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In vitro Evaluation of the Precision of Four Different Electronic Apex Locators in Determining the Working Length of Teeth after Removing Root Canal Obturation Materials

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Abstract: The purpose of this study was to evaluate *in vitro* the accuracy of 4 different Electronic Apex Locators (EALs) for determining the Working Length (WL) of endodontically retreated teeth. Forty human single rooted teeth with mature apices, recently extracted due to periodontal disease or orthodontic reasons, retained in thymole solution 1%, were used for this study. The WL was established by subtracting 0.5 mm from the actual canal length. The root canal systems were instrumented and disinfected and then divided in 2 groups, the control group (n = 8) and the experimental group (n = 32). The root canals of the experimental group were obdurated using vertically compacted gutta-percha with AH 26 sealer. In a wax sheet of 2 mm thickness, 40 holes were made and both control and experimental groups were inserted into them up to their neck while a box containing alginate powder mixed with sodium hypochlorite solution 1% was prepared to simulate the periapical tissues. For the Electronically Determined Length (EDL) four EALs were used: Dentaport ZX (J. Morita Co. Kyoto, Japan), RayPex 5 (VDW GmbH, Germany), Endo Master (Electro Medical Systems SA, Switzerland) and Bingo-1020 (Dent Corp research and development U.S.A.). During canal length measurement, the canal was flushed with 2.5% NaOCL. The measurements were made with the help of a K-file No 20, inserted into the root canal. The difference between AL and EDL was calculated and reported for each tooth. In the control group, the EDLs by Dentaport ZX, RayPex 5 and Endo Master were all 8 (100%) within AL±0.5 mm, while the EDLs of Bingo 1020 were within AL±1.0 mm. In the experimental group we had a variety of prices but the majority of the EDLs determined by the 4 EALs were within AL±0.5 mm. The EALs Dentaport ZX and Endo Master were more accurate than the other two EALs in determining WL in retreated teeth. However, the RayPex 5 and the Bingo 1020 were also reliable in the majority of cases.

Key words: Electronic apex locator, endododicaly retreated teeth, electronically determined length, accuracy, reliability

INTRODUCTION

The apical constriction is the landmark at which endododic instrumentation should preferably end. Since, this ending usually exists shy of the radiographic apex, most Dental Schools instruct students to clean and fill canals 0.5-1.0 mm shy it. Actually, it is this calculation itself that constitutes the weak point of the whole radiographic method as in fact the distance between the apex and the end of the root varies. Consequently, if the difference between the constriction and the apex is not 1 mm, due to for example to a lateral exit of the root canal, subtracting 1 mm will lead to false measurement. Thus, the most important advantage of the electronic method over radiography is that it can measure the root canal length. Moreover, in order to make estimated working lengths even more difficult, the radiographic apex occasionally may be obscured by anatomic structures, restorations and rubber dam clamps. Elongation and foreshortening of the radiograph also could make estimated working lengths very difficult.

A working length established beyond the minor diameter may cause apical perforation and overfilling of the root canal system. This may increase postoperative

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pain and delay or prevent healing. Alternately, a working length established short of the minor diameter may lead to inadequate debridement and under-filling of the canal. Retained pulp tissue may persist and cause prolonged pain. In addition, microleakage into the canal space may result in lack of healing (Kuttler, 1955; Tselnic *et al*., 2005). The original idea of using electronics to locate the apical foramen was introduced in 1918 by Caster. The development of electric apex locators began in 1942, when Suzuki reported that the electrical resistance between the periodontal ligament and the oral mucosa *in vivo* was 6,5 KΩ (Suzuki, 1942). Later, Sunada (1962) proposed an electronic method for detecting the apical foramen. Sunada introduced the principle of biological characteristics theory into clinical practice, stating that electronic apex locators could read the apex by measuring the differences of electrical resistance values between the periodontal ligament and the oral mucosa.

