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Original Article

Influence of calcium hydroxide residues after using different irrigants on the accuracy of two electronic apex locators: An *in vitro* study

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ABSTRACT

Background: The purpose of this study was to evaluate the effect of calcium hydroxide ($Ca[OH]_2$) residues on the accuracy of two electronic apex locators (EALs) (Root ZX and Raypex 6) in the presence of different irrigants.

Materials and Methods: In this an *in vitro* study Eighty single-rooted human mandibular premolars were selected. The crowns of the teeth were removed to standardize the working lengths (WLs). Actual WLs (AWLs) were recorded, and the root canals were shaped using protaper rotary instruments up to size F3. Then, the root canals were dried and filled with injectable Ca $(OH)_2$ paste and the access cavities were temporarily sealed. Teeth were put into four alginate boxes, including two experimental groups (n = 30) and two control groups (n = 10). The pools of alginate were wrapped in wet gazes and stored at 37°C and 100% humidity for 7 days. Then, the root canals were exposed and Ca $(OH)_2$ paste was removed by normal saline or 5.25% sodium hypochlorite irrigation followed by 17% ethylenediaminetetraacetic acid (EDTA), and the electronic WL (EWL) was measured by Root ZX and Raypex 6. Differences of EWL from AWL were calculated. Furthermore, the percentage of acceptable measurements (tolerance limit of ± 0.5 and ± 1 mm) was calculated for each apex locator. One-way ANOVA test with *post hoc* paired *t*-test and Chi-square test was used to analyze the data ($P < 0.05$).

Results: The results showed that there was no significant difference between the accuracy of two EALs and irrigants ($P > 0.05$).

Conclusion: The present study revealed that no statistically significant differences were observed between the two apex locators after $Ca(OH)_2$ paste removal with different irrigants.

Key Words: Calcium hydroxide, sodium hypochlorite, therapeutic irrigation, tooth apex

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INTRODUCTION

Correct length determination of a root canal system can influence the outcome of endodontic treatment.[1] It is widely accepted that the apical constriction is the point that root canal instrumentation and filling should be terminated, where the pulp ends and the periodontal ligament begins.[2] Radiographic and electronic methods are currently used to determine the correct root canal length. Due to the limitations

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of radiography,[3,4] the use of electronic devices has increased in recent years. Although apex locators effectively and reproducibly locate the apical foramen,[5,6] some factors such as endodontic solutions which used during preparation,[7-9] apical constriction diameter,[10] root canal preenlargement,[11] retreatment procedures,[12] and intracanal medicaments[7] can influence the accuracy of readings. Due to the complexity of the root canal system, none of exciting cleaning and shaping methods can completely remove the bacteria. Therefore, intracanal medicaments used in multiple visits are used to reduce the pathogenic species associated with pulp necrosis.[13]

Calcium hydroxide ($Ca[OH]_2$) is an intracanal medicament, which has been widely used, especially in cases with necrotic pulp. $Ca(OH)_2$ must be removed before obturation because its presence on root canal walls adversely affects the penetration of sealers into the dentinal tubules.[14,15] Many techniques and irrigants were introduced for $Ca(OH)_2$ removal.[16,17] To remove the $Ca(OH)_2$ from the root canal, instrumentation by master apical file and simultaneously irrigation by different endodontic irrigants are suggested. There are various techniques to remove $Ca(OH)_2$ from the root canal. This usually accomplished through several irrigant rinses in conjunction with hand or rotary instrumentation or ultrasonics. Most common irrigants have been used included saline, sodium hypochlorite (NaOCl), ethylenediaminetetraacetic acid (EDTA), and combinations thereof.[18] NaOCl is the most common used irrigant in endodontics, and the most frequently described method to remove $Ca(OH)_2$ from the root canal is combination use of NaOCl and EDTA.[19] However, it was shown that instrumentation and irrigation cannot completely clean the root canal walls,[20] and it has been reported that in this method, $Ca(OH)_2$ residues were remained at the apical portion of the canal.[21]

Raypex 6 is the last member of Raypex series electronic apex locators (EALs). The clinical performance of Raypex 4 and 5 was found to be successful.[22,23] Moscoso *et al*. in an *in vitro* study showed that there were no statistically significant differences between Dentaport ZX and Raypex 6 under *in vivo* clinical condition.[24]

Uzunoglu *et al.* in an *in vitro* study showed that the residues of $Ca(OH)_2$ adversely affected the accuracy of Root ZX.[7] To the best of our knowledge, there is no information to evaluate the influence of $Ca(OH)_2$ residues on Raypex 6 EAL. Thus, the aim of this study was to evaluate and compare the effect of Ca(OH) remnants after irrigation by different irrigants on the accuracy of Raypex 6 and Root ZX EAL.

