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The Effect of Different Irrigation Solutions on the Accuracy of Two Electronic Apex Locators in Locating Artificial Root Perforations

Yapay Kök Perforasyonlarını Belirlemede Farklı İrrigasyon Solüsyonlarının İki Elektronik Apeks Bulucunun Doğruluğuna Etkisi

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Abstract

Objective: This study aimed to assess the accuracy of the Raypex 6 (VDW GmbH, Munich, Germany) and Root ZX mini (J. Morita Corp., Tokyo, Japan) electronic apex locators (EALs) with regard to detecting root perforations in dry conditions and in the presence of irrigation solutions [2.5% sodium hypochlorite (NaOCl), 17% ethylenediaminetetraacetic acid (EDTA) and Qmix].

Materials and Methods: Twenty single-rooted human teeth were perforated artificially with a 1 mm diameter in the middle region. The actual canal lengths up to the perforation site were determined, and then the teeth were embedded in an alginate mold. The electronic measurements of the perforations were obtained using a size #20 K-file for each EAL in various conditions.

Results: There were significant differences between the different canal conditions in the Raypex 6 group ($p<0.05$), but no significant differences in the Root ZX mini group ($p>0.05$). There was a statistically significant difference ($p<0.05$) between the two EALs in the presence of EDTA solution, but no statistically significant difference between the accuracy of two EALs in the presence of other solutions and in the dry canal condition ($p>0.05$).

Conclusion: Under the conditions of this study, both apex locators detected root canal perforations within a clinically acceptable (range of -0.18 to 0.31mm) distance from the coronal border of the perforation region. Irrigation solutions within the root canal affected the accuracy of Raypex 6, but not of Root ZX mini.

Öz

Amaç: Bu çalışmanın amacı kök perforasyonunu tespit etmede kuru koşullarda ve irrigasyon solüsyonları varlığında [%2,5 sodyum hipoklorit (NaOCl), %17 etilendiamintetraasetik asit (EDTA) ve Qmix] Raypex 6 (VDW GmbH, Münih, Almanya) ve Root ZX mini (J. Morita Corp., Tokyo, Japonya) elektronik apeks bulucularının (EAB) doğruluğunu değerlendirmektir.

Gereç ve Yöntemler: Yirmi adet tek köklü insan diş kökünün orta bölümünde 1 mm çapında yapay perforasyon oluşturuldu. Perforasyon alanına kadar olan gerçek

kanal uzunlukları belirlendi ve sonra dişler bir aljinat kalıbına gömüldü. Her koşulda her bir EAB için #20 K boyutunda bir eğe ile perfore alana kadar olan elektronik ölçümler elde edildi.
Bulgular: Raypex 6 grubunda farklı kanal koşulları arasında anlamlı fark vardı (p<0,05), ancak Root ZX mini grubunda (p>0,05) anlamlı fark yoktu. EDTA çözeltisinin varlığında iki EAB arasında istatistiksel olarak anlamlı bir fark vardı (p<0,05), diğer çözeltilerin varlığında ve kuru kanal koşulunda iki EAB'nin doğruluğu arasında istatistiksel olarak anlamlı bir fark yoktu (p>0,05).
Sonuç: Bu çalışmanın koşulları altında, her iki apeks bulucu da, perforasyon bölgesinin koronal sınırından klinik olarak kabul edilebilir sınırlar içinde (-0,18 ila 0,31 mm aralığında) kök kanal perforasyonlarını saptamışlardır. Kök kanalı içindeki irrigasyon çözeltileri, Raypex 6'nın ölçüm doğruluğunu etkiledi, ancak Root ZX Mini'nin ölçüm doğruluğunu etkilememiştir.

Introduction

Root perforations are clinical conditions that joint the root canal system with the external root surface and surrounding tissues by destroying the cementum layer, which is the outermost part of the root (1). The etiology of root perforations (pathological, iatrogenic, idiopathic, etc) varies widely. If not correctly diagnosed and treated, the prognosis is poor and may result in related tooth extraction (1,2).

