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Does Root Canal Shaping Effect the Accuracy of Electronic Apex Locators in Curved and Straight Root Canals?

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ABSTRACT

Objective: To assess the influence of root canal preparation (RCP) on the precision of electronic apex locators (EALs) in both straight and curved root canals.

Methods: The experimental setup included forty-two extracted human mandibular molars featuring both straight distal canals (0-10 degrees) and curved mesial root canals (30-50 degrees). Initial working length (AWL1) measurements were conducted under a stereomicroscope at X15 magnification prior to root canal preparation (RCP). Subsequently, electronic working length (EWL1) was determined using two different electronic apex locators (EALs) – Propex-Pixi and EndoRadar. RCP was carried out with ProTaper Ultimate F1, F2 files in mesial canals, and F1, F2, F3 files in distal straight root canals. The RCP procedure involved the implementation of a standard irrigation protocol along with the use of a sonic device for activation. Following RCP, measurements were repeated under a stereomicroscope and documented as AWL2. EWL measurements were also repeated and recorded as EWL2 after the preparation. The variation was calculated by subtracting AWL from EWL for each tooth (EWL1-AWL1 and EWL2-AWL2). Statistical analysis employed Paired Sample t-test and Wilcoxon tests.

Results: There was no statistically significant difference observed in the accuracy of Propex-Pixi and EndoRadar Pro before and after root canal preparation for both straight and curved canals.

Conclusion: Root canal preparation did not alter the accuracy of the electronic apex locators (EALs) used in this study, whether applied to curved or straight root canals.

Keywords: Working length, root canal preparation, curvature, straight canal

1. INTRODUCTION

A successful endodontic treatment depends on various factors, but canal preparation is one of the most important steps (1). The distance between the reference point located at coronal part and the minor apical foramen where the root canal treatment (RCT) should terminate is defined as working length (WL) (2). Many studies (3-5) have shown that determination of reliable WL significantly affects the success of RCT. The ideal WL should terminate at the cementodentinal junction serves as a histological marker that establishes the boundary between pulp tissue and periodontal tissue (3). Reduced WL may result in a recontamination of the root canal space, and over-instrumentation may damage periapical healing (6).

Despite efforts to maintain accurate WL, many studies (2,7,8) have shown a reduction in WL during RCT due to canal anatomy variations and this reduction is most commonly observed in curved canals. This phenomenon arises due to the predisposition of the file to become straighter within the root canal, concluding in the excessive removal of dentin from both the inner wall of the curve and the outer wall of the apical region of the root canal (9,10). Consequently, this action leads to the straightening of the root canal and potentially shortening the WL.

In clinical practice, various methods are employed to locate the canal terminus and measure the WL, including electronic apex locators (EALs), radiographic techniques and tactile perception (11). The traditional radiographic techniques have been the most reliable and popular approach for WL determination. This method provides direct observation of the root canal anatomy. However, there are some disadvantages that render this method unsuitable for every situation; for instance, the radiographic apex and anatomic apex may not always coincide, and there are concerns regarding radiation dosages and superpositions of anatomies (12,13).

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EALs have been a major innovation in RCT. They offer several advantages compared to the radiographic method, including continuous monitoring of WL and a reduction in radiographic exposures (14,15). Once the WL is obtained, regardless of the method used, it is crucial to maintain that length throughout the treatment. However, the accuracy of EAL can be affected by the presence of different electrolytes, residual pulp tissue, excessive bleeding in the root canal (16).

The aim of the present study was to assess the impact of RCP on the establishing of WL using Propex-Pixi (Dentsply Maillefer, Ballaigues, Switzerland) and EndoRadar Pro (Woodpecker, Guilin, China) in teeth with curved and straight root canals. The null hypothesis stated that there would be no difference in the accuracy of EALs for before and after RCP.

2. METHODS

The methodology of the study underwent review and took an approval from the The Clinical Research Ethics Committee of Akdeniz University Faculty of Medicine, with decision number of KAEK-398. The size of sample was calculated using G*Power 3.1.9.7. according to results of the pilot study *(α=.05, power=.95, effect size=0.4*). Fourty-two human mandibular molars in similar length were included in this study.

