Mani, Inc.; Tochigi, Japan) to create a flat surface. All teeth were numbered and stored in normal saline solution.

Actual root canal length measurement: The root canals were irrigated with 5.25% sodium hypochlorite (NaOCl) to remove the organic content of the canal. Canal patency was confirmed with a size 10 K-file, and any teeth with obstruction were replaced. The actual length (AL) of the canal was measured using the anatomical method. This was done using #10 or #15 K-file (Mani, Inc.; Tochigi, Japan) that was placed into the root canal until the tip of the file exited from the apical foramen; next, the file was pulled back slowly until the tip of the file was seen at the major apical foramen. After the file location was examined closely under a 4× magnification, the rubber stop was adjusted carefully on the reference point and fixed using cyanoacrylate glue. After removing the file from the canal, the distance between the base of the rubber stop and the tip of the file was measured using a caliper (Sankin, Mitutoyo Co., Kanagawa, Japan) with an accuracy of 0.1 mm. The AL measurement of each root canal was repeated three times, and the mean value was recorded according to the number of the tooth. Then, the actual working length (AWL) was established by subtracting 0.5 mm from the AL. All canals were irrigated with NaOCl for further cleaning and dried with cotton pellets and gentle air syringe before EWL measurement.

First phase: Primary electronic (PE) working length measurement: To provide an in vitro environment with close similarity to a clinical situation, teeth were embedded in specially formed alginate models in order to simulate periodontal ligaments and enhance the accuracy of EALs. The model, which was described previously by Tinaz et al. [14], consisted of acrylic mold (Acropars; Marlic Medical Industries Co., Tehran, Iran) similar to a dental jaw and filled with alginate (Tropicalgin; Zhermack, Italy). Teeth were put within the alginate to the level of the proximal cemento-enamel junction. To ensure sufficient humidity of alginate, all electronic measurement using EALs were taken within 2 h from the time of model preparation. [15] For primary EWL measurements with two EALs—Root ZX (J. Morita Corp., Tokyo, Japan) and Raypex®6 (VDW, Munich, Germany) —a lip clip was placed within the alginate, and a size #15 K-file was used for all primary EWL measurements. Each device was calibrated according to the manufacturer's instructions.

Primary EWL using EALs was taken by connecting the file to the EAL and gently advancing the file inside the canal until the file slowly passed beyond the apical foramen and the tone indicating file passage was heard. Then, the file was withdrawn slowly from the root canal until the audible signal, the apex signal, or the 0.0 signal was heard and/or displayed on the LCD. The rubber stop of the file was adjusted carefully to the reference point, and, after the file was withdrawn from the canal,

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the distance between the rubber stop and the file tip was measured with a caliper. This operation was conducted separately for both of the EALs. To reduce possible errors and increase the accuracy of the study, this process was repeated three times on each tooth, and the average of the measurements was recorded as the initial EWL.

Second phase: Secondary electronic working length measurement: All of the samples were instrumented using passive the step-back technique. Size 1–3 drills *(*Gates Glidden; Mani, Inc.; Tochigi, Japan*)* were used to prepare coronal and middle thirds of each root canal, and then apical preparation was finished with a size #*35 K*-file with 2% taper. Shaping of the canals was continued passively by using #40, #45, #50, #55, and #60 K-files. Each instrument was smeared with a lubricant (RC Prep, Premier Dental Products Co., PA, USA) before use and during cleaning and shaping. Each canal was irrigated with 2 mL of a 2.5% NaOCL.

Ten samples were selected randomly at this point as the control group (CG), and the rest of the samples (n = 30) were separated so that they could be prepared for the retreatment group (RG). The CG were dried using sterile paper points (Tianjin Zhongjin Biology Development, Tianjin, China). A small cotton pellet was placed at the root canal orifice, and the access cavity was restored with a provisional material (Meta Biomed, Chungcheongbuk-do, South Korea). These samples were not obturated and served as a control group for measuring the accuracy of EALs in the absences of obturating residues.

