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Combination of apex locator and endodontic motor for continuous length control during root canal treatment

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Abstract

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Aim To compare *ex vivo* an experimental setup consisting of an electronic apex locator (EAL) and endodontic motor with an established product (Tri Auto ZX) for accuracy of length control during root canal treatment with three different types of files.

Methodology An experimental setup consisting of porous spongy material and an electrolyte was used. Sixty anterior teeth were randomly assigned to six groups. Access cavities were prepared. During root canal treatment, constant length monitoring was performed either with the Tri Auto ZX or the Raypex®5 apex locator attached to an endodontic motor (Endo IT professional) using ProTaper, M_{two} or FlexMaster files. After root canal preparation the distances between file tip and major apical foramen and file tip and minor apical foramen were measured using a microscope and analysed using two-way ANOVA to evaluate the accuracy of the two systems.

Results Distances between the file tip and the major apical foramen were not significantly different between the file systems and the two EALs. In cases treated with FlexMaster significantly larger distances between file tip and minor apical foramen were found compared to M_{two} and ProTaper. No significant differences were observed between the two EALs. After preparation of the root canals with the Tri Auto ZX, multiple minor apical foramina were mechanically widened.

Conclusion With the limitation of this laboratory study the combination of EAL and endodontic motor was as accurate as the Tri Auto ZX system in terms of length control during root canal preparation.

Keywords: accuracy, apical foramen, electronic apex locator, endodontic motor, working length.

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Introduction

A recent review (Lin *et al.* 2005) concluded that the absence of bacterial contamination and sufficient removal of infected necrotic tissue were the main factors for a positive outcome following root canal treatment. The review also concluded that the accurate determination of working length played a major role in reducing contamination and the bacterial load in the root canal system. Under-instrumentation of root canals, particularly in cases of infected necrotic pulps and asymptomatic apical periodontitis, leads to significantly lower success rates compared cases where an accurate working length was achieved (Sjögren *et al.* 1990, Chugal *et al.* 2003). On the other hand, over-instrumentation with enlargement of the apical constriction, trauma to the apical tissues, extrusion of infected material apically and destruction of the apical binding point for the root filling can affect the outcome of root canal treatment negatively (Sjögren *et al.* 1990, Chugal *et al.* 2003, Souza 2006).

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In practice, the determination of working length and its control remains a challenge. The assessment of working length by tactile sensation alone is not advisable (Seidberg *et al.* 1975). Radiographic examination is appropriate for diagnostic purposes and evaluation of the root morphology, but is not able to determine the working length consistently due to the anatomical variations between teeth (Dummer *et al.* 1984, Olson *et al.* 1991, Gutierrez & Aguayo 1995). Electronic apex locators (EAL) are an alternative for the determination of correct working length (Gordon & Chandler 2004, Nekoofar *et al.* 2006).

The continuous monitoring of working length is important during canal preparation as the working length may vary during the procedure, especially in curved canals. The endodontic instrument causes increased dentine removal from the inner wall of curved canals that straightens the root canal (Caldwell 1976, Farber & Bernstein 1983). Failures to adjust the working length can lead to negative side effects (Bhaskar & Rappaport 1971, Seltzer *et al.* 1973). Therefore, combinations of EAL and low-speed endodontic handpieces have been introduced to achieve the accuracy of conventional EALs during canal shaping (Grimberg *et al.* 2002, Alves *et al.* 2005). Besides the length measurement function these devices also have torque control and speed settings.

As there are a large number of EALs and endodontic motors on the market, the question arises as to whether these two stand-alone devices might be used in combination as an apex locating endodontic motor. As the impedance of a root is complex (Tipler & Mosca 2007), electronic devices or the earthing of the endodontic motor may interfere with the electrical circuit of the EAL. Consequently, the hypothesis of the study was that this experimental setup is able to determine and to monitor the correct working length in combination with three different file systems at least as accurately as a commercially available product (Tri Auto ZX, J. MORITA, Kyoto, Japan).

