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Accuracy of 3 Electronic Apex Locators in Nonsurgical Retreatments of Teeth with Root-Ends Resected at Different Angles: In-Vitro Study

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Research Article

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ABSTRACT

Aim: The accuracy of three electronic apex locators (EALs) during retreatment of root-end resected teeth with different resection bevel angles were evaluated in the present study.
Materials and Methods: Forty mandibular premolar teeth were divided into two groups regarding resection bevel angle after root canal filling. In the first group, the apical 3 mm of each specimen was resected at a 0-degree bevel angle using a diamond bur. The resection bevel angle was approximately 45-degree in the second group. Electronic length measurements were obtained with a size 15 K-file advanced apically in dissolved gutta percha using Dentaport ZX, Propex Pixi, and Apit 15. The filling materials were then completely removed from the root canals, and the actual lengths up to the resection region were determined. The actual length was subtracted from the electronic length measurements for each specimen. Measurements were analyzed statistically using independent sample t-test, repeated-measures analysis of variance, and Bonferroni tests. The level of statistical significance was defined as $p<0.05$.
Results: In the 45-degree group, a significant difference was found between Propex Pixi and Apit 15. Measurements at 0- and 45-degree resection bevel angles were not statistically different from each other in any EAL groups.
Conclusions: The resection bevel angle did not affect the accuracy of the tested EALs. More accurate measurements were obtained with the Propex Pixi at a 45-degree resection bevel angle compared with the Apit 15.

Keywords: Electronic Apex Locator, Resection Bevel Angle, Retreatment, Root Canal.

Kök Uçları Farklı Açılarda Rezeke Edilmiş Dişlerin Cerrahi Olmayan Yeniden Tedavilerinde 3 Elektronik Apeks Bulucunun Doğruluğu: In Vitro Çalışma

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ÖZ

Amaç: Bu çalışmada, farklı rezeksiyon eğim açılarıyla kök ucu rezeke edilmiş dişlerin yeniden tedavileri sırasında üç elektronik apeks bulucunun (EAB) doğruluğu değerlendirildi.
Gereç ve Yöntem: Kırk mandibular premolar diş rezeksiyon eğim açısına göre kanal dolgusu sonrası iki gruba ayrıldı. Birinci grupta, her örneğin apikal 3 mm'si elmas frez kullanılarak 0-derecelik bir eğim açısında rezeke edildi. İkinci grupta rezeksiyon eğim açısı yaklaşık 45-dereceydi. Elektronik uzunluk ölçümleri, Dentaport ZX, Propex Pixi ve Apit 15 kullanılarak çözünmüş güta perka içinde apikal olarak ilerletilmiş 15 numaralı bir K-tipi eğeyle elde edildi. Daha sonra dolgu maddeleri kök kanallarından tamamen uzaklaştırıldı ve rezeksiyon bölgesine kadar olan gerçek kanal uzunlukları belirlendi. Her örnek için gerçek uzunluk, elektronik uzunluk ölçümlerinden çıkarıldı. Ölçümler independent sample t-test, tekrarlı ölçümlerde varyans analizi ve Bonferroni testleri kullanılarak istatistiksel olarak analiz edildi. İstatistiksel anlamlılık düzeyi $p<0.05$ olarak tanımlandı.
Bulgular: 45-derece grubunda Propex Pixi ve Apit 15 arasında anlamlı fark bulundu. 0- ve 45-derecelik rezeksiyon eğim açılarındaki ölçümler, hiçbir EAB grubunda istatistiksel olarak birbirinden farklı değildi.
Sonuçlar: Rezeksiyon eğim açısı, test edilen EAB'ların doğruluğunu etkilemedi. Propex Pixi ile 45-derecelik rezeksiyon eğim açısında Apit 15'e göre daha doğru ölçümler elde edildi.

Anahtar Kelimeler: Elektronik Apeks Bulucu, Rezeksiyon Eğim Açısı, Yeniden Tedavi, Kök Kanalı.

