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ORIGINAL ARTICLE
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Comparative evaluation of the effect of various irrigants and dry canal on electronic apex locators in locating simulated root perforations: an *in vitro* study

Avaliação comparativa do efeito de vários irrigantes e canal seco em localizadores apicais eletrônicos na localização de perfurações radiculares simuladas: um estudo in vitro

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ABSTRACT

Objective: this study aimed to evaluate the effects of irrigants and dry canal on the accuracy of electronic apex locator (EAL) in locating simulated root perforations. **Material and methods:** twenty single-rooted, mandibular premolars were decoronated at CEJ, and the contents were removed with a barbed broach. The canals were instrumented up to a size of 15 K-file. The roots were artificially perforated at 4 mm from the anatomic apex. The actual length (AL) up to the perforation site was determined. The electronic length (EL) of perforations was obtained by Root ZX mini and iRoot in the dry canal and in the presence of 5.2% NaOCl, SmearOff, and 0.9% sodium chloride using a size 20 K-file. The differences between the EL and AL of the perforations were calculated. Statistical analyses using Friedman and Wilcoxon signed-rank tests were used to analyse the data with the level of significance set at $p < 0.05$. **Results:** there were significant differences in different canal conditions with both Root ZX mini and i Root. Measurements in dry canals were significantly longer for both apex locators ($p < 0.05$). Measurements with NaOCl were significantly shorter for both apex locators ($p < 0.05$). Both apex locators produced significantly accurate values for Saline and Smear OFF ($p < 0.05$). **Conclusions:** in this study, both Root ZX mini and i Root were affected by different canal conditions. The most accurate measurements were seen in the presence of saline and SmearOFF.

KEYWORDS

Electronic apex locator; I Root; Perforation; Root ZX mini; SmearOFF; Sodium hypochlorite; Saline.

RESUMO

Objetivo: este estudo teve como objetivo avaliar os efeitos de irrigantes e canal seco na precisão do localizador apical eletrônico (EAL) em localizar perfurações radiculares simuladas. **Material e métodos:** vinte pré-molares inferiores unirradiculares tiveram suas coroas removidas na altura da JEC e o tecido pulpar removido com um extirpa nervos. Os canais foram instrumentados até a largura de uma lima k 15. As raízes foram perfuradas artificialmente a 4 mm do ápice anatômico. O comprimento real (AL) até o local da perfuração foi determinado. O comprimento eletrônico (EL) das perfurações foi obtido pelo Root ZX mini e iRoot no canal seco e na presença de 5,2% de NaOCl, SmearOff e 0,9% de cloreto de sódio usando uma lima K tamanho 20. As diferenças entre o EL e o AL das perfurações foram calculadas. Análises estatísticas, utilizando os testes de sinais por postos de Friedman e Wilcoxon, foram realizadas para analisar os dados com o nível de significância estabelecido em $p < 0,05$. **Resultados:** houve diferenças significativas nas diferentes condições do canal, tanto no Root ZX mini quanto no i Root. As medidas em canais secos foram significativamente maiores nos dois localizadores apicais ($p < 0,05$). As medidas com NaOCl foram significativamente mais curtas para os dois localizadores apicais ($p < 0,05$). Ambos os localizadores apicais produziram valores significativamente precisos para Saline e Smear OFF ($p < 0,05$). **Conclusões:** neste estudo, tanto o Root ZX mini quanto o i Root foram afetados por diferentes condições do canal. As medidas mais precisas foram observadas na presença de soro fisiológico e SmearOFF.

PALAVRAS-CHAVE

Localizador apical eletrônico; I Root; Perfuração; Root ZX mini; SmearOFF; Hipoclorito de sódio; Soro fisiológico.

INTRODUCTION

Root perforation is a mechanical or pathological communication between the root canal system and the supporting tissues of teeth or oral cavity [1]. The time elapsed between perforation and treatment, perforation size, and location are essential when treating the affected site [2].

Identification of root perforations is possible by the direct observation of bleeding, paper point, radiography, and EAL [3]. Root perforations can be diagnosed through periapical radiographs of the mesio-distal aspect of the teeth. However, root perforations are frequently missed in the bucco-lingual axis. D'Addazio et al. [4] determined that periapical radiographs did not identify the majority of perforations, which led to inaccurate diagnosis in 20% of the cases.