Material and methods

Specimen preparation and experimental setup

Sixty extracted human anterior teeth were collected from a pool of extracted teeth. The teeth were stored under moist conditions in a thymol solution. Only teeth with an overall length of 20–25 mm, fully formed apices and with no caries, coronal restorations, signs of resorptions or cracks were chosen. The teeth were radiographed in two dimensions to assure a single root canal was present with a canal curve of <7° using the goniometry function of an imaging software according to (Schneider 1971) (Scanner: Digora Gendex; software: VixWin 2000 v1.8; Dentsply Gendex Dental Systeme, Hamburg, Germany). The pulp chambers were accessed using a water-cooled, cylindrical diamond bur (Brasseler, Lemgo, Germany) in a handpiece. The canal system was flooded with 3.0% sodium hypochlorite using a syringe (Injekt® LL 10 mL, B. Braun, Melsungen, Germany) and a 30-gauge needle (NaviTip™, Ultradent Products, South Jordan, UT, USA). The coronal and middle section of the root canals were shaped using size 15, 20, 25 stainless steel Hedström and K-files (VDW, Munich, Germany) to provide access to the apical third of the root canal. To standardize the size of the apical preparation, root canals were instrumented until a size 08 K-file was visible at the major apical foramen but a size 15 K-file bound approximately 2 mm short of the major apical foramen. Teeth not matching these criteria were discarded.

To simulate the tissues surrounding the teeth a laboratory setup was used. A porous plastic block, normally used for flower arrangements (OASIS® Ideal 1, Smithers-Oasis, Cuyahoga Falls, OH, USA) was placed in a VDW-file container (FlexMaster Systembox; VDW). Ringer's solution (DeltaSelect, Dreieich, Germany), an isotonic liquid for intravenous injection, was placed in the box to assure ion flow between the electrodes of the EAL. The liquid was introduced into the box until the spongy material was completely soaked and 5 mm fluid covered the bottom of the box. Rubber dam (Roeko Flexi Dam non-latex, Coltène/Whaledent, Langenau, Germany) was stretched over the box, both to simulate a clinical situation and to insulate the spongy material from the user, thereby assuring the completion of the measurement circuit of the EAL. Two holes were made in the rubber dam; in one hole, the teeth were placed through the dental dam into the porous block leaving the coronal 2–3 mm of the root out of the block. In the second hole, the lip clip of the EAL was clamped (Fig. 1).

Endodontic treatment units

For mechanical root canal preparation the established Tri Auto ZX was used as a control. This contra-angle handpiece consists of a torque-controlled endodontic motor and an integrated EAL. For root canal shaping the Auto Apical Reverse function (AAR) was set to '0.5' as

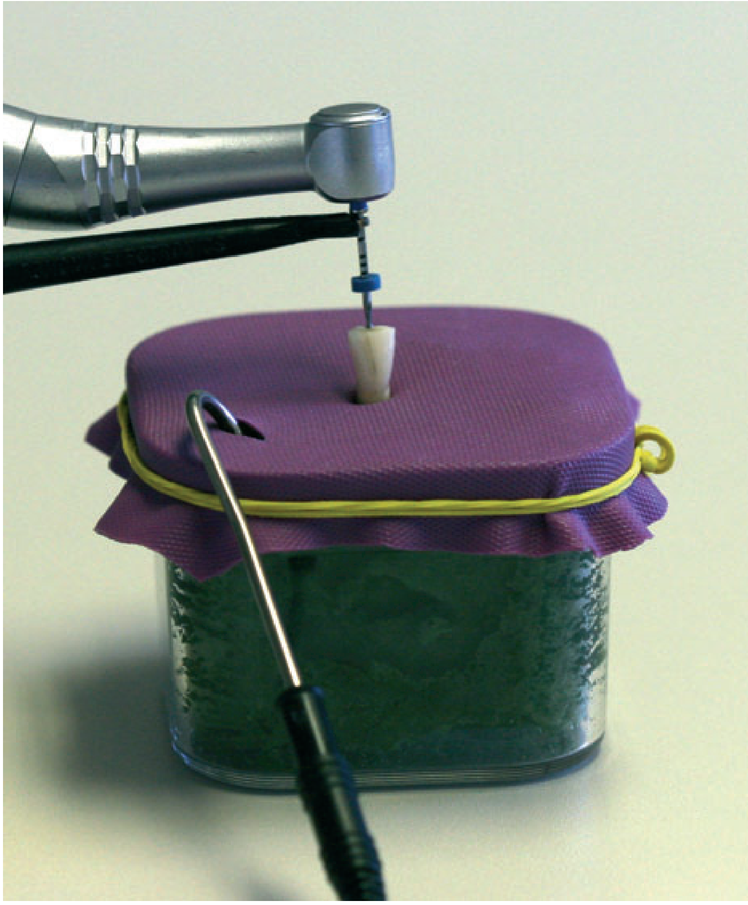

Figure 1 Experimental setup: Plastic box containing porous material and electrolyte covered by rubber dam. The lip clip is tucked into the conductive material. The file clip is attached to the file.

described in the instruction manual to indicate the minor apical foramen (apical constriction). Torque settings for each file were set as recommended. For the experimental setup a combination of the Endo IT professional (contra-angle handpiece and torque-controlled endodontic motor) and the Raypex®5 EAL (both: VDW) were connected. To close the measuring circuit of the EAL, the file clip was clamped to the file shaft. The Auto Stop Reverse function was enabled. The Endo IT professional handpiece was calibrated for each file of each system according to the manufacturer's instruction.