The study excluded the extracted teeth that showed cracks, fracture lines, or had previous RCT after the examination under the operating stereomicroscope (Zeiss Stemi, Carl Zeiss, Germany). Periapical radiographs were taken in the bucco-lingual direction for mandibular molars. Then, the curvature angle of the canal was established using method of Schneider (17). The study exclusively included teeth with straight distal root canals and curved mesiobuccal root canals exhibiting curvature angles falling within the range of 30 to 50 degrees.

With a scaler, residues of hard and soft tissues on the teeth were eliminated. The teeth were immersed in a saline solution to prevent drying out during the study. In all teeth, endodontic access cavities were created. After the apical patency was verified using a number 8 K-file, the teeth in which the number 10 K-file became stuck in apical foramen were included in this study. To ensure a fixed and uniform reference point at coronal area, the cusps of the selected teeth were smoothed down.

2.1. Determination of WL Before Preparation

Each tooth was decoronated to achieve a standardized WL of 15 mm, and patency of apical foramen was checked using a number 10 K-file. Utilizing a stereomicroscope (Zeiss Stemi) with a magnification of X15, a #10 K-type file was meticulously advanced until it became visible at the apical end. Once the file was observed apically, a rubber stop was affixed to the incisal edge. The distance between this rubber stop and the tip of the file was precisely gauged using a digital caliper, and this measurement was documented as the actual length (AL1).

Subsequently, alginate was prepared following the instructions of the manufacturer. The lip clip of the EAL was positioned within the mold containing freshly prepared alginate, and the teeth were submerged into the mold up to the cement enamel-margin. Following this, the electronic length was assessed employing the Propex-Pixi and EndoRadar Pro devices. A number 10 K-file was cautiously advanced into the canal until both EALs (Propex-Pixi and EndoRadar Pro) displayed '0.0' indications on their respective screens.

Once these indications stayed steady for 5 sec on the EALs' screens, a rubber stop was positioned at that specific point to denote the location. Using a digital caliper, the measurement of the distance between the file's tip and the rubber stop was conducted, and this specific value was recorded as Electronic Length 1 (EL1).

2.2. Preparation of Teeth

For the mesial curved canals, ProTaper Ultimate F1 and F2 files (Dentsply Ballaigues, Switzerland) were used for preparation, while the straight distal canals were prepared with F1, F2, and F3 files. Throughout the preparation process, canals were irrigated after each file with sodium hypochlorite (NaOCl, 2 mL of 2.5%) and 5 mL sterile saline solution.

2.3. Determination of WL After Preparation

The measurements were replicated in the same manner prior to the root canal preparation (RCP) phase, and the updated measurements were denoted as AL2 and EL2. To ensure precision and mitigate the potential for operator discrepancies, this complete process was reiterated thrice for each tooth. All the measurements were made by one single operator and another operator read and recorded them.

The extent of variation was established by deducting EL1 from AL1 and EL2 from AL2 for each tooth under consideration. Negative values (-) represented instances where the response was shorter than the recorded value, while positive values (+) indicated instances where the response exceeded the recorded value.

2.4. Statistical Analysis

In this study, statistical analyses were made using SPSS (25.0; IBM, Newyork, USA). The significance level of 5% was set for all tests. The Shapiro-Wilk test was used to evaluate the normality. Wilcoxon Signed Rank Test and Paired T-test was used to compare mean and standard deviation values of WL change for each EAL (Table 1). The Chi-square test was used to compare the success rate of EALs (Table 2).

Table 1. *Mean and standard deviation values of WL change (mm) in root canals for before and after RCP.*

EAL	Mesial canal			Distal canal		
	Mean ± SD		p	Mean ± SD		p
	Before (EL1-AL1)	After (EL2-AL2)		Before (EL1-AL1)	After (EL2-AL2)	
Propex-Pixi	-.140±.96	-.088±.84	**.797**	-.131±63	-.231±68	**.506**
EndoRadar	-.120±1.20	-.065±.78	**.392**	.008±.84	-.029±.55	**.664**

**WL: working length, RCP: root canal preparation, SD: Standart deviation, EL: Electronic length, AL: Actual length.*

Table 2. *Success rate of Propex-Pixi and EndoRadar at ±0.5 mm tolerance range on mesial and distal canals.*