To solve this problem, Sunada [5] introduced an electronic device to locate the apical foramen. This device is also advocated to be used for the detection of root perforations, which eliminates the radiographic problem. The efficiency of these devices has been documented in the literature for detecting root perforations under in vitro conditions [6,7].

Root ZX apex locator is a benchmark against which other EALs are compared. This instrument evaluates the quotient of impedances of two frequencies (0.4 kHz and 8 kHz) to identify the position of the file inside the canal [8]. Root ZX Mini (J Morita, Tokyo, Japan) is a compact version of this device with a similar functionality and accuracy [9]. i-Root (S-Denti Co. Ltd Seoul, Korea) apex locator uses different frequencies (i.e., 5 KHz and 500 Hz). The manufacturer claims that its accuracy is good irrespective of canal contents [10].

The precision of EALs is affected by various electrolytes that are present in the root canals [11]. With the invention of a new irrigant, it is essential to study and compare its effect on the performance of EALs in detecting root canal perforations. Sodium hypochlorite (NaOCl) and saline are the commonly used irrigants. NaOCl is important due to its broad antimicrobial and tissue dissolving properties. However, it is unable to remove the smear layer [12]. Many irrigants that remove the smear layer tend to react with NaOCl and form a precipitate.

SmearOFF (Vista Dental Products, Racine, WI) is a new irrigant that contains CHX gluconate (< 1% weight), tetrasodium ethylenediaminetetraacetate dihydrate (18% weight), and a surface-active detergent as its active component [13]. Piperidou et al. [14] showed that the interaction of SmearOFF and NaOCl on human dentin blocks did not result in the formation of precipitate or parachloroanaline.

The manufacturer suggests that it can be used with NaOCl as a 2-step procedure instead of a 3-step procedure, which usually involves the removal of NaOCl from the canal by irrigation with saline or alcohol before other irrigants are used [15].

To our knowledge, the influence of this new irrigant on the accuracy of the selected EAL in locating root perforations has not been documented in the literature. Thus, the aim of this research was to evaluate the effect of irrigants and dry canal on the accuracy of EALs in locating simulated root perforations.

The first null hypothesis was that the presence of irrigants and dry canals did not affect the precision of EALs in locating the root perforation. The second null hypothesis was that there was no difference in the efficiency of both apex locators under different canal conditions in locating root perforations.

MATERIAL AND METHODS

Sample Preparation

Twenty extracted, straight, single-rooted, human mandibular premolars were selected for the study. The inclusion criteria were single-rooted tooth with a single canal and a completely formed apex. The exclusion criteria were pre-existing restoration, caries, morphological defect, root resorption, and fractures. X-ray images from buccolingual and mesiodistal angles were taken to evaluate the root canal anatomy. Soft tissue and calculus were removed from the root surfaces with hand instruments, soaked in 5.25% NaOCl for 15 minutes, and then stored in 0.2% thymol in normal saline solution to achieve disinfection.

Sample calculation was performed using a 95% confidence interval to obtain a precision of 5%. A sample size of 20 was selected for this study. All 20 teeth were evaluated using both EALs under various canal conditions. Each tooth was decoronated at the cementoenamel junction and flattened using steel discs (Brasseler, Savannah, GA, USA) to obtain a constant reference point for all measurements. The contents of the canals were removed with a barbed broach (VDW, Germany), and the canals were instrumented up to a size 15 K-file (Dentsply Maillefer). Apical patency was checked with a size 10 K-file (Dentsply Maillefer). Irrigation was performed with 5.25% NaOCl followed by 2.5 mL of distilled water.

Simulation of perforation

The roots were artificially perforated at 4 mm from the anatomic apex from the outside of the proximal (buccal) root surface into the pulp space at a 90-degree angle with a size 012 round diamond bur (Mani, Inc. Japan). The perforations were approximately 1.5 mm in size.