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Introduction

At present, all reliable endodontic techniques are based on the thorough cleaning, disinfection, and filling of root canals. For a successful root canal treatment, the infected root canal contents must be completely removed, microorganisms and their products must be eliminated, and the root canal system must be sealed hermetically.[1] Although nonsurgical root canal treatment has become a routine dental procedure, long-term healing is not observed in all treatments. Due to the high number of treatments performed, the small number of failed cases turn into relatively large number of patients requiring further treatment.[2]

Many reasons are reported in the endodontic literature for the failure of initial nonsurgical root canal treatment. These are inadequate access cavity planning; untreated main and/or accessory canals[3]; poorly cleaned and filled canals[4]; errors during root canal instrumentation such as ledges, perforation, or instrument fracture[5,6]; and procedural errors such as overfilling.[7] Coronal leakage due to inadequate coronal restoration is also responsible for post-treatment failure.[8]

Orthograde root canal retreatment, surgical endodontic treatment, transplantation, tooth replantation, extraction with no prosthetic replacement, extraction and replacement by using a dental prosthesis, and extraction and replacement with single implant-supported crown are the treatment approaches that can be preferred in the failure of the initial root canal treatment.[9-11]

Although it is not a routine procedure, an orthograde revision may be required for root-end resected teeth in case of persistent infection or secondary root canal infection.[12,13] Root-end resection alone cannot usually initiate the recovery of apical periodontitis caused by intraradicular infection. It can be achieved by nonsurgical revision (orthograde retreatment) of insufficient or infected root canal filling.[13] Therefore, the first step should be to remove filling material completely and clean and shape the root canal system adequately.[14]

The determination of the radiographic working length is often a problem in the procedures for revising the root canal filling of resected teeth because it is difficult to identify the apical terminus of the root canal on radiographs depending on the resection bevel angle.[13] Apical microsurgery procedures performed with an operating microscope and surgical ultrasonic tips reduce the need for inclined cutting of the root-end. However, when the resection bevel angle is different from 0-degree, the apical terminus of the root canal will be shorter than the radiographic apex, and the working length will generally be determined longer.

Electronic apex locators (EALs) accurately determine the working length in initial root canal treatments and retreatments.[15-18] However, the large apical terminus size of the root canal may affect the accuracy of EALs in the resected teeth, as the apical anatomy is changed and apical narrowing of the canal is removed by root resection.[12,13]

Different generations of EALs have been introduced to measure working length by locating the root apex. The DentaPort ZX (Morita, Tokyo, Japan) is a combined device that measures the working length by simultaneous measurement of impedance values in the same canal using two different frequencies (8 kHz and 0.4 kHz).[19] The Propex Pixi (Dentsply Maillefer, Ballaigues, Switzerland), on the other hand, is a pocket-sized, multifrequency type EAL.[15] The Apit 15 (Osada Electric Co., Ltd., Tokyo, Japan) also measures at two frequencies. It determines the apical constriction by comparing the impedances of two different frequencies.[20] It has been shown in previous studies that EALs determine the apical terminus within a clinically acceptable range in root-end resected teeth.[12,13] The purpose of this in-vitro study is to evaluate the accuracy of three different EALs in determining the apical terminus during retreatment of root-end resected teeth with different resection bevel angles.

Materials and Methods

The study design was approved by the Non-Interventional Clinical Research Ethics Committee of Sivas Cumhuriyet University, Sivas, Türkiye (2018-05/17). Forty human mandibular premolars with single straight root canals extracted for orthodontic or periodontal reasons were used in the study. Root canal morphology were determined via buccolingual and mesiodistal preoperative radiographs. After the teeth were kept in 5.25% sodium hypochlorite (NaOCl) for 15 minutes to remove organic debris, the soft and hard tissue residues were removed from the root surfaces using a periodontal curette. Teeth with root fractures/cracks, open apices, resorption, caries, or calcified root canals were excluded from the study. Selected teeth were stored in distilled water until used. Access cavities were prepared and apical patency was checked with a 10 K-file. To obtain approximately 17 mm standardized root length and a constant reference point for all measurements, the coronal parts of the teeth were removed. The working length of each root canal was determined by subtracting 0.5 mm from the measured length after the tip of a size 15 K-file was visible at the major foramen.

All root canals were instrumented with the S5 system (Sendoline, Täby, Sweden) up to size 30/.04 using EndoTouch TC2 (SybronEndo, Glendora, CA, USA). New instruments were used for every 4 canals. 2 mL of 2.5% NaOCl were used as an irrigation solution after each instrument change. After shaping, the canals were rinsed with 5 mL of 17% ethylene-diaminetetraacetic acid for 1 minute followed by 5 mL of NaOCl. A final rinse with 5 mL of distilled water was performed. Root canal obturation was done using AH Plus (Dentsply DeTrey, GmbH, Konstanz, Germany) and gutta percha (Diadent, Chongju, Korea) with cold lateral compaction technique. Finally, temporary filling material was placed into the access cavity, and all samples were stored under 100% humidity at 37 °C for seven days to provide complete hardening of the sealer.