In teeth with root perforation, the materials used during endodontic treatment and the debris produced during preparation are at high risk of contact with the perforated region (3). This may lead to irritation and contamination risk during endodontic treatment in relation to the area affected (4). In addition, the incorrect detection of the perforation area also increases the likelihood of procedural errors such as over instrumentation and overfilling. For this reason, accurate detection of the perforation area is important for the prognosis of endodontic treatment (5). Various techniques such as operation microscopy, endoscopy, optic coherence tomography, digital radiography, and electronic apex locator (EAL) can be used to detect root perforations, as well as direct observation of the bleeding in the perforated area and indirect evaluation with a paper point (2,6). In the presence of bleeding in the perforation area, it may not always be possible to detect the perforation region directly or indirectly with the help of a paper point. In addition, for the detection of the perforation area may be misleading because of its limitations (7,8).

EALs are also useful to determine the area of perforation in endodontic treatment applications. They are easy to use, produce immediate results, and reduce exposure to radiation. Thus, these devices provide more acceptable treatment for both the clinician and the patient (7). The Root ZX mini (J. Morita Corp., Tokyo, Japan) is an EAL with a compact, easily portable design, working with proportional method developed by modifying Root ZX (9). Raypex 6 (VDW GmbH, Munich, Germany) is an EAL that works with the multi-frequency method and is the latest member of the Raypex series (10).

Studies have shown that fluids (irrigants, blood, pulp, exudates, etc) in the root canal could affect the accuracy of EAL (10). The aim of this study is to evaluate the accuracy of two different EALs in the detection of the perforation area in teeth with artificial root perforations in the presence of various root canal irrigants. The null hypothesis of the study is that there are no differences with regard to determining the root perforation between the solutions and the EALs used.

Materials and Methods

The research design was approved by Bolu Abant İzzet Baysal University Clinical Researches Local Ethics Committee (approval number: 2018/26, date: 24.05.2018). The current study was carried out in accordance with the World Medical Association Declaration of Helsinki and written informed consent was obtained from all participants. Based on a previous study (5) a power calculation was performed using G*Power 3.1 software (Heinrich Heine University, Dusseldorf, Germany). The calculation indicated that the sample size for each group should be at least six teeth.

Sample Selection

In this study, 20 mandibular premolar teeth with a single root and single canal extracted for orthodontic and periodontal reasons were used. Root canal anatomy was evaluated by taking periapical radiographs from buccal-lingual and mesio-distal directions for each tooth. The teeth with immature roots, calcification, fractures, and root canal treatment were replaced with new ones. After the sample selection, the teeth were disinfected in 2.5% sodium hypochlorite (NaOCl) solution for 48 hours. The teeth were then washed under water and stored in distilled water until use. Conventional endodontic access cavities were prepared using diamond round burs (Dentsply Maillefer, Ballaigues, Switzerland). The apical patency was checked using a #10 K-file (Dentsply Maillefer). The crowns of the teeth were removed with diamond burs (Diatech, Charleston, USA) under water cooling as to ensure that the root length was 15 mm. Thus, a constant and flat reference point was obtained for the measurements. After the tip of #10 K-file became visible in the apical foramen of the teeth, the working length of each root canal was determined to be 1 mm shorter than this measurement.

Canals were prepared using a #15 K-file (Dentsply Maillefer). After preparation, the canals were irrigated with 2 mL of 5.25% NaOCl (CanalPro; Coltene-Whaledent, Allstetten, Switzerland) followed by 2 mL of distilled water and were dried with paper points (DiadentGroup International Inc, Chongju, Korea). The 010 size round diamond burs (Dentsply Maillefer) was placed on the proximal surface of the roots at a 90-degree angle to create artificial perforation areas 1 mm in diameter at a distance of 5 mm from the apical foramen. The diameter of the perforation areas was checked by measuring using digital calipers.

Before measuring the electronic length (EL), the actual lengths (AL) of the canals up to the perforation area were recorded with a 20 K-file (Dentsply Maillefer) at 20X magnification under a stereomicroscope. The teeth were then embedded in alginate (Blueprint, Denstly, England) and the lip clip was contacted with the alginate during the measurement. Measurements were made in 5 different conditions, dry and in the presence of NaOCl, ethylenediaminetetraacetic acid (EDTA), Qmix, and chlorhexidine digluconate (CHX) solutions.

For EL measurement, Root ZX mini (J Morita Corp., Tokyo, Japan) and Raypex 6 (VDW, Munich, Germany) were used in accordance with the manufacturer's recommendations. A #20 K-file was used for the measurements by placing it in the canal and advancing it to the apical. When the EAL gave the apex exit signal, the stopper of the file was brought to the reference point and this measurement was recorded using the endoblock (Dentsply Mini-Endobloc). All measurements were performed after root canal irrigation with 2.5 mL of solution of the corresponding group. To completely remove the previous solution between different groups, canals were irrigated with 5 mL distilled water and dried with paper points. All irrigation procedures were performed with a double side-port needle (31 gauge NaviTip Sideport; Ultradent Products Inc, South Jordan, UT, USA).

Measurements were repeated 3 times in each canal, and the average of these 3 values was determined as the raw length. All measurements were made by the same operator experienced in the use of EALs. The difference between the EL and the AL of the perforations was calculated for each sample. A negative value indicates a shorter measurement, while positive value indicates a longer measurement than the AL. If the value is 0, this means that the AL and the EL are equal.

Statistical Analysis

All statistical analyses were performed using SPSS for Windows (version 16.0, SPSS Inc., Chicago, IL, USA). The Friedman and Wilcoxon signed-rank tests were used to analyze the data. The significance was determined at $p<0.05$.

Results

The mean difference between the EL and AL of the perforation and the standard deviation (SD) of each EAL in different canal conditions is shown in Table 1. In the Raypex 6 group, there was a significant difference between the measurements in the presence of EDTA

Table 1. The mean difference between the electronic length and the actual length of the perforation with the standard deviation for each electronic apex locator in different canal conditions (mm)

	Dry Mean ± SD	NaOCl Mean ± SD	EDTA Mean ± SD	CHX Mean ± SD	Qmix Mean ± SD
Raypex 6	0.22 ± 0.36^{Aa}	-0.04 ± 0.37^{Abc}	-0.18 ± 0.32^{Ab}	0.20 ± 0.35^{Aac}	0.22 ± 0.45^{Aca}
Root ZX mini	0.22 ± 0.28^{Aa}	0.12 ± 0.39^{Aa}	0.18 ± 0.31^{Ba}	0.11 ± 0.39^{Aa}	0.31 ± 0.30^{Aa}

Different superscript uppercase (A, B, C) letters in the same column indicate a statistically significant difference (p<0.05), different superscript lowercase (a, b, c) letters in the same row indicate a statistically significant difference (p<0.05), SD: Standard deviation, EDTA: Ethylenediaminetetraacetic acid, CHX: Chlorhexidine digluconate, NaOCl: Sodium hypochlorite and in the presence of CHX, Qmix, and a dry canal; also, between the measurements with NaOCl and measurements made in dry canal and a CHX presence ($p<0.05$). Electronic measurements were shorter than the AL in the presence of NaOCl and EDTA solutions, while measurements were longer than the AL in other conditions. There were no significant differences among the different canal conditions in the Root ZX mini group ($p>0.05$). While a significant difference was noted among the two EALs in the presence of EDTA solution ($p<0.05$), there was no statistically significant difference between the accuracy of two EALs in the presence of other solutions and in dry canal conditions ($p>0.05$).

Discussion

Successful treatment of root perforations depends on the covering of the perforation area by a biocompatible material that will not impair the health of the periodontal ligament (11). For this reason, it is important to determine the perforation area correctly for an appropriate treatment (11).

Radiographs are widely used to detect the perforation area. However, periapical radiographs are not always sufficient in determining the root perforation region, because of the superposition of anatomical structures and provide a 2-dimensional image of a 3-dimensional anatomy (11). Cone-beam computed tomography (CBCT) has been shown to be a more reliable method for detecting perforation than periapical radiography (11,12). On the other hand, in a previous study, it was concluded that CBCT had a higher risk of misdiagnosis in the detection of strip perforation (13).

EALs have been described as a highly reliable method of locating root perforation in many studies (2,5,14). It has also been shown that EAL gives more accurate results than periapical radiographs (15). In EAL measurements, electrical principles are more important than biological properties of surrounding tissue (16). For this reason, *in vitro* studies investigating the accuracy of EALs use materials that simulate the electrical resistance of periodontal ligament (PDL). Saline, alginate, agar agar, and gelatin are used to simulate the electrical resistance of PDL (5). In the literature, it has been reported that there is no statistical difference between studies investigating the accuracy of EAL in *in vivo* and *in vitro* conditions, so that *in vitro* models have yielded reliable results (17). However, *in vitro* models have the disadvantage of not fully reflecting *in vivo* studies (18).