EAL	Success rate of EAL in mesial canals				Success rate of EAL in distal canals			
	Before RCP		After RCP		Before RCP		After RCP	
	n	%	*n*	%	*n*	%	*n*	%
Propex – Pixi	20[a]	47.6%	22[a]	52.4%	18[a]	42.9%	23[a]	54.8%
EndoRadar	21[a]	50.0%	23[a]	54.8%	25[a]	59.5%	24[a]	57.1%

3. RESULTS

A total of 42 mandibular molars were included in this study, encompassing teeth with both straight distal canals and teeth with curved mesial canals. Mean and standard deviation values of WL change for before and after RCP were shown in Table 1. It was observed that no significant difference was found between the pre and post-preparation measurements in the distal and mesial root canals when using Propex-Pixi and EndoRadar Pro. With a tolerance limit for accuracy set at ± 0.5 mm, the achievement of the EALs were displayed in Table 2. The analysis demonstrated that there existed no notable distinction between the success rates of measurements taken before and after the RCP for both the mesial and distal canals, as observed in both the Propex-Pixi and EndoRadar Pro devices. Thus, it can be concluded that both EALs were not affected by the RCP.

4. DISCUSSION

In a curved and narrow root canal, the principal objective of RCP is to transform it into a consistently conical and tapering structure, wherein the smallest area is achieved at the apical extent of RCP. This tapered form allows for better disinfection, and obturation of the root canal, promoting successful RCT outcomes. The cleaning and shaping procedures invariably result in the removal of dentin from the canal walls, irrespective of the chosen preparation technique (18). However, it is essential to maintain a balance during this process to avoid excessive dentin removal, which can lead to complications including thinning of the canal walls, perforation or transportation. ProTaper Ultimate file which was preferred in this this study for RCP, has distinct crystallographic arrangements, which play a key role in ensuring a well-balanced combination of flexibility and strength (19). The system prioritizes proper shaping in the apical third for effective RCT. This also ensures a conservative approach in the coronal two-thirds, minimizing unnecessary removal of tooth structure and preserving as much of the natural tooth as possible (20).

The straightening of canals during the instrumentation process is more likely to occur in cases of curved canals (21). As files navigate through the curvatures, they tend to straighten, resulting in the removal of additional dentin from both the outer wall of the apical section and the inner wall of the curvature of the root canal. This alteration can lead to a modification in the original canal shape, which might influence the WL and the final outcome of the RCT. It has been observed that with an increase in the curve of the apical area of the canal, the likelihood of obtaining inaccurate radiographic WL measurements also rises (22). On the other hand, the determination of the WL in the mesial root canals of mandibular molars has exhibited a higher degree of accuracy and remained relatively consistent with their actual lengths, even when varying degrees of canal curvature were present (23). These observations align with the outcomes of our study. In contrast, studies by Sadeghi et al. (24) and Santhosh et al. (25) have highlighted notable differences between Electronic Length (EL) and Actual Length (AL) in curved canals. However, it's important to note that these studies didn't incorporate canal preparation stages, thereby not assessing the impact of root canal preparation on the precision of EALs in curved canals.

In the context of embedding extracted human teeth for *in vitro* EAL studies, it is important to use materials that closely mimic the properties of the periodontal ligament, such as having similar electroconductive and colloidal consistency. Many studies have utilized materials like agar-agar, gelatin, alginate, or saline solution for this purpose (3,12,15). Among these options, alginate molds have been favored due to their firm consistency, which prevents intrusion of materials, as well as their good electroconductive properties (24). In this study, an alginate mold was selected to closely replicate the properties of the periodontal tissue, aiming to achieve accurate and reliable results in the evaluation of the EALs.

Utilizing a saline solution has been demonstrated to yield dependable measurement data. Kaufman et al. (26) stated that saline and EDTA solutions are considered reliable solutions for electronical measurements. Goldenberg et al. (27) chose saline solution for protocols because it possesses similar properties with alveolar bone. Therefore, sterile solution was preferred in this study during electronic measurement.

