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Accuracy of an Electronic Apical Foramen Locator in Revision Endodontic Treatment in the Presence of Different Solvents: A Randomized Controlled Clinical Trial

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Abstract

Purpose: To evaluate the accuracy of an electronic apical locator in the determination of working length during an endodontic retreatment, in presence of different solvents *in vivo*.

Methods: One hundred twenty canals needing retreatment were included in the study. Among those, 30 canals filled with guttapercha, 30 with filling paste only, 30 with resin points and 30 were judged empty of filling material. The retreatment was initiated using the corresponding solvent respectively: xylol, orange solvent, acrylic liquid monomer and sodium hypochlorite. When the first exploring file reached the estimated length, two measurements were done using the electronic apex locator and the radiograph method. The values were compared by two observers blinded to the aim of the study. A non-parametric test of Kruskal-Wallis was used. A p-value less than 0.05 was considered statistically significant. The results were noted in charts.

Results: The results showed an accuracy of 83% in presence of xylol, 87% in presence of orange solvent, 77% in presence of monomer, and 87% in presence of ClONa, which gives an average of 83%.

Conclusion: The presence of the solvents tested and sodium hypochlorite have no significant effect on the percentage of accuracy of the apical foramen locator. The particular cases of periapical lesions and apical resorption should make the subject of a different study.

Keywords: *Tooth Apex; Electric Impedance; Root Canal Therapy; Electrical Conductivity*

Introduction

Cleaning, shaping and filling the root canal system are the major steps of nonsurgical endodontic treatment. These procedures are controlled by the depth of penetration of the instruments inside the canal called the working length (WL) [1]. Accurate detection of the root canal terminus and precise calculation of WL are critical in retreatment procedures. In fact, accuracy in both factors will help reducing the probability of insufficient removal of root filling material and the probability of damaging the periapical tissues by instrumentation beyond the tooth [2,3].

Many methods have been used over the years to establish the WL, including predetermined normal tooth length, mathematical equations, tactile sense and many other techniques [4]. The radiograph of the tooth with an endodontic instrument placed in the canal has been widely considered to be the most reliable technique for many years. However, the radiographic measurement has some limitations, such

as the difficulty of visualizing the apices in case of dense bone, large tori and superimposition of the zygoma, and the concern of increasing the irradiation of the patient. The latter concerns especially cases of retreatment where the necessity of depth control is frequently mandatory during desobturation [5].

The introduction of electronic apex locators (EAL) since 1962, has been a real breakthrough in endodontics [6]. First, using an EAL as an aid to endodontic therapy could potentially reduce the number of diagnostic radiographs required for WL determination. Second, locating the apical foramen using a combination of an EAL and radiographs for WL determination is more accurate than using radiographs alone [5]. However, the first and second generations of apex locators were not accurate in presence of blood, irrigants or local anesthetics [7]. The third generation, in particular the Root ZX® (J.Morita Inc., CA, USA), offered a very high percentage of accuracy compared to the radiographs [7]. Vajrabhaya., *et al.* found that the Root ZX had a precision rate of 100% in extracted teeth [8]. Shahabang., *et al.* proved in an *in vivo* study, that the Root ZX was capable of establishing the position of the foramen with a margin of 0.5 mm in 96.5% of the cases [9], and safer results were obtained with a radiographic verification [10]. The accuracy of EALs compared to radiographs can range from 10% to 40% [10]. The superiority of apex locators compared to radiography was even extended to digital radiography [11]. The Root ZX has proved its precision in conventional endodontic treatment; however, rare studies have been conducted to evaluate the accuracy of this instrument in cases of retreatment using different types of solvents. Although it was demonstrated that apex locators are useful in retreatments [12], the accuracy was dependent on the complete removal of the filling material [13] that would need the use of solvents. It would be important to find out if the Root ZX-II has the same accuracy in presence of different solvents used in desobturation. The aim of this study was to evaluate the accuracy of an electronic apical foramen locator (Root ZX-II, J. Morita Inc., USA) in the determination of working length during an endodontic retreatment, in presence of different solvents *in vivo*.

Materials and Methods

Ethical consideration

All participants were informed about the objectives of the study and the procedures that were done. A written informed consent was also obtained from them. The ethical committee of the Lebanese University of Beirut approved the study.

Study design

We conducted an interventional study over a year in a private practice.

Sample size and criteria of selection

Inclusion and exclusion criteria: the original sample size was 400 canals belonging to 300 teeth and considered inadequately treated on the preoperative radiograph. Teeth that needed restoration with prosthetic crowns were selected for this study. One hundred fifty five canals were excluded from this sample when teeth couldn't properly be isolated electrically and when the operator considered canals, with a "wide" or "resorbed" apical diameter on a preoperative radiograph. This is due to the fact that previous studies have ruled that large diameters could yield a wrong measurement [14,16]. Teeth were also excluded, when obliterations were present and precluded attempts to reach the preoperative working length [18]. A surgical microscope Zumax® (Suzhou, China) was used in order to visually identify the nature of the filling material by its color and its consistency in canals.

