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In vivo comparison of working length determination with two electronic apex locators

K. T. Wrbas, A. A. Ziegler, M. J. Altenburger & J. F. Schirrmeister

Department of Operative Dentistry and Periodontology, University School and Dental Hospital, Albert-Ludwigs-University Freiburg, Freiburg i. Br., Germany

Abstract

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Aim To compare the accuracy of two electronic apex locators (EALs) in the same teeth *in vivo*.

Methodology The working lengths in 20 teeth with a single canal were determined with two different EALs (Root ZX; J. Morita Corporation, Tokyo, Japan and Raypex® 5 VDW, Munich, Germany) before extraction. When the first EAL was used the files were advanced until the display indicated the 'apical constriction'. The files were then fixed in removable and replaceable light curing composite patterns. The procedure was repeated in the same tooth with the second EAL and a different file. The teeth were then extracted and the apical 4 mm of the root canals were exposed. After that the apical parts with the repositioned files in the canals were digitally photographed under a light microscope. On the images the minor diameter and the major foramen of each sample were marked and the respective distances of the file tips from these positions were measured with a computer program. Subsequently the values of the two groups of EALs were compared using a paired sample *t*-test.

Results The minor foramen was located within the limits of ±0.5 mm in 75% of the cases with the Root ZX and in 80% of the cases with Raypex® 5. The paired sample *t*-test showed no significant difference between the EALs regarding determination of the minor foramen.

Conclusion The use of EALs is a reliable method for determining working length. The differences between the two EALs were not statistically significant.

Keywords: apical constriction, apical foramen, endodontics, root apex working length.

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Introduction

Accurate determination of working length during root canal treatment is a challenge. The apical constriction, where the pulp tissue is connected to the apical periodontal tissue, is recommended as the physiologic apical limit for instrumentation and filling of the root canal. The constriction is the part of the root canal in the apical region with the smallest diameter; it is also referred to as the minor diameter (Ricucci & Langeland 1998).

Electronic apex locators (EALs) reduce the number of radiographs required, and are recommended to complement and assist radiographic methods of working length determination. Moreover, they can indicate cases where the apical foramen is some distance from the radiographic apex and might be helpful in detecting root canal perforations (Gordon & Chandler 2004).

Modern EALs determine the working length by measuring impedance with different frequencies between the file tip and the canal fluid. The impedance is small at the apical constriction and has a higher value at the major foramen (Hoer & Attin 2004).

Correspondence: Dr Karl-Thomas Wrbas, Klinikum der Albert-Ludwigs-Universität, Universitätsklinik für Zahn-, Mund- und Kieferheilkunde, Abteilung für Zahnerhaltungskunde und Parodontologie, Hugstetter Str. 55, D-79106 Freiburg i. Br, Germany (Tel.: +49 761 270 4889; fax: +49 761 270 4762; e-mail: thomas.wrbas@uniklinik-freiburg.de).

The accuracy of EALs, tested in different teeth, has been the subject of numerous previous studies (Gordon & Chandler 2004, Kim & Lee 2004).

The aim of this study was to compare the accuracy of two frequency-dependent EALs under clinical conditions, in detecting the minor diameter in the same tooth. Frequency-dependent EALs measure the impedance difference between two frequencies or the ratio of two electrical impedances (Kim & Lee 2004). The hypothesis of the study was that modern apex locators provide identical results in working length determination *in vivo*.