After advancements in endodontic treatments, the number of single-visit endodontic therapies has increased (28). Modern endodontic techniques, advancements in canal shaping, irrigation methods, and intra-canal materials have led to shorter treatment times while enhancing the success and reliability of the treatment. However, it is important to note that single-visit treatment may not be suitable for every case. In such cases, to avoid experiencing a loss of WL between visits, it is necessary to perform a re-measurement. By re-measuring, the risk of over – or under-preparation of

the canal can be minimized, leading to a more successful endodontic outcome. Thus, it is important for the EALs to measure the WL accurately after the RCP.

In the context of RCP, a major challenge lies in precisely determining the WL of the canal. Some variables have been established to impact the accuracy of EALs, including the presence of electroconductive fluids, periapical pathosis, the dimension of the major apical foramen, the shape and size of the file, and the operator's skill level (29,30). Among many studies exploring the effectiveness of EALs in defining the apical foramen, it has been noted that wider apical diameters can indeed influence the precision of EAL measurements (31,32). Taking into account Herrera et al.'s (32) investigation, which demonstrated that EAL measurements were notably more precise when the majör foramen diameter was 0.25 mm compared to measurements within the range of 0.45 to 0.70 mm, the current study incorporated this finding into its approach. In alignment with this, the present study observed an enhanced success rate of the EALs after preparation, except for the EndoRadar Pro in post-preparation measurements of the distal lateral canal, which is consistent with previous research. To ensure consistency, the study selected teeth with a smaller foramen diameter, allowing for the passage of a 10/15 file. This selection strategy aimed to optimize the accuracy of EAL measurements by focusing on teeth with an appropriate foramen size that is more conducive to obtaining reliable readings.

This study exclusively focused on the mesiobuccal canals of mandibular molars for inclusion. This deliberate selection aimed to mitigate potential significant discrepancies in apical termination sizes that might arise from different types of canals. It's worth noting that the dimension of the canal at its apical termination point can impact the precision of EL determination (33).

Olivera et al. (34) conducted an efficacy study of five apex locators and found that Propex Pixi demonstrated a success rate of 67% when the measurement was 1 mm short of apical foramen. In the study on 30 single-rooted extracted teeth conducted by Serna Pena et al. (35) it was found that the accuracy of Propex-Pixi was 73% when the measurement was in ±1 mm tolerance range. De-Deus et al. (36) investigated the precision of EALs using µCT and disclosed that the accuracy of Propex-Pixi was determined to be 52.1% within a ±0.5 mm tolerance range. In another study conducted on curved mesial canals (37), the accuracy rate of Propex-Pixi was found to be 54.3% within a ± 0.5 mm range. In this study, the success rates of Propex-Pixi and EndoRadar Pro at ±0.5 mm tolerance range on curved canals were 52.4% and 54.8% respectively. The variation in the success rate of accuracy can be due to the tolerance range, variation in the solution used during measurements, and root canal morphology. In addition, a previous study (38) stated that the performance of Propex-Pixi and Root ZX II were not affected from the different root canal sealers. Another study (39) investigated the accuracy of different apex locators including Propex-Pixi in determining the minimum perforation diameter and showed that all devices were successful in identifying the root perforations. However, EndoRadar Pro is a new EAL, and as far as our knowledge, no literature is available to compare its accuracy.

There are some studies reported changes in WL following due to root canal Preparation (8,36,37). However, any previous study was evaluated the effect of RCP on the accuracy of EALs during determination of WL according to our knowledge. The null hypothesis that root canal preparation has no affect on the accuracy of EALs usen in this study was accepted based on the results of this study.

This study has certain limitations, including the lack of periodontal ligament and intraoral conductive fluids due to its in vitro nature. Although occlusion reduction was performed to establish a reference point, achieving consistent WLs within each tooth is complicated because of the inherent variations in canal anatomy for mesial canals of mandibular molars. While the present study offers valuable insights into the impact of RCP on WL measurements using Propex-Pixi and EndoRadar Pro, researchers and readers should consider these limitations when interpreting the results and applying them to clinical scenarios. Future studies with more representative in vivo conditions may help further validate and refine these findings.

5. CONCLUSION

In the scope of this study, the extent of root canal curvature was found to lack any substantial influence on the precision of the EALs. Likewise, the process of root canal preparation did not exhibit any discernible effect on the accuracy of the EALs. Consequently, the findings propose that neither the curvature of root canals nor the RCP significantly affect the accuracy of the EALs within the context of this specific investigation.

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