Two hundred and forty five canals were kept and sorted into groups considering the filling material:

- Group A: Canals visibly filled, with gutta-percha (n = 73).
- Group B: Canals visibly filled with resin points (n = 77).
- Group C: Canals visibly filled with a filling paste alone (n = 33).
- Group D: Canals that were located in treated teeth but did not show a radiographic evidence of filling material, were considered empty of any filling material (n = 62).

The first 30 canals of each group were then included in the study.

Solvents

Three different solvents were used:

- For group A: Xylol (Merck. France).
- For group B: Acrylic liquid, methyl methacrylate monomer (Lang Dental MFG.CO wheeling. IL.USA).
- For group C: Orange solvent (Sultan Chemist Inc. Englewood NJ.USA).
- For group D: Sodium Hypochlorite (ClONa) at 5.25%, which is not a solvent but is considered as the most used irrigating solution. This group was considered the control group.

The apex locator

The apex locator tested in this study was the Root ZX-II.

Retreatment methodology

One experienced operator conducted the retreatment protocol. During the first session, the old restoration material was eliminated completely after placing the rubber dam. The access cavity was then cut and a temporary reconstruction of the tooth was done when necessary. The surgical microscope was then used in order to visualize and identify the material by its color and texture. This enabled us to classify the canals into the 4 different groups. Access cavities were then filled with temporary cement (Cavit Pink. 3M Espe Germany).

During the second session, the dental dam was placed, and the temporary cement removed. The access cavity was cleaned with an ultrasonic tip (P5. Amadent American Medical and Dental Corp, Cherry Hill NJ.USA), allowing us to remove the temporary coronal restoration. The negotiation of the canal was initiated with a Rm® retreatment file (MicroMega, Besançon, France) known for stiffness and short length enabling the operator to transpierce the material in presence of corresponding solvent. This file was then replaced by a 10 K file (Maillefer, Ballaigues, Switzerland). In presence of solvent, the same sequence was repeated until the file reached the estimated length. At this stage, the Root ZX-II was used to calculate the electronic measurement as per the manufacturer's instructions. When the EAL indicated the foramen, the silicone stopper was fixed on the coronal reference point.

Evaluation methodology

When the EAL indicated the foramen, a radiograph was taken with the file in place using the RINN Endo Ray II® Ring and Film Holder (Dentsply, Tulsa, USA). This allowed the use of paralleling techniques and reduce the error of exposure.

The control of radiographs was done by two observers who were blinded to the aim of the study. They were asked to evaluate the distance between the tip of the file and the foramen with a half mm precision. When the file was shorter than the foramen, the measurement was considered negative. When the file went beyond the foramen, it was considered positive. The zero value was attributed when the tip of the file was coinciding with the foramen. Numbers were attributed to radiographs and canals in order to maintain anonymity.

Statistical analysis

The results given by the observers were registered on a chart, with a scale of 0.5mm for each solvent. A non-parametric test of Kruskal-Wallis was used to observe if the presence of any of tested solvents could affect the precision of Root ZX-II, using Statistical Package for Social Sciences (SPSS) 20.0 version. A *p*-value less than 0.05 was considered statistically significant.

Results

Comparison between observers

Distance from the foramen	A		B	
	n	%	n	%
< -0.5	16	13.3%	16	13.3%
[-0.5; 0.5]	101	84.2%	100	83.4%
> 0.5	3	2.5%	4	3.3%
Total	120	100	120	100

Table 1: *Frequency and percentage of distances between the tip of the instrument and the foramen, noted by the controllers A and B for the 4 groups during the radiographic control of the WL established by the Root ZX-II.*

The weighted kappa coefficient is 0.68. This indicates that there's a substantial agreement between both observers.

Accuracy of apex locator in presence of different solvents

Descriptive analysis

The results gave a percentage of acceptable readings by the Root ZX-II of 83% in presence of xylol, 87% in presence of orange solvent, 77% in presence of monomer, and 87% in presence of ClONa. The average was of 83% (Table 2).

Solvent	Number of acceptable measurement	Total number of canals in each group	Percentage (%)
Xylol	25	30	83%
Orange solvent	26	30	87%
Monomer	23	30	77%
ClONa	26	30	87%
Total	E = 100	N = 120	Average: 83%

Table 2: *Numbers and percentage of acceptable measures of the Root ZX-II. Measurement for the EAL was considered acceptable when it ranges ± 0.5 mm of the radiographic foramen, based on similar studies [15].*

Kruskal-Wallis test

Solvent	N	Average ranks
Xylol	30	18.44
Orange solvent	30	18.50
Monomer	30	7.61
ClONa	30	19.44
Total	120	

Table 3: *Kruskal-Wallis test in the evaluation of apex locator accuracy in different solvents.*

Chi-square	0.150
df	3
p-value	0.985

With a p-value of 0.985, we can conclude that there are no significant differences in the behavior of Root ZX-II in presence of different solvents.