The samples were then randomly divided into two groups of 20 specimens each according to the resection

bevel angle. In the first group, the apical 3 mm of each specimen was resected at a 0-degree bevel angle using a diamond bur. The resection bevel angle was approximately 45-degree in the second group. All samples and lip clips of the EALs were embedded in an alginate mould. The filling material was removed from the coronal thirds with a size 3 Gates-Glidden bur. Eucalyptol was then introduced into each root canal to soften the gutta percha. The electronic canal lengths (ELs) were measured with a size 15 K-file advanced apically in the dissolved gutta percha using a digital caliper. ELs were recorded with the Dentaport ZX device at the last green bar, with the Propex Pixi at the 0.0 mark and with the Apit 15 at the meter readings "APEX" line in each group.

After all EL measurements were obtained, the root canal filling materials were completely removed. The actual lengths (ALs) were measured by visualization of the tip of a size 15 K-file at the resection site using a dental loupe with 3.5× magnification. Measurements were repeated three times for each tooth by the same operator, and the mean of these measurements was calculated. The AL was subtracted from the EL measurements for each specimen. Respectively, positive and negative values represented measurements that were long and short of the AL, whereas 0.0 showed coinciding measurements.

Statistical analysis was done with IBM SPSS Statistics version 22.0 (IBM Corp., Armonk, NY). The Kolmogorov-Smirnov test was used to assess the normality of data, and measurements were analyzed statistically using independent sample t-test, repeated-measures analysis of variance, and Bonferroni tests. The level of statistical significance was considered as $p<0.05$.

Results

The mean and standard deviation (SD) values of the difference between EL and AL for each EAL in root-end resected teeth with different resection bevel angles are shown in Table 1. According to the data obtained, no statistically significant differences were observed between the EALs evaluated in teeth resected at an angle of 0-degree ($p=0.250$). There was a significant difference between the EALs when the measurements were taken in teeth resected at an angle of 45-degree ($p=0.002$). The Propex Pixi was more accurate than the Apit 15 at a 45-degree resection bevel angle. Measurements at different resection bevel angles were not statistically different in any EAL groups ($p>0.05$).

Discussion

In a nonsurgical retreatment procedure, which is among the treatment options in case of failed apical surgery, the working length determination may have some hardships as the resection level or angle cannot be exactly determined on the radiograph.[21] When the apex was resected with an angle different from 90-degree to the long axis of the root, it may not be possible to accurately establish the radiographic working length.[22] The present study investigated the reliability of the Dentaport ZX, Propex Pixi, and Apit 15 in the presence of root canal filling material in teeth resected with different resection bevel angles**.**

Previous studies reported that these devices could accurately determine the working length.[15,23-25] Furthermore, other studies showed that these EALs determined the working length accurately after removing the root canal fillings during retreatment procedures.[18,26,27] However, as in apically resected teeth, apical constriction is not always present in teeth with apical root resorption or in teeth with open apices.[28] EAL readings differ from the actual working length for teeth with apical foramina exceeding 0.5 mm, such as immature permanent teeth.[29] Herera *et al.*[30] stated that the accuracy of the Root ZX device within ± 0.5 mm was 87% in 0.6 mm foramen diameter and 84% using files size 45 or larger in 0.7 mm foramina. However, when the foramen diameter was 0.9 mm or 1.0 mm, the accuracy of the device was 73% or 63%, respectively, even within a tolerance of ±1.0 mm. In teeth with simulated apical root resorption, within ± 0.5 or ± 1.0 mm, a previous study reported the accuracy of 76.6% or 96.9% for the Root ZX, 82.8% or 96.9% for the Apit, respectively.[31] In another study, within the margin error of ± 0.5 and ± 1.0 mm, the Root ZX was precise in 77% and 94% of the primary molar teeth with root resorption, respectively.[32]

In the present study, the accuracies of the tested EALs were not affected by different cutting angles. However, the SD value of the Dentaport ZX was lower at 0-degree resection bevel angle than 45-degree resection bevel angle, and a low SD is obtained when the EAL measurements are consistent. These findings cannot be compared with existing data. To the best of our knowledge, no reports on the accuracy of EALs for determining apical terminus in teeth resected with different resection bevel angles are available.