MATERIALS AND METHODS

Eighty mandibular single-rooted premolars were selected for this *in vitro* study. Calculus and soft-tissue debris were removed from the teeth and then stored in 1% thymol solution for disinfection. To minimize the variables, the crowns of the teeth were decoronated at the level of cementoenamel junction with a diamond disc to standardize the length of roots to 15–17 mm. The root canals patency was checked using a K-file size 10 (Dentsply Maillefer, Switzerland), and the working lengths (WLs) were determined using size 10–20 K-files depending on the apical foramen sizes. A K-file was inserted into the canal and the tip of the file was checked until it became visible through the foramen under microscope (Dunwell Tech, USA) at ×12 magnification. An actual WL (AWL) was measured 0.5 mm short of the apical foramen, and a single operator prepared all root canals. The coronal one-third of the canals were flared with size 2–3 Gates-Glidden burs (Jota AG co., Switzerland) and remaining root canals were shaped using protaper rotary instruments (Dentsply Maillefer, Switzerland) at a speed of 300 rpm up to size F3 (size 30). Between each instrument, copious irrigation by sodium hypochlorite (NaOCl) 5.25% solution (Poura, Iran) with a syringe and a 27-gauge needle 2-mm shorter than WL was done. Then, all the root canals were finally irrigated with 5 ml 17% EDTA (Master-Dent, Dentonics Inc., USA) and 5 ml distilled water. The teeth were dried by paper point (Meta Biomed, South Korea) and filled with injectable $Ca(OH)_2$ paste (SURE-Paste, Sure Dent Corp., Korea), and the access cavities were temporarily sealed with Cavit (Cavisol, Golchai Co., Iran). Mesiodistal and buccolingual radiographs were taken to confirm complete root canals filling. An alginate model was used for testing apex locators to mimic the clinical situation. Four plastic boxes were filled with alginate (Tropicalgine, Zhermack, Italy) and the teeth were randomly distributed in them. Two boxes were designed for experimental groups according to the apex locator and irrigants (n = 30), and two boxes were prepared for control groups (n = 10). The pool of alginate was wrapped in wet gazes and stored at 37°C and 100% humidity for 7 days. The apex locators used in this study were: Root ZX (J Morita Corp., Tokyo, Japan) and Raypex 6 (VDW, Munich, Germany).

$Ca(OH)_2$ removal was performed by two different irrigants: normal saline (Darou Pakhsh, Iran) and NaOCl 5.25% followed by EDTA. To avoid bias, during $Ca(OH)_2$ removal, apical foramens of all the teeth were filed until size 30. The teeth in the positive control group were not filled with $Ca(OH)_2$ paste, and in the negative control group, the $Ca(OH)_2$ was not removed from the root canals. Then, WLs were measured by two EALs when the root canals were filled with irrigants such that the apical third of the tooth was fulfilled with the irrigants. The metal lip clip was placed into the alginate, and the silicon stop was adjusted to the nearest available anatomical landmark of the teeth. The measuring file was moved into the canal until the display level the APEX point displayed on the monitor for Root ZX, then operator passed the file over the APEX point and the termination point was the first line in the red area. With the Raypex 6, the termination point was determined and the red bar began flashing according to the manufacturer's instruction. Then, the K-file was fixed as the WL and withdrawn from the root canal, and the distance from the reference point to the file tip was measured, and then, 0.5 mm was subtracted from every measurement to achieve the situation of apical constriction. Each measurement was repeated three times by a static endodontic ruler, and the mean average electronic WL (EWL) was recorded. Differences from AWL were calculated (AWL–EWL). Furthermore, the accuracy of apex locators was calculated as the percentage of acceptable measurements (tolerance limit of ±0.5 and ±1 mm). One-way ANOVA with *post hoc* paired *t*-test was used to analyze the data ($P < 0.05$). Chi-square tests were used to compare percentages ($P < 0.05$).

RESULTS

The difference between the mean EAL and the AWL was calculated for teeth in the presence of different irrigants in tolerance limit of ±0.5 and ±1 mm. The calculated absolute difference values are reported in Table 1. There was no significant difference between the accuracy of two EALs and irrigants ($P > 0.05$) [Table 1].

The control group with no $Ca(OH)_2$ removal was significantly different from experimental groups ($P < 0.05$), and the control group with no $Ca(OH)_2$ placement was not significantly different from experimental groups ($P > 0.05$). The calculated apex locators' accuracy in the presence of two irrigants is shown in Table 2.

Table 1: The absolute difference value between the mean effective attenuation length measurements and the actual working length for Raypex 6 and Root ZX*

Group	|AWL – EWL| for Raypex 6	|AWL – EWL| for Root ZX
Irrigation with 10 ml 0.9% saline	0.0840±0.5772^{a,A}	0.0066±0.427^{a,A}
Irrigation with 10 ml 5.25% NaOCl/EDTA	0.1586±0.4554^{a,B}	0.1203±0.4153^{a,B}
No CH removal (negative control group)	0.5230±0.4356^{b,C}	0.4370±0.4651^{b,C}
No CH placement (positive control group)	0.1190±0.3853^{a,D}	0.0200±0.6303^{a,D}

Same lowercase superscript letter in columns means no significant difference at P=0.05 level; Same uppercase superscript letter in rows means no significant difference at P=0.05 level; *Paired *t*-test. EWL: Electronic working length; AWL: Actual working length; NaOCl: Sodium hypochlorite; EDTA: Ethylenediaminetetraacetic acid; CH: Calcium hydroxide

DISCUSSION

In this study, the accuracy of two different EALs was evaluated after $Ca(OH)_2$ removal by different irrigants.