Discussion

The aim of the endodontic treatment/retreatment is to shape, clean, and fill the root canal system till the apical foramen [11]. The exact determination of the WL has always been considered as an essential step to success in endodontic treatment [4]. In orthograde endodontics, the presence of blood, pus and multiple irrigating solutions does not affect the reading of modern EALs [8,9,16]. In conventional retreatments, it is recommended to use solvents to enable the dissolution of filling material present in the canal [17,22]. Our study aimed to compare the effect of three different solvents on the measurements and the accuracy of the Root ZX-II in retreatments; the apical reference point chosen for the study was the apical foramen as recommended by Cimilli., *et al* [19]. The results showed an accuracy of 83% in presence of xylol, 87% in presence of orange solvent, 77% in presence of monomer, and 87% in presence of ClONa and an average accuracy of 83%. This result is similar to the *in vivo* study by Dunlap., *et al.* on the precision of EALs in vital and necrotic pulps with an accuracy of 82.3% [16]. Multiple factors present in the canal might affect precision of EALs. Studies have assessed the presence of filling material and solvents in retreatment cases and their effect on readings of EAL s [12,13,15,20,21]. Our results are comparable to the results of Alves., *et al.* [12] using Tri Auto ZX®, with 76% precision and a tolerance limit of ± 0.5 mm. Our results are also in concordance with the results of Er., *et al.* [23], showing a high percentage of accuracy using tetrachloroethylene (90%) and eucalyptol (80%). However, with the use of Resosolv® (Pierre Rolland, Merignac, France) containing dimethylformamide, Er., *et al.* [23] obtained an accuracy of (40%). Er., *et al.* [23] suggested that electrical conductivity might be a real factor for reducing the precision of EALs. In fact, electrical conductivity of dimethylformamide is much higher compared to xylene and chloroform (dimethylformamide 37, xylene 2.27 and 4.8) [24,25]. This difference might affect the precision of EALs. In the present study, xylol was used for Group A, with gutta-percha fillings; the accuracy was of 83%. Goldberg., *et al.* [15] in an *in vitro* study conducted on single-rooted teeth, using xylene, files with wider diameter (K20) and Root ZX, obtained a precision 95% with a tolerance of 0.5 mm. The difference with our study might be due to the conditions of the study including sample selection, not only limited to single rooted teeth, and the file size that might affect the accuracy of measurement [14]. Although it is widely accepted to use chloroform as solvent of gutta-percha during retreatments [17], we didn't choose this product, following Ring., *et al.* recommendations considering this solvent cytotoxic and possibly carcinogenic, and its possible substitution with orange solvent to effectively dissolve gutta-percha [22].

The presence of filling material inside the canals may cause an obliteration that might affect the accuracy of EALs. In a clinical study, El Ayouti., *et al.* [18] demonstrated the negative effect of obliterations inside the canals, on accuracy of the measurement of EAL s, in a dental practice. The authors considered dysfunction of apex locators, in obliterated canals, as a problem due to interruption of the electrical circuit and could be interpreted as an absence of actual canal patency [13]. However, the elimination of the obliteration, can reestablish the electrical circuit and the readings of the EAL. In an *in vitro* study, by Aggrawal., *et al*., [20] the authors did not find a statistically significant effect of the presence of filling materials on the accuracy of Root ZX and ProPex®, however, in this study sample canals were previously prepared and filled to WL, and subsequently, retreated, in these conditions, there is no chance to find obliterated canals. The removal of permanent obliterations, would allow progression of the file through the apical third and the conduction of electrical circuit. Our study did not show a significant difference (*p-value* = 0.985) in EAL s behavior, this might also be due to the exclusion of canals with permanent obliterations. From our findings, it can be concluded that EAL s have a high percentage of precision during retreatments.

Our study is, to our knowledge, one of the few *in vivo* studies to test the accuracy of EALs during retreatments. This study was conducted during conventional endodontic retreatments of our daily practice, where radiographic verification is often recommended to evaluate and complete the electronic calculation. Moreover, the sample size used is not to be neglected.

Concerning study limitations, the solvents that were used were of low electrical conductivity. This might affect the results. It would be interesting to include in further studies, high electrical conductivity solvents and assess the accuracy of EALs.

Conclusion

During retreatments, EALs proved to be reliable in getting an early measurement of root canal length. Combining radiographs with EALs will assist practitioners to reach predictable and safe results and will reduce the number of radiograph retakes and patient exposure to harmful ionizing radiation.

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