Root canal preparation

Sixty of the teeth prepared as described above were randomly assigned to six different groups. Two main groups, representing the two root canal treatment units (Tri Auto ZX and Raypex®5) and three subgroups (ProTaper, M_{two}, FlexMaster) in each group according to the three different file types were used in this study.

Before canal preparation and after irrigation (sodium hypochlorite, 3%) working length was determined using and size 08 K-file and either the Raypex®5 or the Tri Auto ZX switched to the apex locator mode. In both groups, files were first taken to 'over-instrumentation' and then pulled back to the apical constriction as indicated in the apex zoom (Raypex®5) or '0.5' (Tri Auto ZX) respectively. Subsequently, root canals were then shaped with K-files size 8, 10, 15 with FileCare® EDTA (VDW) at full working length to establish a glide path as recommended. Prior to and during mechanical instrumentation, each root canal system was irrigated with 3.0% sodium hypochlorite solution. Latex examination gloves (DermaClean, Ansell Healthcare, Brussels, Belgium) were worn to isolate the user against the Tri Auto ZX and the experimental setup. The lip clip was placed in the spongy material and the clamp was attached to the file (Fig. 1). During subsequent canal preparation files were not adjusted to working length, rather monitoring of the working length took place either by the display of the Raypex®5 EAL or via the AAR-function of the Tri Auto ZX. The following rotary file systems were used:

ProTaper (Dentsply Maillefer, Ballaigues, Switzerland)

The ProTaper shaping files S1 and SX were introduced into the canal performing brushing motions to prepare the coronal and middle sections of the root canal. Then files S1 and S2 were used at working length. ProTaper finishing files F1, F2 and F3 were brought to full working length, avoiding excessive pecking motions. Except for shaping file SX, all files reached working length. This procedure was interrupted intermittently by irrigating and recapitulating the canal using a size 15 K-file.

M_{two} (VDW)

A size 10, .04 taper file was brought to full working length either by performing lateral cutting (brushing motion) or a pecking motion (up and down motion). After reaching full working length files size 15, .05 taper, size 20, .06 taper, size 25, .06 taper and a size 30, .05 taper were used as described above. After each file the canal was irrigated and recapitulated.

FlexMaster (VDW)

In the coronal part of the root canals, files size 30, .06 taper, size 25, .06 taper, size 20, .06 taper and size 30, .04 taper were used. As recommended, this was carried out in a crown-down manner to a length 2–3 mm short of the indicated working length by performing pecking motions and interrupted intermittently by irrigation and recapitulation. File size 20, .02 taper reached working length followed by .02 taper files with tip sizes 25 and 30.

Analysis of the root canal

At the end of the root canal preparation the last instrument was brought to working length as indicated by the respective EAL. Rubber stoppers and the file itself were then fixed in the tooth with a light-curing composite (Tetric EvoCeram, Ivoclar Vivadent AG, Schaan, Liechtenstein). The apical 3–5 mm of the roots were carefully removed using a diamond blade and a scalpel until the instruments and the canal walls were visible. This was performed under a light microscope whilst paying attention to the anatomical canal characteristics (Wrbas *et al.* 2007). For the analysis of the roots a video camera (AxioCam MRc5; Carl Zeiss, Oberkochen, Germany) connected to a stereomicroscope (Leica WILD M3Z; Leica Mikrosysteme Vertrieb, Bensheim, Germany) and a computer in combination with a calibrated measurement software (software: AxioVs40 vers. 4.5.0.0., Carl Zeiss; calibration grid: Carl Zeiss) were used. The distance between file tip and major apical foramen was measured as well as the distance between file tip and minor apical foramen (accuracy ±0.005 mm). Major and minor apical foramina were defined according to (Nekoofar *et al.* 2006). There the apical portion of the root canal is considered as an inverted cone and its base indicates the major apical foramen. The apex of this inverted cone indicates the location of the minor apical foramen or apical constriction (Fig. 2). Two-way ANOVA (SPSS 16.0.1; SPSS inc., Chicago, IL, USA) was used to determine the effects of the two independent variables 'used EAL' and 'used file system' on the dependent variables 'distance file tip – minor apical foramen' and 'distance file tip – major apical foramen'. The level of significance was set to 0.05.