The first generation of EALs was resistance-based and detected the point where the file displaces from within the canal to periodontal ligament. Problems inherent in using direct current led to the development of second generation EALs that used a single frequency of alternating current (Komamura *et al*., 1965) detect changes in the impedance of the canals. The major disadvantage of second generation EALs was the poor accuracy because of the influence of fluids and pulp tissue. Advances in EALs technology have led to the development of EALs that make accurate readings in the presence of electrolytes (third and the latest generation devices). Using a ground clip on the patient's lip and a file probe inside the canal, the electronic apex locators determine the location of the actual anatomic apical foramen. These devices can be very technique-sensitive, leading to inconsistent results and frustration for the novice user. However, when used on a consistent basis, they are a quick and extremely accurate way to determine working lengths (Berman and Fleischman, 1984; Berman, 2003).

The latest generation of electronic apex locators such as Endex, Root ZX, Ray Pex 5, Dentaport z-x, Bingo 1020, Endo Master, Justy II and ProPex are considered to be accurate even in the presence of conducive fluids in the canal. The accuracy of the measurements reportedly is not affected by NaOCL, EDTA, saline solution, blood etc. or the various clinically encountered exudates. These devises are also based alternating current, but they operate on the principle that the impedance difference between electrodes depends on the signal frequencies used (Palmer *et al*., 1971; De Moor *et al*., 1999; Dunlap *et al*., 1998; Shabahang *et al*., 1996).

Many studies have demonstrated the accuracy of the majority of EALs in determining the Working Length (WL) (Shabahang *et al*., 1996; Ebrahim *et al*., 2006a, b, c). However, does the reliability of EALs remain the same when it comes for endododic retreatment? Are they really accurate when used following removal of root canal obturation materials?

Pommer *et al.* (2002), Goldberg *et al.* (2005) and Ebrahim *et al.* (2007) evaluated the accuracy of many different EALs in determining the working length (WL) during endodontic retreatment. They found that the majority of the EALs that were examined were accurate within AL±1 mm in a percentage of 80% and higher.

The purpose of this study was to evaluate *in vitro* the accuracy of 4 different Electronic Apex Locators (EALs) for determining the working length of endododically retreated teeth. The EALs used are Dentaport z-x (J.Morita Co. Kyoto, Japan), RayPex 5 (VDW GmbH, Germany), Bingo-1020 (Dent Corp research and development U.S.A.) and Endomaster (Electro Medical Systems SA, Switzerland).

MATERIALS AND METHODS

Forty human single rooted teeth with mature apices, typical morphology recently extracted due to periodontal disease or orthodontic reasons, retained in thymole solution 1%, were used for this study. They also did not have metallic restorations nor fractures, or radiographically invisible canals. The root canals had a clear radiographic appearance. Soft tissue and calculus were removed from the root surfaces with an ultrasonic scaler (EMS Piezon® Master 600, Ch. de la Vuarpillière 311260 Nyon Switzerland). Standard access penetration was carried out using a high speed diamond fissure bur under water coolant. The incisal edges were prepared with a sand paper disk, in order to keep a standard reference point for the measurements and the contents of the pulp chamber were removed. The root canal was irrigated with 5.25% NaOCL through a 27- Gauge needle (Nipro, Osaka, Japan) and dried with cotton pellets. The actual canal length (AL) was determined by introducing a size 10 K-file (F.KG. Debtaire, La Chauxde-Fonds, Switzerland) into the canal until the tip of the file became visible at the major apical foramen under a stereomicroscope (Zeiss Stemi 2000-C, Carl Zeiss) at 15X magnification. The micrometric system that was adjusted to the microscope had the ability to give accurate measurements of the distances. A rubber stop was then adjusted to our K-file and the distance between rubber stop and the file tip was calculated and constituted the Actual Length (AL). From the AL we abstracted 0.5 mm and found our Work Length (WL). The cleaning and shaping of root canals was carried out according to the crown-down technique. To

simulate apical resorption, a no. 3 carbide round bur (no.330 S.S White) was used to create an abnormal defect at the root apex of each tooth.