Measurement of Actual length (AL) under DOM

Prior to the electronic measurement, the actual lengths (ALs) up to the perforation site were determined by visualizing the tip of a size 20 K-file (Dentsply, Maillefer) at the perforation site under a dental operating microscope (S 100 / OPMI pico; Carl Zeiss, Goeschwitzer, Germany), and the distance from the rubber stop to the file tip was measured to the nearest 0.05 mm with a calliper.

Measurement of electronic length (EL) with EALs

Silicon square cube moulds (20 mm) were filled with alginate. An apex locator clip and all samples up to the cemento-enamel junction were embedded in an alginate mould to simulate the periodontal ligament. Electronic measurements of the perforations were obtained using two electronic apex locators, Root ZX mini (J Morita, Tokyo, Japan) and iRoot (Meta systems Co., Seoul, Korea), according to the manufacturer instructions in dry canal and in the presence of 5.2% NaOCl, SmearOff and 0.9% sodium chloride using a size 20 K-file. Initially, all root canals were dried with paper points for dry canal measurements. Then, 2.5 mL of each test irrigant was used to flood the canal. Cotton pellets were used to dry the root surface and to eliminate excess irrigating solution. Each canal was irrigated with 2.5 mL of distilled water and dried with paper points before switching to the next irrigant.

The EALs were used according to the manufacturer instructions. For Root ZX mini, a size 20 K-file with a rubber stop was advanced into the canal until an "APEX" reading was obtained. Then, it was withdrawn until the last green bar was reached. For i Root, the file was advanced until the EAL display indicated the "00" mark.

The rubber stop was adjusted, the file was withdrawn, and the EL of the perforation was recorded for different canal conditions. All teeth were measured by the same operator, who was experienced in the use of EALs and was blinded to previous AL values.

The differences between the ELs and ALs of the perforations were calculated. Negative and positive values indicated measurements that were shorter and longer than the AL, respectively, whereas 0.0 indicated coinciding measurements.

Statistical Analysis

After data collection, data entry was performed in Microsoft Excel. Data analysis was performed using the Statistical Package for Social Sciences version 22 (SPSS Inc., Chicago, IL). The normality of data was confirmed using a histogram. It was determined that the distribution of sample reading was not normal. Repeated measurements were performed on the same sample to compare the accuracy of two apex locators under different canal conditions, and the Friedman and Wilcoxon signed-rank tests were used to analyse the data. The level of significance was set at $p < 0.05$.

RESULTS

The mean difference between the EL and AL of the perforation with a standard deviation (SD) for each EAL under different canal conditions (in mm) is shown in Table 1. There were significant differences in different canal conditions for both Root ZX mini and i Root.

The obtained measurements in dry canals were significantly longer than the AL using both apex locators ($p < 0.05$). Among the irrigants tested, EL with NaOCl was significantly shorter than the AL for both apex locators ($p < 0.05$). Both apex locators provided significantly accurate values with saline and Smear OFF ($p < 0.05$). No significant difference was noted between EALs when the measurements were obtained under different canal conditions.

Table 1 - Mean difference between the EL and AL of the perforation with the standard deviation (SD) for each EAL for various canal conditions

Apex locator	Dry Canal Mean + SD	5.2% Sodium hypochlorite Mean + SD	Saline Mean + SD	Smear OFF Mean + SD
Root ZX mini	$0.71 + 0.38^{Aa}$	$0.40 + 0.31^{Bb}$	$0.04 + 0.19^{Cc}$	$0.16 + 0.18^{Dc}$
iRoot	$0.73 + 0.36^{Aa}$	$0.45 + 0.36^{Bb}$	$0.06 + 0.21^{Cc}$	$0.18 + 0.21^{Dc}$

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

DISCUSSION

Root canal perforations are a serious treatment complication that compromises the health of periradicular tissues and tooth retention. The successful treatment of root perforations depends on the location and size of the defect, the time between perforation and treatment, an accurate determination of the location, and the sealing of the perforation site [16].

The media used for mounting models need to have electrical resistances that are similar to that of periodontal tissue to allow accurate data collection. Alginate has been described as an ideal embedding medium because of its relatively firm consistency, which allows the operator to accurately determine working length [17]. Alginate has a tendency to desiccate unless it is kept in a moist environment. Therefore, all recordings were completed within two hours of pouring alginate.