Although no significant differences were noted among the tested EALs in the 0-degree group, the Propex Pixi gave more accurate measurements than the Apit 15 in the 45-degree group. Dentaport ZX is based on the same principle as the original Root ZX. ElAyouti *et al.*[13] reported that the Root ZX (90%) was the most accurate in detecting the apical terminus of the root-end resected teeth within ± 1.0 mm compared with the Raypex 4 (78%) and Apex Pointer (75%) devices. They concluded that all the EALs tested were able to determine the apical terminus of resected teeth within an acceptable range. Uzun *et al.*[12] also claimed that the EAL function of the Tri Auto ZX which features the same electronics as the Root ZX useful for WL determination in orthograde retreatment procedures of root-end resected teeth. However, the auto-reverse function is not useful for these procedures. Similar to the observations of ElAyouti et al.[13] and Uzun *et al.*[12], the present study showed that the three devices were reliable because the greatest mean difference value was 0.238 mm and the accuracy of detecting the resection site within ± 1.0 mm was 100% for all tested devices.

Table 1. Mean and standard deviation (SD) values of the difference between the electronic length and the actual length for each Electronic Apex Locator in root-end resected teeth with different resection bevel angles (mm)

	0-degree Mean ± SD	45-degree Mean ± SD	p values
Dentaport ZX	0.180 ± 0.244^{Aa}	0.209 ± 0.373^{ABa}	0.776
Propex Pixi	0.181 ± 0.332^{Aa}	0.103 ± 0.325^{Aa}	0.454
Apit 15	0.235 ± 0.323^{Aa}	0.238 ± 0.323^{Ba}	0.973
P values	0.250	0.002*	

Different superscript uppercase letters in the same column indicate a statistically significant difference (*p<0.05). Different superscript lowercase letters in the same row indicate a statistically significant difference (*p<0.05).

Table 2 Frequency [n (%)] of the measurements relative to the resection site (0.0).

	0-degree			45-degree		
	Dentaport ZX	Propex Pixi	Apit 15	Dentaport ZX	Propex Pixi	Apit 15
<-1.0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
-1.0 to -0.51	0 (0)	0 (0)	0 (0)	1 (5)	2 (15)	0 (0)
-0.50 to 0.0	3 (15)	5 (25)	4 (20)	4 (20)	3 (15)	4 (20)
0.01 to 0.50	15 (75)	12 (60)	14 (70)	10 (50)	14 (70)	13 (65)
0.51 to 1.0	2 (10)	3(15)	2 (10)	5 (25)	1 (5)	3 (15)
>1.0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Negative values indicate measurements short of the actual length.

Within ± 0.5 mm of the resection site, the accuracies of three EALs (Dentaport ZX, Propex Pixi, and Apit 15) were 90, 85, and 90% for 0-degree resection bevel angle, and 70, 85, and 85% for 45-degree resection bevel angle, respectively (Table 2).

The strictest tolerance limit of ± 0.5 mm[22,33,34] and the more lax tolerance margin of ± 1.0 mm[15,16,27] have been used to evaluate the accuracy of the EALs in many studies. In the present study, difference values falling within these limits were deemed clinically acceptable since it was difficult to visually check the relationship between the rubber stop and the reference point, the rubber stop and the caliper, or the file tip and the caliper. Also, it was difficult to visualize the exact point where the tip of the file reached the resection site, even with magnification, especially in teeth resected with a 45-degree angle. In the 0- or 45-degree groups, the Dentaport ZX resulted in overestimation in 85% or 75% of the canals, respectively. In both 0- and 45-degree groups, the percentages of overestimation were 75% for the Propex Pixi and 80% for the Apit 15. This present result differed from the study of ElAyouti *et al.*[13], who reported that the Root ZX exhibited high accuracy without over-instrumentation of the root canal. The different methodologies might explain this discrepancy; ElAyouti *et al.* determined the electronic measurements with a small size file by taking the average of the two readings (apical 0.0 and coronal 0.0 readings) after root canal filling removal and canal enlargement. A root canal with a large apical size may cause underestimation of the root canal length, especially when using a small size file.[23,35-37]

Conclusions

According to the findings of our study, the mean values of the tested EALs were within the tolerance range of ± 0.5 mm according to the actual length, so the measurements obtained were clinically acceptable. The working length can be successfully determined with electronic apex locators even in the presence of root canal filling in the orthograde revision of root-end resected teeth. The accuracies of the Dentaport ZX, Propex Pixi, and Apit 15 in resected teeth were not affected by the different resection bevel angles. However, Dentaport ZX was accurate to ±0.5 mm in 90% of teeth resected at a 0-degree angle and 70% of the teeth resected with a 45-degree angle. Propex Pixi responded more successfully than the Apit 15 at a 45-degree resection bevel angle

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Conflicts of Interest Statement

The authors declare no conflict of interest.

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