In the retreatment group, the canals were obturated using the lateral condensation technique with master GP #35 (2% taper, Tianjin Zhongjin Biology Development, Tianjin, China) and AH26 (Dentsply DeTrey, Konstanz, Germany) sealer. A small cotton pellet was placed at the root canal orifice, and access cavity was restored with a provisional material and this group served as a retreatment group for measuring the accuracy of EALs in the presence of obturating residues.

All the teeth in the control and retreatment groups were stored for 15 days in the incubator at 37℃ and 100% humidity. After this period, in the retreatment group, 5–6 mm of the obturation material was removed from the coronal and middle third of the root canal using a #2 and/or #3 drill (Gates Glidden; Mani, Inc.; Tochigi, Japan). GP solvent (chloroform, Kimia, Iran) was injected to soften and facilitate GP removal. Hedstrom files (Mani, Inc.; Tochigi, Japan) #20, #25, and #30 were used to penetrate into softened GP until it reached the apex and no GP got out of the canals, Although it is proven impossible to remove all traces of GP and sealer from the canal walls. [16] To determine the secondary EWL, in both the control and retreatment groups, teeth were placed in the alginate model, and the lip clip was immersed in the alginate as described previously. Secondary EWL measurement was performed for both the control and retreatment groups using a size #25 K-file. All EWLs were measured separately for each tooth and reviewed independently by two experienced operators with extensive experience in using EALs. The operators were unaware of ALs of the samples. EWL measurements were repeated three times and the average was calculated for each operator. The mean value between the two operators' measurements was recorded for each tooth and each of the EALs.

Data was analysed using paired t-test, t-test. SPSS software (IBM SPSS Statistics 22, SPSS Inc., Chicago, IL, USA) was used for all data analysis, and a p-value of < 0.05 was considered significant.

Results

The difference between AWL and EWL (primary [PE] and secondary [CG, RG] was calculated, and the ranges of ±1.0 and ±0.5 of AWL were used as measures for assessing the accuracy of the two EALs. [17] The two EALs' accuracy within the range of ±0.5 mm of AWL was similar, and the accuracy for PE (n=40), CG (n=10), and RG (n=30) was 92.5%, 100%, and 90%, respectively. The accuracy of EALs within the range of ±1 mm of AWL also was similar and equal to 100% in all groups. Table 1 shows the accuracy of the EALs within the two ranges of ± 0.5 mm and ±1 mm of AWL. The mean and standard deviations (in mm) of the difference between EWLs and AWL are shown in table 2.

The Pair T-test analys is comparing the two EALs of each group showed significant differences between PE ($p<0.001$) and in RG ($p<0.001$) of the second phase, but no differences were observed between the two EALs in CG of the second phase of the study ($p=0.084$). Statistical analysis showed significant differences between the EWLs determined by each EALs in two phases of the study, when comparing the PE (first phase) with CG ($p=0.003$) and RG ($p<0.001$) of the second phase separately (p values were similar for both

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EALs). In the second phase of the study, analysis of t-test data showed no differences in EWL measurements between the CG and RG by Root ZX (p=0.929) and Raypex®6 (p=0.937).

Table 1. Distance between AWL and EWL (AWL–EWL) and accuracy of the two EALs within ±0.5 mm and ±1 mm of the AWL

	Phase I		Phase II			
			RG		CG	
EWL–AWL (mm)‡	Raypex®6	Root ZX	Raypex®6	Root ZX	Raypex®6	Root ZX
-1 mm to -0.51 mm	3 (7.5%)	3 (7.5%)	0 (0%)	0 (0%)	1 (10%)	1 (10%)
-0.5 mm to -0.0 mm	35 (87.5%)	32 (80%)	24 (80%)	16 (53.3%)	7 (70%)	3 (30%)
0.01 mm to 0.5 mm	2 (5%)	5 (12.5%)	6 (20%)	14 (46.7%)	2 (20%)	6 (60%)
0.51 mm to 1 mm	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
accuracy (±0.5 mm)	92.50%	92.50%	100%	100%	90%	90%
accuracy(±1 mm)	100%	100%	100%	100%	100%	100%
Total	40 (100%)	40 (100%)	30 (100%)	30 (100%)	10 (100%)	10 (100%)