Results

Distance file tip – major apical foramen

In none of the specimens was the file tip found beyond the major foramen, neither in the groups treated with the Raypex®5/Endo IT control or with the Tri Auto ZX.

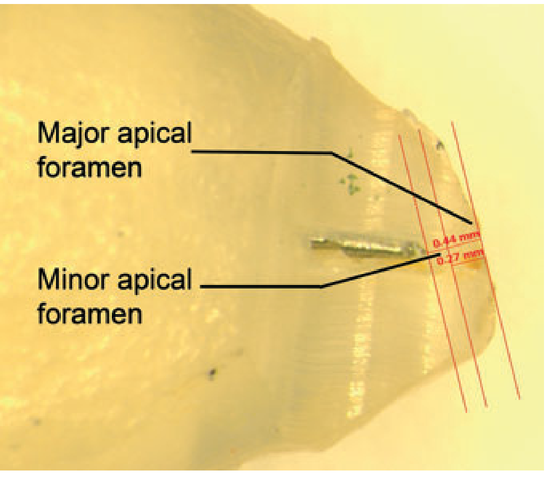

Figure 2 Apical region of a tooth, including distances and canal walls.

Table 1 Mean values and standard deviations (±SD) of the distances between file tip and major apical foramen and file tip and minor apical foramen for the main groups represented by the EALs, their three subgroups represented by the types of files and for each file system regardless of the used EAL

		Distance file tip – major apical foramen (mm)			Distance file tip – minor apical foramen (mm)		
		Raypex®5	TriAutoZX	Both EAL	Raypex®5	TriAutoZX	Both EAL
All file systems	Mean (±SD)	0.66 (±0.44)	0.78 (±0.47)		0.24 (±0.55)	0.32 (±0.58)	
ProTaper	Mean (±SD)	0.63 (±0.21)	0.80 (±0.16)	0.72 (±0.20)	0.12 (±0.16)	0.26 (±0.23)	0.19 (±0.20)
M_{two}	Mean (±SD)	0.61 (±0.20)	0.82 (±0.31)	0.72 (±0.28)	0.06 (±0.18)	0.20 (±0.34)	0.13 (±0.28)
FlexMaster	Mean (±SD)	0.74 (±0.30)	0.72 (±0.30)	0.73 (±0.29)	0.53 (±0.30)	0.53 (±0.29)	0.53 (±0.29)

EAL, electronic apex locator.

Mean distances between file tip and major foramen varied between 0.61 mm (experimental setup and M_{two}) and 0.82 mm (Tri Auto ZX and M_{two}) (Table 1). The analysis of the distances between the respective file systems showed no significantly different results for groups treated with ProTaper, M_{two} and FlexMaster ($P = 0.978$). The results of the two length measurement devices, regardless of the used file types, were also not significantly different ($P = 0.068$). There was no significant interaction effect between the used EALs and the used file systems ($P = 0.309$).

Distance file tip – minor apical foramen

Due to the fact that the canals had been treated, no information was available on the morphology of the constriction types (Dummer *et al.* 1984). In 11 cases, the minor apical foramen was mechanically widened although the file tips were short of this region when analysed. This appeared only in cases where the root canal treatment was performed with the Tri Auto ZX, whereas the allocation of the cases between the different file systems was equal. In four cases, equally distributed between the two EALs, the file tips were found where the canal walls begin to diverge in the area between minor and major apical foramen. Of the 30 measurements performed by every EAL 25 (83.3%) determined working lengths in the Raypex®5 group and 20 (66.7%) measurements in the Tri Auto ZX group were within ±0.5 mm of the minor apical foramen. In all groups distances were within ±1 mm of the minor apical foramen. The mean distances between file tip and minor apical foramen varied between 0.06 mm (M_{two} and Raypex®5/ Endo IT control) and 0.53 mm (FlexMaster and Tri Auto ZX; FlexMaster and Raypex®5/ Endo IT control) (Table 1). Regardless of the used EAL the distance between the file tip and the minor apical foramen were significantly higher in the group treated with FlexMaster compared to M_{two} and ProTaper ($P < 0.001$). Although the distances between file tip and minor apical foramen were generally larger in groups treated with the Tri Auto ZX no significant difference was found ($P = 0.191$). Also no significant interaction effect between the used EALs and file systems was observed ($P = 0.627$).