Materials and methods

Two apex locators (Root ZX; J. Morita Corporation, Tokyo, Japan and Raypex® 5, VDW, Munich, Germany) with identical working frequencies (0.4 kHz and 8 kHz) were used. Fifteen adult patients, ages 36–71 years, participated in the study. Twenty single-rooted teeth with one canal that were scheduled for extraction for periodontal, endodontic or prosthetic reasons were used. Approval by the institutional review and ethical board before commencement of the study was obtained and written consent was obtained from each patient. The teeth had completely formed apices confirmed by radiographic evaluation before treatment. Pulps in 13 teeth were nonvital. After local anaesthesia (Ultracain® DS, sanofi-aventis, Frankfurt/Main, Germany), the teeth were isolated with rubber dam, and caries and existing metal restorations were removed. The access cavity was prepared in such a way that straight-line access to the root canals was provided and undercuts were avoided. After the identification of the root canals, the coronal portions of the canals were flared with Gates Glidden drills sizes 2–4 (VDW, Munich, Germany). The root canals were rinsed with 1% sodium hypochlorite solution and the pulp chamber was cleaned. The working lengths were then determined by a single operator. The Root ZX and the Raypex® 5 were used according to the manufacturers' instructions. The lip clip was attached to the patient's lip and a stainless steel size 15 reamer was connected to the electrode of the apex locators. The file was advanced until the display of the Root ZX indicated the apical constriction and the instrument was fixed within a removable light curing composite pattern (Ceram X; Dentsply, Konstanz, Germany). Then the composite pattern was removed from the tooth. The procedure was repeated in the same tooth with another instrument using the Raypex® 5. In each case it was a priority that the composite pattern could be repositioned exactly in the respective tooth. The length was electronically rechecked to confirm the same file position before and after reposition of the composite pattern. In each case the EALs were randomly used. The teeth were extracted and placed in 5.25% sodium hypochlorite solution to remove remaining tissue from the external root surfaces. Then, the apical 4 mm of the root canals and the apical canal constrictions were exposed in a longitudinal direction under a light microscope at 24× magnification. The dentine was removed with a finishing bur until only a thin layer of tissue remained. The remaining layer was removed with a scalpel. The apical parts of the specimens were photographed twice with a digital camera (AxioCam MRc 5; Carl Zeiss, Jena, Germany) under a light microscope (Axioskop 40, Carl Zeiss) at 36× magnification. The first image was made with the repositioned composite pattern for the measurement with Root ZX. The second image was made with the composite pattern for the working length determination with Raypex® 5. Two investigators marked together the minor diameter, the major foramen and the respective distances of the file tips on the images. The investigators did not know which device had produced which image. When the apical constriction was less defined or was shaped like a slot, the apical end of the constriction was used as a reference. The distances from the file tips to the minor diameters and to the major foramina were measured on the digital photographs according to the requirements of the computer based measuring system (AxioVision AC software, Carl Zeiss) (Fig. 1). If the file tip was short of the minor diameter and the major foramen, the value was negative. The value was positive, if the file tip was beyond these anatomical structures. The target interval was set at ±0.5 mm to the minor diameter. The results of the two groups of apex locators were compared using a paired sample *t*-test (SPSS 12.0 for Windows, SPSS Inc., Chicago, IL, USA). The level for accepting statistical significance was set at $P < 0.05$.

Results

The minor diameter and the major foramen could be determined in all the teeth.

Figure 2 shows the distances of the file tips for the EALs in relation to the minor diameter. The mean distance between the instrument tip and the minor diameter was +0.22 mm (±0.49 mm) for the Root ZX.