‡ Negative values indicate measurements over the AWL

EWL, electronic working length. AWL, actual working length. SD, standard deviation. RT, retreated teeth. FT, flared teeth

Table 2. Mean difference between EWL and AWL (in mm) with SD for both phases

	Phase I	Phase II	
Apex locator	PE (n=40)	RT (n=30)	FT (n=10)
Raypex®6 (mean†±SD)	-0.24±0.18	-0.10±0.10	-0.09±0.24
Root ZX (mean†±SD)	-0.15±0.19	-0.02±0.12	-0.02±0.26

† Negative values indicate measurements over of the AWL. EWL, electronic working length. AWL, actual working length. SD, standard deviation. PE, primary electronic working length measurement. RT, retreated teeth. FT, flared teeth.

Discussion

The aim of the present study was to evaluate the accuracy of two EALs (Raypex®6 and Root ZX) in determining root canal WL, before and after cleaning and shaping of the canal and after the removal of the filling materials of the canal. The results showed that in the presence of the remaining root canal obturation materials, the accuracy of both EALs was acceptable and was within ±0.5 mm of AWL. Statistically significant differences were found between the EWLs by the two EALs in PE (before cleaning, shaping and filling the canal) and RG (after re-treatment), indicating that EWLs determined by the Root ZX are closer to AWL. However, in the second phase of the study, no statistically significant differences were found between the RG and CG for the two EALs. Many studies evaluated the accuracy of EALs in determining EWLs of the canal during routine root canal treatments [13,18-21], while few studies evaluated the accuracy of EALs in endodontic retreatments. [22-24]

Recently, Mancini et al. (2014) [25], Chirila et al. (2011) [22], Aggarwal et al. (2010) [26] and Ebrahim et al. (2007) [23] evaluated the accuracy of different EALs in determining the WL of teeth during endodontic retreatment and in the presence of obturating residues. Chirila et al. [22], Aggarwal et al. [26] found that gutta percha and sealer had effect conversely, Mancini et al. [25] and Ebrahim et al. [23] found that root canal obturation remnant materials did not have any clear effect on the accuracy of EALs.

Many studies used an error range within ±0.5 mm of actual length, a range that is considered extremely accurate; however, other studies have relied on an error rate within ±1 mm. Compared to the ±0.5 mm range, the error range within ±1 mm seems to be more clinically acceptable, because of the apical region variations.[23,27]

Moscoso et al. [18] and Aydin et al. [19] showed that the accuracy of Raypex®6 in endodontic treatment was within ±0.5 mm in 88.22% and 85% of the cases, respectively, and within ±1.0 mm in 100% and 95% of

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the cases, respectively. In the present study, Raypex®6 EWL measurement in the first phase of the study was accurate within ±0.5 mm and ±1.0 mm in 92.5% and 100% of the cases, respectively; these results are consistent with previous studies. [18,19] To our knowledge, no other study has evaluated the Raypex®6 in the presence of remaining root canal obturation materials in endodontic retreatment.

Similar to our findings, Shabahang et al. [27], Lucena-Martin et al. [15], and Versiani et al. [28], evaluated the accuracy of Root ZX in endodontic treatment and they found that Root ZX was accurate within ±0.5mm 96.2%, 95% and 90.5% respectively, results that were almost similar to the values obtained in the present study. Within ± 1.0 mm, Root ZX accuracy is shown to be 94% to 100%. [18,24,29,30] In the present study, Root ZX was accurate within ±1 mm in 100% of the cases. Goldberg et al. [24], Aggarwal et al. [26] and Chirila et al [22], evaluated the accuracy of Root ZX in endodontic retreatment, and they found EWLs determined by Root ZX were accurate within ±0.5mm in the range of 80% to 96.6%, and within ±1mm about 100%, however in the present study, the accuracy of this EAL within both ±0.5mm and ± 1mm was 100%. The difference between previous studies and the present study can be related to the difference in type of root canal obturation materials, the type of media, considering the apical foramen as the apical end of the working length and EAL settings (Apex Mark).