In this study, the content of the root canal affected the accuracy of both Root ZX mini and i Root. Hence, the first null hypothesis was rejected. Both Root ZX mini and i Root were equally accurate under different canal conditions. Hence, the second null hypothesis was accepted.

We kept the perforation size as 1.5 mm. This was larger compared to some of the previous studies [18,19]. Larger defects can occur externally on the root surface due to resorption, use of larger files, or intracanal procedures for post placement.

In this study, we observed that the accuracy of Root ZX mini and i Root were affected by different canal conditions to assess the perforation. Shin et al. [19 stated that Root ZX, which is the original model of Root ZX mini, was affected by variable canal conditions while assessing root perforation. i-Root apex locator is a fifth-generation apex locator. It uses frequencies of 5 KHz and 500 Hz. The manufacturer guarantees that its accuracy is good even in the presence of various canal contents [10]. However, our results differed from those in some of the previous studies in which the irrigants used did not affect the accuracy of different EALs, such as Root ZX, in determining root canal perforations [20]. This discrepancy may be explained by the use of different devices, methodologies, and irrigants in various studies.

The measurements by Root ZX mini and i Root were significantly larger in dry root canals than those in irrigated root canals, larger measurements were acquired in NaOCl than those in saline and SmearOFF. Hence, in this study, we determined that NaOCl and dry canal conditions produced the least accurate results by both EALs. This observation is attributed to the low electroconductivity of canal conditions. Electrical conductivity is the ability of different types of matter to conduct electric current. The electrical conductivity of a material is defined as the ratio of the current per unit cross-sectional area to the electric field producing the current [21]. It is an intrinsic property of a substance that depends on the temperature and its chemical composition. Our findings are consistent with those of Venturi and Breschi [22] who stated that the measurements were inaccurate and unstable for the Root ZX under low conductive conditions such as in dry canals. We obtained the same results for both EALs.

Shin et al. [17] observed that the electrical conductivity of a 1% NaOCl solution was 172,420 μS/cm. We used 5.2% NaOCl, which has a higher ionic concentration in the liquid state. Our findings agree with those of Jenkins et al. [23] who found that working length measurements tended to be slightly shorter in solutions with higher electrical conductivity, such as NaOCl solutions.

The most accurate measurements for both EALs were obtained with Smear OFF and saline. This can be attributed to the conductivity of a dissolved electrolyte which depends on its concentration. Shin et al. [19] found that the electrical conductivity of physiologic saline was 44,940 μS/cm. The lower electric conductivity of saline may be responsible for the accurate working length determination until perforation. Our findings are in agreement with Shin et al. For the smear OFF group, our findings cannot be corroborated or contraindicated because this is the first study to compare the effect of smear OFF on the detection of perforation. The good results achieved may be attributed to the low electrical conductivity of smear OFF. Therefore, it can be concluded that different concentrations of endodontic root canal irrigants may have dissimilarities with each other.

The results of our study showed that both Root ZX mini and i Root can be used to locate root perforations in the presence of saline and smear OFF as root canal irrigants. While interpreting the results of this research in the clinical setting, caution should be exercised for two reasons. First, we simulated a perforation defect of 1.5 mm, which may be unrealistic in a clinical setting. Perforation defects larger than 1.5 mm are likely to be clinically present. However, we chose 1.5 mm defect because a defect size of 1 mm was considered unrealistic in a study [19].

Second, the conductivity of a dissolved electrolyte depends on its concentration [21]. Therefore different concentrations of endodontic irrigants may have dissimilarities with one another. In addition, SmearOFF is a new irrigant, and future research should focus on its properties as an irrigant owing to its electrical conductivity. Studies, during which the effect of the size of perforation defect on the root and irrigating solutions is evaluated should be investigated to analyse the effect of these parameters on the effectiveness of EALs.

CONCLUSION

For the conditions used in this study, it can be concluded that both Root ZX mini and i Root were equally accurate in determining root canal length until perforation. The content of the root canal affected the accuracy of both EALs in locating a perforation, and the most accurate measurements in locating the perforation were obtained in the presence of saline and smear OFF using both EALs.

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Conflicts of interest

There are no conflicts of interest.

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