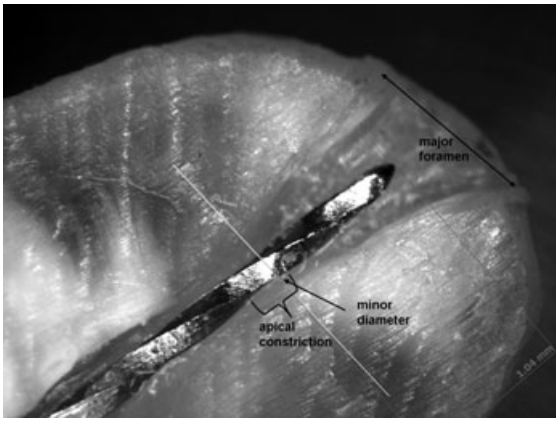


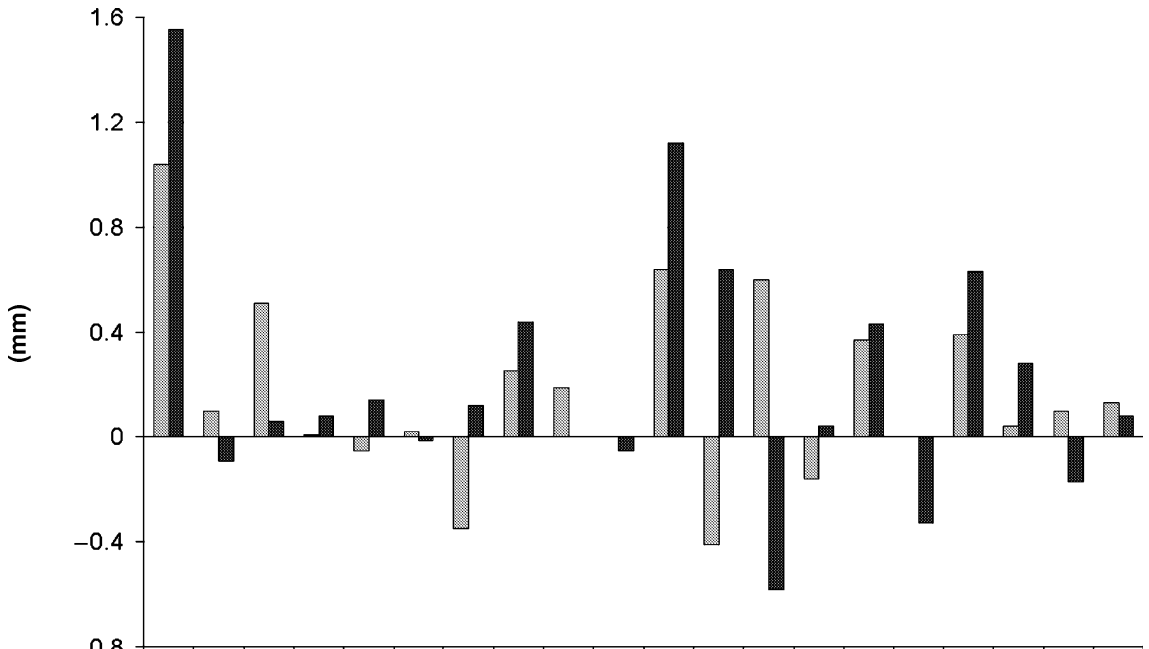
Figure 1 Evaluation of the digital image of the sectioned root apex. File tip is between the minor diameter and the major foramen.

The mean distance was +0.17 mm (±0.35 mm) for the Raypex 5. The minor diameter was located exactly with Root ZX in 5% of cases and in 10% of cases with the Raypex® 5. Within the limits, minor diameter ±0.5 mm, the target interval was located in 75% of cases with the Root ZX. Twenty per cent of the measurements fell outside the target interval and were too long for the defined limit. One measurement (5%) was too short. The Raypex® 5 was within the limits of ±0.5 mm to the minor diameter in 80% of cases; 20% of the measurements were too long.

Discrepancies from 0.03 to 1.18 mm occurred between the measurements of the two EALs in the same specimen. In none of the cases was an exact agreement between the results of the two EALs in working length determination found.