The results of the present study showed that, before shaping and flaring of the root canals, EWLs measured by Root ZX were significantly different and closer to AWL, a finding consistent with a previous study by Guise et al. [31] Conversely, Moscoso et al. [18] found that there was no significant difference between Raypex®6 and Denta Port ZX (J. Morita Corp., Tokyo, Japan); however, the EWLs determined by Raypex®6 were closer to AWL. After removing the root canal obturation materials, statistically significant differences were found between the EWLs determined by the two EALs in the present study, and the EWLs determined by the Root ZX were closer to AWL. Goldberg et al. [24] showed no significant difference between three EALs (Root ZX; ProPex [Dentsply-Maillefer, Tulsa, USA]; and NovApex [Forum Technologies, Rishon Le-Zion, Israel]) in the presence of remaining root canal obturation materials, and the EALs determined by Root ZX were closer to AWL than were the two other EALs. Duran-Sindreu et al. [32] showed that in canals with a widened coronal section, there is a statistically significant difference between Root ZX and iPex (NSK, Tokyo, Japan) EALs, and the EWLs determined by Root ZX were closer to AWL.

The difference between CG and RG at the second stage of the present study was the presence of remaining root canal obturation materials in the RG group. Because no statistically significant difference was found between the two groups (CG and RG), it can be concluded that the remaining root canal obturation materials did not have a clear effect on the accuracy of EALs, a finding that is similar to results reported by Chirila et al. [22] However, Mancini et al. [25] evaluated the accuracy of Root ZX in determining EWL after preparation of the canals (EL1); after removing the root canal obturation materials in endodontic retreatment (EL2), and Statistical analysis showed significant differences between EL1 and EL2. Thus, in contrast to our findings, the remaining root canal obturation material affected the accuracy of the EALs in the Mancini study. Different study set-up also could be a reason for these differences.

The difference between the control group in the first and second phases of the study was preparation of canals and the size proportion of the measuring file with apical constriction; however, in the RG group, in addition to above mentioned features, there were remaining root canal obturation materials. Given that, there was significant difference in two EALs between first and second phases and also its was determined previously that the remaining root canal obturation materials, do not have a clear effect on the accuracy of the EALs, it can be concluded that, the reason of the increased accuracy in determining EWL in the second phase of the study compared to the first phase, is pre-flaring of canals and proportion of the size of the measurement file with apical constriction. [33,34]

EALs operate based on electronic principles rather than depending on the biological properties of involved tissues [35] thus, it is necessary for the EALs to be evaluated in an environment that best simulates conditions and characteristics of periodontal ligaments. [11,36] Several media have been recommended for simulation of the periodontal ligament. [37-39] Alginate is one that offers advantages, such as better stability and ability for tooth manipulation, similar electrical resistance to periodontal ligament, ease of use, low cost, and the ability to control experimental conditions. [11,40,41]

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The results of the present study, consistent with previous studies, [23,24,26] confirms the usefulness of EALs in endodontic treatment and retreatment. Further studies should assess different EALs in the presence of various canal-filling materials and solvents, as well as various canal irrigation solutions.

Conclusion

The accuracy of two EALs in primary endodontic treatment and retreatment was similar and acceptable, although Raypex®6 was more likely than Root ZX to overestimate EWL. Pre-flaring improves the accuracy of EALs, and remaining root canal obturation slightly affects their accuracy. The clinical usage of EALs in combination with radiography is recommended for endodontic treatments and retreatments.

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Conflict of interest: Authors deny any conflict of interest related to this study.

Authors' Contributions

The study was designed by Azadeh Harandi and Ali Soleymani. Data were collected by Yasser Samadi. Analysis and interpretation of data, drafting of the manuscript and critical revision of the manuscript for important intellectual content were pre-formed by Soraya Khafri and & Azadeh Harandi and Ali Soleymani. Supervision of the study was performed by Azadeh Harandi and Saeid Tavanafar.

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