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Effect of Preflaring on Accuracy of Endodontic Length Determination by Four Electronic Apex Locators

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ORIGINAL ARTICLE

Effect of Preflaring on Accuracy of Endodontic Length Determination by Four Electronic Apex Locators

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ABSTRACT

Objective: Root canal anatomy significantly impacts the working length determination. This study aimed to investigate the effect of the preflaring technique on the accuracy of four electronic apex locators. **Methods:** Forty-five single-canal central maxillary teeth were selected. The working length was measured before and after the coronal preparation by four types of electronic apex locators in the range of ±0.5 and ±1 mm matched for the apical constriction. The actual working length was calculated under a microscope. Data were analyzed using ICC and paired *t-tests* in SPSS16. A $p < 0.05$ was considered significant. **Results:** The accuracies of Root ZX, DTE, Denjoy, and Coxo apex locators in the range of ± 0.05 mm were 71.1, 93.3, 84.4, and 75.6% before preflaring, and 82.2, 93.3, 97.8, and 100% after that. The corresponding values in the range of ±1 mm were 86.7, 97.8, 93.3, and 100% before and 97.8, 100, 100, and 100% after preflaring. Significant differences were found between the working lengths measured by the four devices and the actual working lengths before and after preflaring. **Conclusion:** The preflaring technique could impact the performance of apex locators in determining the working length and may be advocated for better outcomes.

Key words: apical constriction, electronic apex locator, major foramen, working length

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INTRODUCTION

The main point of root canal preparation is to remove the microorganism to resolve the infection and prevent canal recontamination, affecting endodontic treatment's success. This goal can be achieved by determining the correct working length.[1] Treatment with a length greater than the actual canal length destroys periapical tissues, inflammation, and external body reaction. In contrast, treatment with a length less than the working length results in tissue remains and treatment failure.[2,3] The termination point of the canal preparation is determined based on the narrowest section of the root canal where the pulp tissue ends, and the periodontal tissue begins.[4] According to microscopic studies, there is a gap of 0.5-1 mm between the minor and major apical constriction in 68% of cases.[5,6] Radiography, tactile sensation, and apex locators determine the exact working length.[6] X-ray techniques have various disadvantages, such as patient exposure to an ionizing beam, two-dimensional images of a three-dimensional object, and the inability to accurately determine the location of the apex because the radiographic apex is determined rather than the anatomical apex.[7,8] During instrumentation, the tactile sensation of the endodontic file from the position of the apical constriction may be unreliable due to calcifications, the curvature of the canal, or the open root ends.[9]

Since the invention of the apex locator in 1962 by Sunada, different generations of apex locators have been introduced as a tool for determining the exact working length.[10–12] Apex locators show different functions depending on resistance in early generations or two or multiple frequencies in later generations under the influence of blood, moisture, calcification, and residual dentin in the apical region.[2,11]

Mandlik compared the performance of radiovisiography, electronic apex locator, and hand touch in determining apical constriction. He found that the electronic apex locator was more reliable for determining the working

length.[2] Various techniques, such as preflaring, are used to prepare the dental canal. This technique removes dentinal barriers in the coronal part of the dental canal. It allows a direct connection between the file's tip and more apical canal areas. According to the literature, in cases where this technique is used to prepare the dental canal, the canal end by tactile sensation detection increases from 35% to 75%.[13,14]

The preflaring technique has been recommended in various apex locator systems and instrumentation techniques. However, in most studies, accuracy comparisons in determining working length were only performed at one specific distance from the constriction.[15] On the other hand, these studies were carried out on brands that are less known worldwide or have more limited use. Considering that Root ZX was the most commonly used EAL in the included studies, this study joins three other brands, all of which function as third-generation apex locators based on the multi-frequency impedance system.[15,16]

Accordingly, this study aims to investigate the impact of preflaring on the performance of four apex locators: Root ZX (J. Morita Corp., Tokyo, Japan), DTE (Wood Pecker, Foshan China), DENJOY (Denjoy Dental Co. Changsha, China), and Coxo (Foshan Coxo Medical Instrument Co. China). Moreover, as a null hypothesis, there is no significant difference in the effect of preflaring on the accuracy of determining working length in endodontics between the four apex locators mentioned.

METHODS

This study was performed with the ethical approval of IR.GOUMS.REC.1397.163 under protocol number 110295 in the Dental Research Center of the Faculty of Dentistry, Golestan University of Medical Sciences, Iran.

This study used 45 single-canal teeth (central maxilla) with mature root apex extracted due to periodontal problems. Direct radiography also was used to confirm a type I canal and the absence of any root *resorption*. Exclusion criteria included canal calcification, open apex, the presence of any internal or external *resorption*, bicanal tooth, and severe curvature of the root.

All samples were immersed in isotonic sodium hypochlorite solution (Golpasand Co., Babol) for 15 min to disinfect and remove the remaining tissues. The teeth were stored in a physiologic serum solution (Iran Pharmaceutical Drug Company) until use. The flowchart below shows the steps for conducting the study (Figure1).

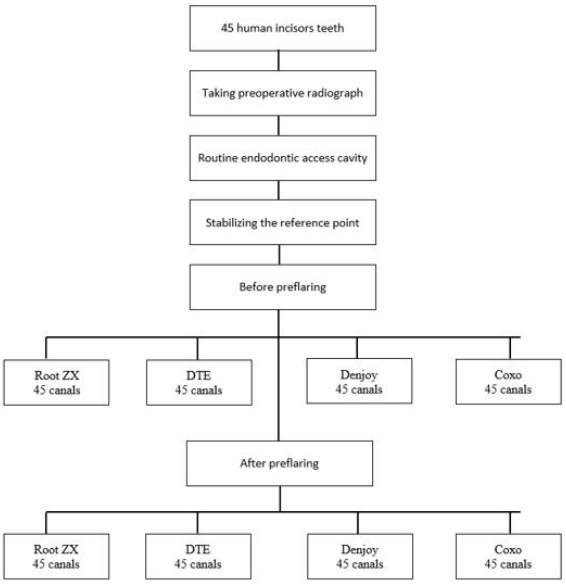

Figure 1. Illustrative flowchart representative of the study design.

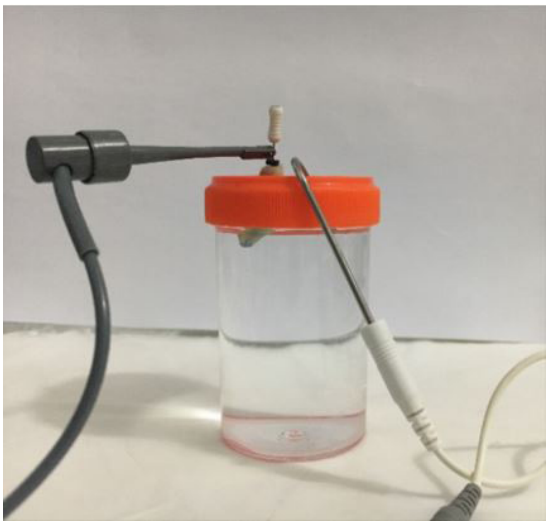

Figure 2. A cylinder containing normal saline to simulate the oral environment and the electrical circuit. The rubber stop was secured on the middle of a flattened surface of the incisal edge.

After preparing the coronal access cavity with a high-speed diamond turbine bur (Jota 801/014, Switzerland) with cooling, the location of the canals was determined by the probe. The path's lack of obstruction was ensured by passing K FILE # 8 (Mani, Japan) from the end of the apex. The canals were then washed with hypochlorite 1% (NaOCl) with a 23-gauge needle to remove debris and pulp residues.

For electronic evaluation of the working length, a cylindrical can made of poly(methyl-methacrylate) with two holes for placing the tooth and lip attachment

was used. The can was filled with normal saline for electronic evaluation of the samples. After drying the tooth surface and removing residual moisture from the canals by paper points (Meta Biomed, Chungbuk, Korea), the exact working length of all samples was measured with electronic apex locators as follows. First, manual stainless steel K file #10 (Mani Inc, Tochigi, Japan) with silicone rubber was slowly passed through the apex area and then returned to the narrowest point of the canal as per the apex manufacturers' instructions (0.5 apexes). The silicon rubber was then fixed at the incisal edge. Due to the matching measurement method of four apex locators, it is necessary to fix the reference point of the measurement on the rubber stub during the examination. So, the incisal surface of all teeth must be free of caries, cracks, or fractures and be completely smoothed by milling to stabilize the position of the rubber stop in the center of this surface (Figure 2).

The file length removed from the canal was measured with a ruler to within 0.25 mm and recorded as electronic working length.

Electronic apex locators determined the lengths of all canals before and after preflaring. To determine the length of the dental canal for preflaring, we passed K file #8 through an apical foramen. Consequently, the file was pulled back until the tip of the file was positioned at the apical foramen edge, observed under a microscope with 4X magnification. The rubber stopper was accurately fixed on the incisal edge. Then, the file was removed from the teeth and placed on an endodontic ruler (Zolal Teb Shimi Co., Tehran), and the distance between the file tip and the rubber stopper was recorded as the canal length. The working length was obtained by subtracting 0.5 mm from the measured length. Two-thirds of the measured length were calculated for coronal preparation and preflaring.

Canal preflaring was performed by an endodontist using a rotary device (X-Smart; Dentsply Maillefer) and SX and S1 ProTaper files (Dentsply Maillifer, Ballaigues, Switzerland) to two-thirds of the working length with brushing movements. After preflaring, the canal was washed with 2 mL sodium hypochlorite (1%). Then, the working length was again measured using the four apex locators. Finally, the actual working length was determined as follows. First, 4 mm of the root end was removed from the buccolingual dimension using a finishing bur (Jota, Switzerland), and a thin layer of dentin tissue was left. Then, the remaining layer was gently removed by a scalpel to prevent damage to the dental structure (handle No. 3 with blade No. 15). Then, the tip of K file #10 was placed in the canal, approximating the narrowest apical point. The actual working length was measured and recorded by direct observation of an apical constriction under a stereomicroscope (Optix, Penpix Z3, and China) with a magnification of 20X (Figure 3).

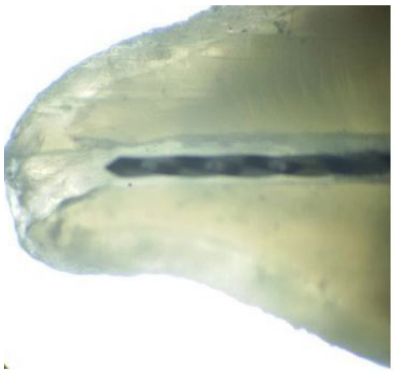

Figure 3. The microscopic micrograph of the apical constriction by passing the kfile#15.

The difference in the working lengths measured by four apex locators before and after preflaring and the actual working length measured by the stereomicroscope were analyzed by the interclass correlation coefficient and paired *t-test* at a significance level of 0.05.

RESULTS

The detailed results are presented in the following tables and diagrams. To evaluate the accuracy of apex locators, we compared the recorded data from the apex locators to the actual tooth lengths using the Intraclass Correlation Coefficient (ICC) method. According to the ICC values, which were 0.982 and 0.983 before and after preflaring, we ensured an excellent correlation between the apex locators' results and actual working length. According to Table 1, Root-ZX, DTE, Denjoy, and Coxo determined that the working length exactly matched the apical constriction in 8.9%, 31.1%, 17.8%, and 17.8% of cases before preflaring, respectively. Besides, Roots ZX, DTE, Denjoy, and Coxo determined that the working length exactly matched the apical constriction in 17.8%, 44.4%, 33.3%, and 48.9% of cases after preflaring, respectively. At distances of ±0.5 mm and ±1 mm to the apical constriction, the results of four apex locators are reported in Table 1 before and after preflaring, respectively.

To compare the actual working lengths with those measured by four apex locators, we first analyzed data using the Shapiro-Wilk test to evaluate the normal distribution. All data showed a normal distribution ($p > 0.05$). Then, the paired *t-test* was used to compare actual and measured lengths. The mean measured actual length is 21.08 mm. The mean working lengths measured by Root ZX, DTE, Denjoy, and Coxo before preflaring was 21.46, 21.9, 21.46, and 21.45%, respectively. After preflaring, the mean working lengths measured by Root ZX, DTE, Denjoy, and Coxo were 28.21, 20.95, 21.16, and 21.18 mm, respectively (Table 2).

Table 1. The number and percentage of samples in the range of apical constriction before and after preflaring.

Range of variation from the actual length		Root ZX	DTE	Denjoy	Coxo
Before preflaring	At a distance of ±0.5 mm to the apical constriction	4 (8.9%)	14 (31.1%)	8 (17.8%)	8 (17.8%)
	at a distance of ±1 mm to the apical constriction	32 (71.1%)	42 (93.3%)	38 (84.4%)	34 (75.6%)
		43 (95.6%)	44 (97.8%)	42 (93.3%)	45 (100)
After Preflaring	At a distance of ±0.5 mm to the apical constriction	8 (17.8%)	20 (44.4%)	15 (33.3%)	22 (48.9%)
	at a distance of ±1 mm to the apical constriction	37 (82.2%)	42 (93.3%)	44 (97.8%)	45 (100%)
		44 (97.8%)	45 (100%)	45 (100%)	45 (100%)

Table 2. Descriptive statistics and comparison of the mean difference between the actual length and that observed with electronic apex locators before and after preflaring.

Method		Length measured by electronic apex locators		The difference in the actual length		Paired T-test	
		Mean	SD	Mean	SD	T	p
Actual working length		21.08	2.19	—	—	—	—
Before preflaring	Root ZX	21.46	2.25	0.377	0.496	5.397	0.010
	DTE	21.29	2.19	0.205	0.366	3.762	0.010
	Denjoy	21.46	2.18	0.372	0.360	6.936	0.010
	Coxo	21.45	2.20	0.361	0.347	6.967	0.010
After preflaring	Root ZX	21.28	2.27	0.200	0.498	2.689	0.010
	DTE	20.95	2.22	-0.133	0.322	-2.774	0.008
	Denjoy	21.16	2.14	0.777	0.323	1.613	0.014
	Coxo	21.18	2.23	0.100	0.263	2.548	0.014

According to the results, the working lengths measured by all four apex locators were reduced after preflaring. In other words, the working lengths were closer to the actual lengths after preflaring.

The difference between the mean working length measured by Root ZX and the actual length was 0.377 mm before preflaring. However, the differences between the actual length and those measured by DTE, Denjoy, and Coxo were 0.205, 0.372, and 0.361 mm, respectively. The mean differences between the working lengths and the measurements of Root ZX, DTE, Denjoy, and Coxo after preflaring were 0.20, -0.133, 0.077, and 0.1 mm, respectively.

The differences in the mean working lengths measured by Root ZX, DTE, Denjoy, and Coxo before and after preflaring were 0.177, 0.338, 0.294, and 0.261 mm, respectively. According to the paired *t-test*, there was a significant difference between the working length measured by apex locators before and after preflaring ($p < 0.05$). The mean and standard deviation of each mesearment before and after preflaring are shown in figure 4.

The paired *t-test* evaluated the working lengths measured by four apex locators before and after preflaring. No significant differences were found between Root ZX and Coxo ($p = 0.773$ and 0.118), Root ZX and Denjoy ($p = 0.918$ and 0.09), and Coxo and Denjoy ($p = 0.819$ and 0.643). However, a significant difference was found between Root ZX and DT, Coxo and DTE, and Denjoy and DTE ($p < 0.05$) both before and after preflaring.

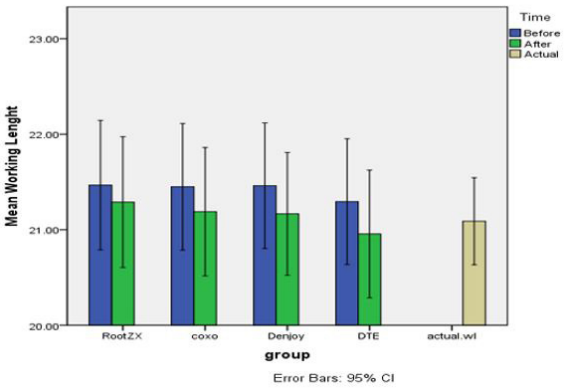

Figure 1. Electronic apex locators measured the mean working length before and after preflaring.

DISCUSSION

The proper working length is one of the main factors in determining the prognosis of root canal treatment.[17] On the other hand, protecting the minor apical foramen is essential to achieving proper filling and preventing

the apical exit of the canal content.[5] The success of root canal treatment depends on determining the exact working length.[1,6] However, the precision of apex locators has always received much attention from researchers.[18–20] One of the most critical factors affecting the determination of working length is preflaring to remove coronal dentin and easier contact of the tip of the file with the apical constriction.[21,22] The preflaring technique has been recommended in various apex locator systems and instrumentations.[15,16,23,24] However, it is unclear whether preflaring influences the accuracy of the apex locators used in this study.

Several methods, including radiography, tactile sensation, and various electronic methods, are used to determine the length of the dental canal, each with its advantages and disadvantages.[25] Many studies have demonstrated the advantages and clinical efficacy of various models of electronic locators. Given the introduction of newer generations, dentists are looking for less costly apex locators, even with more precision than conventional apex locators.[5] Various studies have assessed the accuracy of apex locators in determining the working length. There are differences in applying an apical reference point, so some authors consider the minor apical constriction as an apical reference point and ending point of the canal measurement.[26,27] In contrast, others choose the major foramen or apical foramen.[28,29]

However, considering cases where the measurement was consistent with the apical constriction before preflaring, these values were 8.9% for Root ZX, 17.8% for Denjoy and Coxo, and 31.1% for DTE. The corresponding values after preflaring were 17.8%, 44.4%, 33.3%, and 48.9%, respectively. Various studies have reported accuracies of 43%–89% for apex locators.[30,31] At a distance of ±0.5 mm to the apical constriction, the accuracies of Root ZX, DTE, Denjoy, and Coxo before preflaring were 71.1%, 93.3%, 84.4%, and 75.6%, respectively; the corresponding accuracies after preflaring were 82.2%, 93.3%, 97.8%, and 100%. These values were in a study by Pascon et al.[32] and Werbas et al.[33] between 31% to 39% and 70% to 80%, respectively. At a distance of ±1 mm to the apical constriction. The results of this study are consistent with those of ElAyouti et al.[34] and ElAyoti et al.,[35] where accuracies of 73%–90% were reported for apex locators. In general, the results of our study indicated that the working lengths measured by four apex locators were close to the actual lengths after preflaring, which agrees with other studies in this field.[30,34,36]

This study evaluated the performance of Root ZX, Denjoy, Coxo, and DTE apex locators. All four apex locators significantly improved the accuracy of determining the working length in each specimen after the preflaring procedure. Therefore, the null hypothesis was rejected, and it was clearly shown that preflaring could improve measurement accuracy.

Finally, several factors, including the mechanism used to determine length, the device's operation, and the device's resistance, capacitance, or frequency, can affect results.[37,38] Therefore, these four apex locators should be further investigated in this regard.

CONCLUSION

Preflaring is effective in the accurate calculation of the actual root canal length. According to the results, all apex locators, except for DTE, showed an acceptable accuracy in determining working length within the accuracy range specified in this study.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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