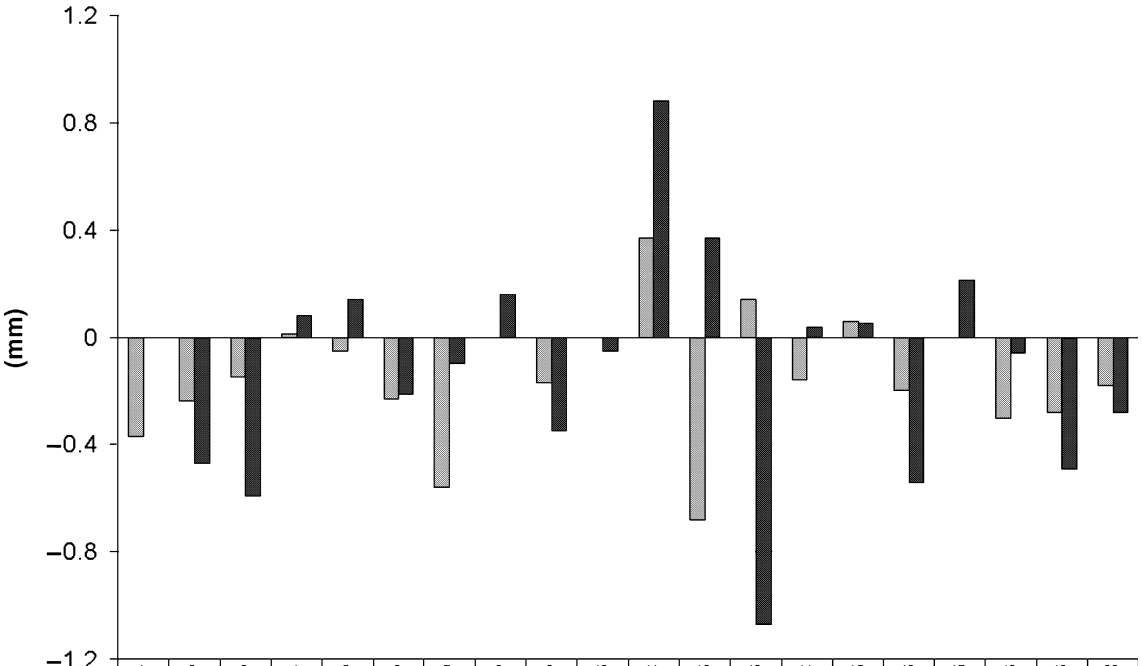
Figure 3 shows the position of the file tips for the EALs in relation to the major foramen. For Root ZX, the mean distance between the tip of the file and the major foramen was −0.12 mm (±0.41 mm). The file tips were in seven cases less than +0.5 mm and in one case +0.88 mm beyond the major foramen. For the Raypex® 5 the average distance from the file tip to the major foramen was −0.15 mm (±0.24 mm). Four files passed the major foramen by less than +0.5 mm.

The paired sample *t*-test showed that there was no significant difference between the results of Root ZX and Raypex® 5 in determining of the minor foramen ($P = 0.7211$) and for the position of the file tips to the major foramen ($P = 0.740$).



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Raypex5 (mm)	1.04	0.1	0.51	0.01	−0.05	0.02	−0.35	0.25	0.19	0	0.64	−0.41	0.6	−0.16	0.37	0	0.39	0.04	0.1	0.13
Root ZX (mm)	1.55	−0.09	0.06	0.08	0.14	−0.01	0.12	0.44	0	−0.05	1.12	0.64	−0.58	0.04	0.43	−0.33	0.63	0.28	−0.17	0.08

Figure 2 Distance – instrument to minor diameter. Distances of the instrument tips for Root ZX and Raypex® 5 in relation to the minor diameter.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Raypex 5 (mm)	−0.37	−0.24	−0.15	0.01	−0.05	−0.23	−0.56	0	−0.17	0	0.37	−0.68	0.14	−0.16	0.06	−0.2	0	−0.3	−0.28	−0.18
Root ZX (mm)	0	−0.47	−0.59	0.08	0.14	−0.21	−0.1	0.16	−0.35	−0.05	0.88	0.37	−1.07	0.04	0.05	−0.54	0.21	−0.06	−0.49	−0.28

Figure 3 Distance – instrument to major foramen. Distances of the instrument tips for Root ZX and Raypex® 5 in relation to the major foramen.

Discussion

The present *in vivo* study was performed to evaluate the accuracy of two EALs under authentic clinical conditions. The working length was determined in agreement with the recommendations of the European Society of Endodontology (1994).

In some studies a general accuracy with tolerance of ±1.0 mm to apical constriction is regarded as clinically acceptable, especially concerning primary teeth or teeth without a well-defined apical constriction (Shabahang *et al.* 1996, Goldberg *et al.* 2002, Kielbassa *et al.* 2003). The measurements of the present study were attained in a target interval of ±0.5 mm to the minor diameter of the apical constriction, using the Axio Vision AC software. This clinical tolerance of ±0.5 mm is considered to be the strictest acceptable. Measurements within this minimal tolerance are highly accurate (Kim & Lee 2004).