Discussion

The use of an endodontic motor in combination with a separate EAL has not yet been described in literature. Therefore, the objective of the present study was to test this combination under laboratory conditions with respect to its function and accuracy. Compounds used for these laboratory setups include agar-agar in different concentrations (Aurelio *et al.* 1983, Nahmias *et al.* 1987, Fouad & Krell 1989), gelatine (Donnelly 1993) or alginate (Kaufman *et al.* 1989, Kaufman & Katz 1993). These materials have numerous disadvantages. They are expensive, designed for single use and must be stored under special conditions. Furthermore, their preparation is time consuming and the results obtained cannot be reproduced (Fouad & Krell 1989). In contrast, the present experimental setup is a less complicated, inexpensive and is reusable. Sodium hypochlorite (3.0%) was used for irrigation as it does not affect the accuracy of the EALs utilized (Meares & Steiman 2002, Nekoofar *et al.* 2006). To allow an even more comprehensive evaluation, three different file systems were chosen according to their mode of utilization. Hence, file diameters used for root canal treatment varied at all times, but this did not negatively influence the EAL function (Nguyen *et al.* 1996, Lee *et al.* 2002).

According to the recommendation of the European Society of Endodontology (2006) the apical constriction is recommended as the end-point of root canal treatment. Instruction manuals and displays of the utilized

EALs imply that they are capable of locating the minor and major apical foramen. Kobayashi & Suda (1994) described that two frequencies, impedance ratio measurement based EALs (Raypex®5 and TriAutoZX) are able to locate the minor apical foramen. Measured mean discrepancies of file tip and minor apical foramen of around 0.24 mm (experimental setup) and 0.32 mm (Tri Auto ZX) were in similar ranges and in accordance with findings already reported (Welk *et al.* 2003). In the literature 75.0–82.3% of the determined working lengths are accurate to within ±0.5 mm of the minor apical foramen (Dunlap *et al.* 1998, Meares & Steiman 2002, Tselnik *et al.* 2005) and are believed to be clinically acceptable (Ounsi & Naaman 1999, Grimberg *et al.* 2002). Working lengths determined by the experimental setup were within these limits in 83.3% of the cases, although fewer measurements conducted with Tri Auto ZX were within this limit (66.7%).

Whilst there is doubt about the possibility of locating the minor apical foramen (Hoer & Attin 2004), it has been summarized that modern EALs are able to detect the point where the file tip reaches the tissues of the periodontal ligament (Nekoofar *et al.* 2006). In none of the groups were the file tips found beyond the major apical foramen. Reviewing the possible negative side effects of over-instrumentation (Sjögren *et al.* 1990, Chugal *et al.* 2003, Souza 2006), this fact is important to improve the quality of root canal treatment. Measured mean distances between file tip and major apical foramen, varying from 0.61 to 0.74 mm (experimental setup) and from 0.72 to 0.82 mm (Tri Auto ZX), are comparable to a mean distance of 0.75 mm found by (Ounsi & Naaman 1999). In a comparative study a previous model of the Raypex®5 also determined the major apical foramen significantly more accurately than an EAL comparable to the Tri Auto ZX, but was discussed as clinically negligible (Kaufman *et al.* 2002). Although no negative interference between the Endo IT control and the Raypex®5 was observed the user had to wear latex gloves to prevent him from being in direct contact with the handpiece or the tooth in order to obtain correct measurements.

After shaping, only in root canals treated with Tri Auto ZX were the minor apical foramina damaged by root canal instruments, although the file tips were found short of the minor apical foramen. Although the AAR-function is described as an add-on to avoid accidental over-instrumentation (Grimberg *et al.* 2002), this phenomenon has already been described in a study evaluating the AAR-function of the Tri Auto ZX (Campbell *et al.* 1998). A level of 'one' is recommended to preserve the apical structures (Campbell *et al.* 1998, Carneiro *et al.* 2006). The preset '0.5' in this study was chosen according to the instruction manual to determine the apical constriction. The screw-in effect of the files in combination with the lower AAR-function setting in this study probably overstrained the reaction time of the AAR-function and led to this phenomenon. On the other hand, it was very challenging to remain within the indicated area of the minor apical foramen during length monitoring using the Raypex®5, especially when pecking motions were performed. This was mainly observed in combination with FlexMaster. The screw-in effect of the file-system in combination with pecking motions and the above-described problems to maintain the correct working length with the respective EAL might explain the higher discrepancies between file tip and major and minor apical foramen when FlexMaster was used.

Conclusion

This laboratory study proved the accuracy of the experimental setup in comparison to the Tri Auto ZX.

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