In order to simulate the electrical resistance of the PDL, the alginate model which has been proved to be a reliable method, was used in this study because the construction phase is simple, the operator does not see the file tip, and it provides consistent measurements (19). Since alginate is a material that may deform over time, it was renewed in each group of measurements in the present study.

In the present study, the size of root perforation was standardized to 1 mm in all teeth. In studies evaluating the accuracy of EALs, *in vitro* study models were developed by creating perforation areas smaller or larger than 1 mm in size (20,21). In the literature, one study reported that perforations of 1 mm size and larger do not fully reflect the clinical condition (20). However, perforations of 1 mm diameter can be caused by iatrogenic or pathological reasons such as post placement, post removal, or root resorption.

There is no consensus on the effects of different canal conditions on the accuracy of EAL in the literature. Li et al. (22) reported that the accuracy of Propex, Raypex 5, and Root ZX was not affected when detecting root perforations (1 mm size) under different canal conditions. However, Venturi and Breschi (23) revealed that the accuracy of Apex Finder and Root ZX were influenced by intra-canal conditions. In the present study, it was observed that the accuracy of Root ZX mini was not affected in the determination of root perforation in different canal conditions, whereas the accuracy of Raypex 6 was affected by such conditions. When the literature was reviewed, no in vitro study had been conducted to evaluate the accuracy of Raypex 6 under different canal condition. The difference between the two devices may be due to differences in working principles and technology (9,10). In addition, the differences in the results of these studies can be explained by methodological differences, and by the ability and experience of the operator with regard to using the EAL.

In the present study, there was no significant difference in the Raypex 6 measurements when NaOCl compared with EDTA and Qmix; and CHX compared with Qmix. On the contrary, the EL determined in the presence of CHX was statistically different from that determined in the presence of NaOCl and EDTA. There was also a statistically significant difference between the Qmix and EDTA groups in Raypex 6 measurements. In the literature, there was no study investigating the effect of Qmix on the accuracy of EAL measurements. For this reason, the results of this study were not directly compared with the results of the studies related to this subject in the literature. It has been reported in the literature that the accuracy of apex finders is affected by the electroconductive properties of the solutions (5,8,18). Therefore, the reason for the differences between the solutions can be explained by the differences in the electroconductive properties.

In some studies, investigating the accuracy of the EAL, ±0.5 mm was accepted as a tolerable error range (16,24), while in some studies a ±1 mm range was accepted (25). In a study conducted by D'Assuncao et al. (2) with perforation detection using Mini Apex Locator, Root SW, and Root ZX II devices, the mean values were 0.005, -0.007 and -0.008, respectively. In the present study, the mean distance from the tip of the file to the root canal perforations was in the range of 0.11 to 0.31 for Root ZX mini and 0.22 to -0.18 for Raypex 6. These differences may be due to methodological differences, including the mounting model which was used by D'Assuncao et al. (2) to minimize the procedural errors during measurements. However, according to the literature, the results obtained in this study show that both EAL measurements are within the acceptable range.

It has been reported that the SD is more important than the difference between AL and EL, and that a low SD is closely related to the reliability of the device when evaluating the accuracy and reproducibility of the EAL measurements (26,27). In the present study, the findings obtained using the Root ZX mini in dry condition and in the presence of EDTA and Qmix were more consistent than those using the Raypex 6 device. Duran-Sindreu et al. (27) also found higher SD in the presence of NaOCl and CHX with Root ZX compared with iPex.

Conclusion

Under the conditions of this study, both devices detected the root canal perforations within a clinically acceptable range of -0.18 to 0.31 mm distance from the coronal border of the perforation site. The content of the root canal affected the accuracy of Raypex 6 but did not affect the accuracy of Root ZX mini.

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Ethics

Ethics Committee Approval: The research design was approved by Bolu Abant İzzet Baysal University Clinical Researches Local Ethics Committee (approval number: 2018/26, date: 24.05.2018).

Informed Consent: Written informed consent was obtained from all participants.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Supervision: D.A., Concept: Z.U.A., D.A., Design: Z.U.A., D.A., Data Collection or Processing: B.M., Z.U.A., Analysis or Interpretation: Z.U.A., Literature Search: D.A., Writing: Z.U.A., D.A.

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