The teeth were then randomly divided into 2 groups. The first group (n = 8) served as control and the second one (n = 32) was the experimental group. As far as the control group was concerned the root canals were dried using sterile study points and a small cotton pellet was placed at the canal offrice. The access cavity was then filled with temporary obstructing material (*Caviton*). The teeth were then stored for 10 days at 36°C and 100% humidity. For the experimental group, the root canals were obdurated using vertically compacted compacted gutta-percha with AH sealer. The gutta-percha master cone was trimmed and fitted apically, coated with sealer placed into the canal in (WL) and then vertically thermoplasticised by a continuous wave of condensation technique (Ultrafil hygienic Corporation Avron, OH 70° calcium). A small cotton pellet was placed at the canal offrice and the access cavity was filled with Caviton. All teeth were radiographed in both bucco-lingual and mesio-distal directions to ensure the adequacy of the root filling.

In the experimental group, the obduration material was removed with the help of Gates Glidden drills no. 2 and 3 for the coronal and middle third and with the help of 20 K-file and gutta-percha solvent for the apical third.

In a wax sheet of 2 mm thickness, were made forty holes and the teeth of both control and experimental group were inserted into them up, to their neck and stabilized with sticky wax. Alginate powder was mixed with sodium hypochlorite solution 1% instead of water and a plastic box of 20×6×3 cm was filled with it. The wax sheet was placed at the top of the plastic box so that the roots of the teeth were embedded into the alginate, which also contained a piece of copper band connected with the electrodes of the electric apex locators. The use of alginate as a conductory medium was proposed by Kaufman and Katz.

For the Electronically Determined Length (EDL) 4 EALs were used: Dentaport ZX (J.Morita Co. Kyoto, Japan), RayPex 5 (VDW GmbH, Germany), Endo Master (Electro Medical Systems SA, Switzerland) and Bingo-1020 (Dent Corp research and development U.S.A.). Each device was adjusted according to the manufacturers' instructions before use. During canal length measurement, the canal was flushed with 2.5% NaOCL. The measurements were made with the help of a K-file No 20, inserted into the root canal. When according to the apex locator, the file was at the apex a rubber stop was carefully adjusted to the reference level and the file was withdrawn to measure the distance between the rubber stop and the file tip under a stereomicroscope (Forty, American Optical Corp., U.S.A.). The distance (D) between the AL and EDL was calculated and A±0.5 mm and AL±1.0 mm were used to evaluate the accuracy of the 4 EALs.

RESULTS

The results can be seen on Table 1 and 2 and on Fig. 1 a and b, respectively.

The control group in this study exhibited significantly better scores than the experimental group. In the control group, the EDLs by Dentaport ZX, RayPex 5 and Endo Master were all 8(100%) within AL±0.5 mm while the EDLs of Bingo 1020 were within AL ±1.0 mm. In the experimental group, the EDLs of the 4 EALs (Dentaport ZX, Endo Master, RayPex 5, Bingo 1020)were within AL±0.5 mm, 94, 81, 72 and 70% of the time and within AL±1.0 mm, 100, 94, 84 and 84% of the time, respectively.

Table 1: Distance between AL and EDL (AL-EDL) in the control group (n = 8)

Al-EDL(mm)	Dentaport ZX	Endo master	RayPex 5	Bingo 1020
-1.0 to -0.51				8(100)
-0.5 to 0.0	8(100)	8(100)	8(100)	

Negative values indicate measurements short of the AL

Table 2: Distance between AL and EDL (AL-EDL) in the experimental group (n=32)

Al-EDL(mm)	Dentaport ZX	Endo master	RayPex 5	Bingo 1020
-1.5 to -1.1		2(6.25)	5(15.65)	5(15.65)
-1.0 to 0.51	2 (6.25)	4(12.5)	4(12.5)	5(15.65)
-0.5 to 0.0	27(84.37)	25(78.12)	22(68.75)	21(66.65)
0.01 to 0.5	3(9.37)	1(3.1)	1(3.1)	1(3.1)