The use of $Ca(OH)_2$ paste between therapeutic sessions is suggested due to its excellent antimicrobial efficacy. The selected method for $Ca(OH)_2$ removal was supported by Lambrianidis who suggested instrumentation by master apical file with copious irrigation.[19,25] Previous studies showed that none of the different removal techniques and irrigants can completely clean $Ca(OH)_2$ from the root canal walls and considerable amounts of medicament remnants were remained,[7,18,25] and these remnants of $Ca(OH)_2$ can adversely affect the outcome of treatment. Holland *et al.* reported that the residual $Ca(OH)_2$ in dentinal tubules causes the decreasing tubular permeability and endangers the outcome of the treatment.[26]

NaOCl is primarily used as an endodontic irrigant and has great efficacy in disinfecting root canals.[27,28]

Van der Sluis *et al.* reported that NaOCl is an effective irrigant in removal of $Ca(OH)_2$ paste, especially in the apical root canal and when used during passive ultrasonic irrigation.[29] Adversely, Salgado *et al.* showed that the worst results of $Ca(OH)_2$ removal were in the NaOCl irrigation group.[30] Removal of $Ca(OH)_2$ from the root canal with copious irrigation of NaOCl

Table 2: The accuracy (%) of electronic apex locators after calcium hydroxide removal (tolerance limit of±0.5 and±1 mm)**

Group	*n*	Accuracy of EAL (%) ±0.5 mm (%)	Accuracy of EAL (%) ±1.0 mm (%)
Root ZX/irrigation with 10 ml 0.9% saline	30	83.3	96.7
Raypex 6/irrigation with 10 ml 0.9% saline	30	80	96.7
Root ZX/irrigation with 10 ml 5.25% NaOCl/EDTA	30	86.7	93.3
Raypex 6/irrigation with 10 ml 5.25% NaOCl/EDTA	30	76.7	96.7

There was no significant difference at *P*=0.05 level in columns and rows. **Chi-square test. NaOCl: Sodium hypochlorite; EDTA: Ethylenediaminetetraacetic acid; EAL: Electronic apex locators

and EDTA is the most frequently described method.[19] Hence, the irrigation with EDTA after NaOCl was used in this study. Although it is likely that EDTA may chelate $Ca(OH)_2$ remnants and the removal of this paste became easier by following NaOCl irrigation, other studies could not confirm that these combinations of irrigants can remove $Ca(OH)_2$ totally and still found extensive $Ca(OH)_2$ remnants.[19,31]

There are several studies about the influence of different irrigants on the accuracy of EALs. According to the manufacturer, the accuracy of new generation EALs is not adversely affected from irrigation. Some studies showed that there was no significant correlation between the accuracy of EALs and irrigation solution and the irrigation do not affect the accuracy of the electronic readings.[32-34] Similarly, in this study for each EAL, regardless of the irrigants, the accuracy of readings was not significantly different in both ±0.5 mm and ±1 mm tolerance. Adversely, Kang and Kim reported that NaOCl gave rise the readings to significant differences among tested EALs include Root ZX. Furthermore, they concluded that when saline was used as an irrigant, the mean discrepancies for Root ZX were >0.05 mm.[9]

Raypex EAL is a widely used EAL and Raypex 6 is a recently developed EAL. Stöber *et al.*, evaluated the clinical performance of Raypex 5, found that it is 75% accurate to ±0.5 mm and 100% to ±1 mm.[35] Furthermore, in an *in vivo* study, Somma *et al.* reported that the accuracy of Raypex 5 and Dentaport ZX is not significantly different and both of the EALs have correct measurements.[22]

Some studies which compared different EALs to Root ZX reported that accuracy of the Root ZX is high.[36,37] In accordance with the previous studies,[36,38,39] based on the results of this study, the Root ZX apex locator revealed high success rate in the presence of both irrigants [Table 2], and similarly, the success rate of Raypex 6 is high and not significantly different from that of Root ZX.

In this study, an *ex vivo* alginate model was selected for investigating EALs. This media has similar electrical resistance to the periodontium. The advantages of this *ex vivo* model were the simplicity, ease of use, and the ability to have strict control over the experimental conditions tested. The disadvantages of laboratory models are the inability to simulate conditions *in vivo*.[5] *Ex vivo* studies use electroconductive materials such as alginate to simulate the clinical situation. Sometimes, the media can leak through the apical foramen and may cause premature readings. Furthermore, it has been shown that some *ex vivo* experimental models report greater accuracy for apex locators than clinical conditions.[40] Therefore, the results of laboratory studies could not be directly extrapolated to the clinical situation, and the authors of the present study suggest further *in vivo* studies to better evaluate these EALs after $Ca(OH)_2$ paste removal.

CONCLUSION

The present study revealed that no statistical significant differences were observed between Raypex 6 and Root ZX EALs after $Ca(OH)_2$ paste removal with normal saline and NaOCl irrigation.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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