The accuracy of EALs is not significantly influenced by different concentrations of sodium hypochlorite (Meares & Steiman 2002). The results of another study showed that the Root ZX supplied reliable measurements regardless of the applied irrigant (Jenkins *et al.* 2001). In the present investigation the root canals were rinsed with 1% NaOCl for cleaning the canals before the measurements. Sodium hypochlorite was used because of the widespread utility as an intracanal irrigant.

Nguyen *et al.* (1996) reported that file size did not affect the accuracy of EALs. Lengths measured with size 15 instruments, compared with lengths obtained using the size comparable with the diameter of the root canal, were the same as or <0.5 mm different (Felippe & Soares 1994). The Root ZX and the Raypex® 5 in the present investigation were used according to the recommendations of the operation manual and in combination with a size 15 instrument. In all teeth the measurements were practicable and reproducible with the inserted instruments. The same file size was used in every case to have comparable conditions for the *in vivo* measurements.

In vivo studies usually compare the accuracy of different EALs using vital and necrotic pulps. Pulpal vitality does not significantly affect the accuracy of EALs (Dunlap *et al.* 1998). Some authors suggest that in necrotic cases with inflammatory root resorption, the apical constriction might be altered, which would

lead to a lower accuracy (Pommer *et al.* 2002). In the present study 13 pulps were nonvital. The magnified digital images of the root ends which were used for the evaluation did not show any resorption.

Several earlier investigations used radiographic lengths as a reference (Frank & Torabinejad 1993, Pratten & McDonald 1996, Pommer *et al.* 2002). Exact determination of the position of the file tip or the actual root canal length is only possible if the teeth are histologically examined after extraction. Different methods are used first to locate the apical constriction or the apical foramen precisely and secondly to measure the exact distance between these anatomic structures and the tips of the inserted instruments (Kim & Lee 2004). Welk *et al.* (2003) conducted an *in vivo* comparison of two frequency-based EALs. The teeth were extracted after measurement and cementation of the files in position. In another study two apex locators were applied. The root canal instruments were fixed with composite at the electronically determined working lengths prior to extraction. After extraction of the teeth, radiographic working length determination followed. Histological and radiographic results were compared (Hoer & Attin 2004).

Haffner *et al.* (2005) tested the accuracy of four different EALs. The length was determined after removing the file from the canal and holding it next to a steel ruler. The teeth were extracted and sectioned longitudinally and the canals were examined under a light microscope.

Precise comparison of the accuracy and differences of types of EALs in determination of the working length is possible, only if the same teeth are evaluated clinically and examined histologically after extraction. Therefore, a new procedure was used in the present study. Working length in the same tooth was determined with Root ZX and Raypex® 5 *in vivo* before extraction. In addition, the histomorphometrical analysis and comparison could be carried out for the two EAL systems in one root because of the replaceable composite patterns. This model offers a direct and exact histological comparison of the results.

The Root ZX has also been object of numerous *ex vivo* and *in vivo* studies (Gordon & Chandler 2004, Kim & Lee 2004). A review of the literature failed to find any investigation of the accuracy of the Raypex® 5. The results of the present study are in agreement with previous *in vivo* studies evaluating the accuracy of EALs in determining the apical constriction with a range of ±0.5 mm. These studies show a clinical accuracy between 75.0% and 82.3% (Dunlap *et al.* 1998, Meares & Steiman 2002, Tselnik *et al.* 2005). The Raypex® 5 was able to locate the apical constriction predictably with (±0.5 mm) 80% accuracy compared with the Root ZX with (±0.5 mm) 75% accuracy. The application of the EALs did not result in a precise location of the apical constriction. This is in agreement with the findings of another recent study (Hoer *et al.* 2005).

Although the measurements for each tooth were carried out under the same clinical conditions by one operator with the EALs using the same frequencies, not one result of the two EALs was in exact agreement. Working length changes throughout root canal preparation. The file may go inadvertently beyond the apical foramen damaging the apical constriction (Kim & