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Influence of Blood on the Accuracy of Raypex 5 and Root ZX Electronic Foramen Locators: An *In Vivo* Study

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The aim of this study was to evaluate *in vivo* the accuracy of the Raypex 5 and Root ZX electronic foramen locators (EFLs) in the presence of blood in the root canal space. Forty single-canal teeth scheduled for extraction were selected. Access cavity was prepared and coronal enlargement was carried out. Approximately two drops of blood were collected by finger prick and injected into the root canal space. The electronic working length (EWL) of each tooth by each device was established twice before (NB group) and after (WB group) injecting blood into the root canal. The tooth was extracted and the actual working length (AWL) was determined. Data were analyzed using McNemar's test. The accuracy rates of Raypex 5 and Root ZX within 0.5 mm in the NB group were 88.9% and 91.5%, with 83.3% and 86.2% in the WB group, respectively. There were no significant differences between the accuracy of each EFL in the two groups ($p>0.05$). Considering the NB and WB groups, there were no statistically significant differences in the accuracy of the EFLs ($p>0.05$). The presence of blood in the root canal space did not influence the accuracy of the EFLs.

Key Words: blood, electronic apex locators, endodontics, working length.

Introduction

Working length (WL) determination is one of the crucial factors for the success of root canal treatment (1). Its over- or under-estimation may give rise to the failure of endodontic treatment (2). Ideally, the apical limit of canal preparation should be at the cementodentinal junction; however, this is a histologic landmark and cannot be determined precisely clinically (1). Therefore, the canal terminus is regarded by most clinicians as the least apical foramen or apical constriction, where there is minimal contact between the root canal filling material and periapical tissues (1).

Radiographic methods have been routinely used for WL determination. However, they are not sufficiently reliable because of limitations such as file size, film position, image distortion, image magnification, tooth inclination, superimposition of bony structures and interpretation variability, which may provide inaccurate findings (3). In addition, radiographs show two dimensions of a three-dimensional structure, which might result in loss of data in some cases (4).

Sunada (5) developed the first electronic foramen locator (EFL) in clinical practice. The first EFLs needed calibration and were not accurate enough in the presence of electrolytes within the root canal (6). Since then, various electronic devices have been introduced based on different operating principles and electronic methods (7).

Raypex 5 (VDW, Munich, Germany) is a frequency-based EFL, which measures the impedance at the frequencies of 0.4 kHz and 8 kHz, but uses only one frequency at each time interval and measurements are based on the mean square values of signals (7). The Root ZX (J. Morita Corp., Kyoto, Japan) is also a two-frequency EFL, which simultaneously measures the impedance at the same frequencies, calculates the quotient of the impedances and exhibits this quotient as a position of the file tip within the root canal (8).

The effects of some factors on the accuracy of EFLs (9-12) and comparisons between the accuracy of EFLs have been investigated (13,14). The presence of blood within the root canal as an electrolyte material may also influence the accuracy of EFLs. To date, there have been few and controversial *in vitro* studies on the effect of the presence or absence of blood within the root canal on the accuracy of EFLs (15-17). However, there are no *in vivo* studies on this issue. Therefore, the aim of this *in vivo* study was to evaluate whether the presence of blood within the root canal influences the accuracy of the Raypex 5 and Root ZX foramen locators under clinical conditions.

Material and Methods

Forty single-canal teeth (14 maxillary incisors, 15 mandibular incisors, 4 maxillary second premolars and 7 mandibular premolars) from 21 patients (8 women and 13 men) with an age range of 38–62 years, scheduled for extraction, were included in this study. Because the pulp vitality does not affect the accuracy of EFLs (18), teeth with necrotic (29 teeth) and vital pulp (11 teeth) were included in the study. Teeth with pulp calcification, open apices, prosthetic crowns, metal restorations, previous endodontic treatment and history of any trauma were not included.

The Ethics Committee of Isfahan University of Medical Sciences approved the study design (No. 393124). Informed written consent was obtained from all the patients at the beginning of the study.

Medical/dental history and radiographic examination were obtained. The patients were asked to use Listerine mouthwash for 1 min; anesthesia was achieved and a dental dam was placed. The cusp tip or incisal edge was flattened with a diamond bur (818.FG.035; JOTA, Ruthi, Switzerland) to provide a reproducible reference point. An endodontic access cavity was prepared, and pulp tissue remnants were removed with #15 and #20 K-file (Dentsply-Maillefer, Ballaigues, Switzerland). Coronal enlargement was achieved with a nickel-titanium ProTaper SX rotary file (Dentsply Maillefer). The root canal was irrigated with 2.5% sodium hypochlorite solution and normal saline by a 27-gauge needle. In some vital teeth, a little bleeding from the root canal was controlled by irrigating with 2.5% sodium hypochlorite solution and waiting about 5 min. Electronic and actual working lengths were measured by an endodontist, in a way similar to a previous study (19).

Electronic WL (EWL) measurement of each tooth by each device was established twice (before and after injecting blood into the root canal). First, as No Blood (NB) group, the canal was irrigated with normal saline solution; excess fluid was removed from the pulp chamber, but no attempt was made to dry the canals and then EWL was measured. Second, as With Blood (WB) group, the canal was dried with sterile paper points. Approximately 2 drops of blood were collected from each patient by finger prick in a sterile disposable micropipette (Blaubrand, Wertheim, Germany) and injected into the root canal space. The excess blood was removed from the pulp chamber, but no attempt was made to dry the canals and then EWL was measured. The Raypex 5 and Root ZX devices were used according to the manufacturers' instructions. The lip clip was attached to the patient's lip, and the file clip was connected to a #15 K-file. With the Raypex 5, the file was inserted into the root canal to the major apical foramen (red line) and then pulled back until the 3 green bars were observed in the display. With the Root ZX, the file was inserted into the root canal to the major apical foramen ("APEX" mark and signal) and then pulled back until the display showed the 0.5-mm mark. Measurements were considered correct if the reading remained stable for at least 5 s. A silicone stop was then carefully adjusted to the flattened coronal reference point; the file was removed from the root canal and the distance between the file tip and the silicone stop was measured with a high-precision digital caliper (Mitutoyo Corp, Tokyo, Japan). Electronic measurements were repeated 3 times and the mean of the values was recorded as EWL.

For actual WL (AWL) measurement, the rubber dam was removed; the tooth was extracted and placed in 5.25% sodium hypochlorite for 1 h to remove any debris or organic tissue from the root surface and then rinsed under tap water. After that, a #15 K-file was inserted into the canal until the file tip could be observed through the major foramen at ×16 magnification by a dental operating microscope (OPMI Primo, Carl Zeiss, Jena, Germany). The file was then pulled back until the file tip was placed tangential to the major foramen. A silicone stop was adjusted to the same reference point; the file was removed from the root canal and the distance between the file tip and the silicone stop was measured with the same digital caliper. Then 0.5 mm was subtracted from this measurement. The measurements were repeated 3 times and the mean of the values was recorded as the AWL.

In each tooth, the AWL was subtracted from the EWL to define the distance between the file tip (EWL) and the point 0.5 mm coronal to the major foramen (AWL). Positive values defined measurements beyond the AWL (over) and negative values defined measurements short of the AWL (under). Data were evaluated using SPSS 20 (IBM, Armonk, NY, USA). The accuracy of each EAL within ±0.5 mm was compared between the NB and WB groups using the kappa value and McNemar's test. The relationship between the two variables "EALs" and "presence/absence of blood" was also evaluated using the kappa value and McNemar's test. Statistical significance was set at $p<0.05$.

Results

Four teeth were excluded from the study, two because of unreliable electronic measurements and two because of root fracture during extraction. Therefore, 36 teeth were included in the statistical analysis. The accuracy rates of Raypex 5 within the error range of ±0.5 mm in the NB and WB groups were 88.9% and 83.3%, respectively. For Root ZX, they were 91.5% and 86.2%, respectively (Table 1).

Table 1. Number (percentage) of electronic measurements relative to the actual working length

EWL-AWL (mm)*	Raypex 5		Root ZX	
	NB (n=36)	WB (n=36)	NB (n=36)	WB (n=36)
-1.0 to - 0.51	3 (8.3%)	4 (11.1%)	3 (8.4%)	4 (11.1%)
-0.50 to 0.0	17 (47.2%)	18 (50.0%)	23 (63.8%)	20 (55.6%)
0.01 to 0.50	15 (41.7%)	12 (33.3%)	10 (27.8%)	11 (30.5%)
0.51 to 1.0	1 (2.8%)	2 (5.6%)	0 (0.0%)	1 (2.8%)

EWL-AWL: electronic working length minus actual working length; WB: with blood group; NB: no blood group. *Negative values indicate measurements short of the AWL. Positive values indicate measurements beyond the AWL.

There were no statistically significant differences between the NB and WB groups with regards to the accuracy of Raypex 5 (kappa=0.77; McNemar test=0.500) and Root ZX (kappa=0.72; McNemar's test=0.500). Moreover, considering the two groups of NB and WB, there were no significant differences in the accuracy of Raypex 5 and Root ZX (kappa=0.82; McNemar's test=0.500)

Discussion

The accuracy of frequency-dependent EFLs with a clinical tolerance of ±0.5 mm is approximately 65%–100% (6). Use of irrigating solutions such as normal saline, sodium hypochlorite and chlorhexidine is an important aspect of endodontic treatment. The influence of different irrigating solutions as electrolyte materials on the accuracy of EFLs has been investigated (20-23). Some authors reported that endodontic irrigants could affect the accuracy of EFLs (21,22). Others found that EFLs performed well irrespective of the used irrigant (20,23). Besides, pulp extirpation during endodontic treatment results in bleeding in the root canal. Since blood is an electrolyte, it may influence the accuracy of EFLs. A review of the literature revealed that only three conflicting *in vitro* and not *in vivo* studies have been published on this issue (15-17). Hence, the purpose of this study was to evaluate the influence of blood in the root canal space on the accuracy of two well-known EFLs, the Raypex 5 and Root ZX, *in vivo*. Bashar et al. (15) used Foramatron D 10 EFL on 60 extracted maxillary and mandibular anterior teeth and claimed that WL measurement by the EFL in the presence of blood within the root canal remained mostly within a clinically acceptable range of ±0.5 mm. He et al. (16) used Raypex 5 and TRRY EFL on 47 extracted single-rooted teeth and concluded that both EFLs could measure root canal length accurately despite the influence of blood within the root canal. Ebrahim et al. (17) used Root ZX on 36 extracted mandibular premolar teeth and reported that compared to sodium hypochlorite, the presence of blood, a file size close to the prepared canal diameter is required for accurate root length measurement. However, in this *in vivo* study were used Raypex 5 and Root ZX on 36 single-canal teeth and it was found that presence of blood within the root canal did not affect the accuracy of the EFLs. Differences between the results of different studies might be attributed to differences in device type, tooth type and study method.

Ex vivo and *in vivo* methods have been used to evaluate the accuracy of EFLs. *Ex vivo* methods were developed in which extracted teeth were immersed in an electrolyte material with electrical resistance similar to that of the periodontium. These methods have some advantages such as simplicity, ease of use, ability to have strict control and ability to test a great number of samples in a short period compared with *in vivo* methods. However, the disadvantages of these methods are the possibility of electrolyte media leakage through the apical foramen, which could result in premature readings (24) and inability to simulate completely the clinical conditions (25). Therefore, the results of *ex vivo* studies may raise doubts about their clinical relevance. Thus, considering the ethical issues, an *in vivo* method was used for the purpose of this research.

Cleaning and shaping of the root canal should be limited to the canal terminus. It is considered by most clinicians as the apical constriction or the minor apical foramen, which is located at 0.5–1 mm coronal to the major apical foramen (1). Therefore, the apical landmark was considered at 0.5 mm coronal to the major apical foramen. Moreover, a range of ±0.5 mm from the apical landmark was considered acceptable for the electronic measurements, based on similar previous studies (19,23). Although EFLs detect the major apical foramen and they are not able to detect the root apex or apical constriction, they are generally called "electronic apex locator". Therefore, the use of an "electronic apical foramen locator" or simply "EFL" may be more appropriate (7,10).

In this study, the accuracy rates of Raypex 5 and Root ZX decreased slightly in the presence of blood in the root canal. Although a decrease in the accuracy of the EFLs in the presence of blood was not statistically significant, it is advisablethat clinicians consider the possibility of decrease.

Within the limitations of this study, the accuracy of Raypex 5 and Root ZX EFLs was not influenced by the presence of blood in the root canal space.

Resumo

Este estudo objetivou avaliar in vivo a precisão dos localizadores foraminais eletrônicos (EFLs) Raypex 5 e Root ZX em presença de sangue no canal radicular. Foram utilizados 40 dentes unirradiculares destinados a extração. Foi preparada cavidade de acesso e feita ampliação coronária. Cerca de duas gotas de sangue obtidas por punção digital foram injetadas no canal. O comprimento eletrônico de trabalho (EWL) foi medido duas vezes antes (Grupo NB) e depois (Grupo WB) da injeção do sangue. O dente foi extraído e o comprimento real de trabalho (AWL) foi determinado. Os dados foram analisados com o teste de McNemar. As taxas de precisão a ±0,5 mm de Raypex 5 e Root ZX foram 88,9% and 91,5% no Grupo NB, e 83,3% e 86,2% para o Grupo WB, respectivamente. Não houve diferença significativa entre a precisão de cada um dos EFLs em ambos os grupos (p>0,05). Considerando os grupos NB e WB, não houve diferença significativa entre as precisões dos EFLs (p>0,05). A presença de sangue no canal radicular não influencou a precisão dos EFLs.

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