Negative values indicate measurements short of the AL

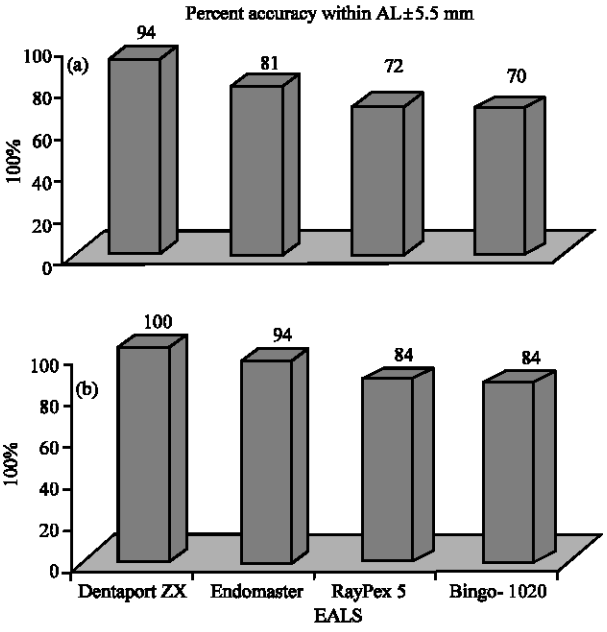

Fig. 1: Experimental group (n = 32)

DISCUSSION

The use of electronic apex locators for the calculation of working length during endodontic therapy provides the clinician with accurate and reliable measurements for each individual root canal. Several studies have demonstrated that the latest generation of electronic apex locators can accurately determine the working length in between 7-96. 5% of the root canals with mature apices (Stavrianos *et al*., 2003).

The purpose of this study was to evaluate *in vitro* the accuracy of 4 different Electronic Apex Locators (EALs) for determining the working length of endododically retreated teeth. In an other recent clinical research of Ebrahim *et al*. (2007), with similar methodology, the EDLs determined by Dentaport-ZX were within AL±0.5 mm 92% of the time and within ±1 mm 100% of the time. A systematic review in bibliography does not reveal any *in vitro* studies evaluating the accuracy of RayPex-5, Endomaster or Bingo-1020 in determining the working length of teeth after removal of the root canal obturation materials.

It has been proven that the complete removal of all traces of gutta-percha/sealer from canal walls is essential for the success of the retreatment. In this way, we manage to uncover the remaining necrotic tissues of bacteria that may be responsible for periapical inflammation (Bergenholtz *et al*., 1979). Unfortunately, in everyday clinical practice complete removal of obduration materials is almost impossible (Wilcox *et al*., 1987; Zmener *et al*., 2006) and that affects the accuracy of the EALs as shown in our research, where the control group exhibited significantly better scores than the experimental group.

In the present survey the error range used is ±05 mm from the actual length, which is considered highly accurate (Pagavivo *et al*., 1998; Saito and Yamashita, 1990). Some researchers thought, based on the fact that there is a wide range in the shape of the apical zone accepted a ±1 mm margin of error (Shabahang *et al*., 1996; Keller *et al*., 1991).

The control group in this study exhibited significantly better scores than the experimental group. The results of Dentaport ZX, Endomaster and RayPex 5 were 100% within the AL±0.5 mm limit while those of Bingo 1020 were 100% within the AL±1 mm.

As far as the experimental group is concerned the accuracy of all the EALs was decreased due to the fact that it is almost impossible to remove all the obduration materials during a root canal retreatment. More specifically only Dentaport ZX and Endomaster managed to overcome 80% accuracy with an AL±0.5 mm error range and can be regarded reliable when it comes for endodontic retreatment. On the other hand RayPex 5 and Bingo 1020 reached a percentage of 72 and 70%, respectively. Of course all 4 EALs become acceptable when it comes for root canal retreatment if we adopt an error range of AL±1 mm.

Closing we should mention that all these conclusions made by our survey cannot be extrapolated in everyday clinical practice. The research of the accuracy of EALs in determining the working length of endodontically retreated teeth is still in infantry level and more survey should be made before we reach permanent conclusions.

CONCLUSION

In this study, the EALs Dentaport ZX and Endo Master proved to be more accurate than the other 2 EALs in determining WL in retreated teeth. However, the RayPex 5 and the Bingo 1020 were also reliable in the majority of cases.

The removal of all traces of gutta-percha/sealer from the canal walls is impossible however, the better the removal of obduration materials is, the more accurate become the measurements of EALs in an endodontic retreatment.

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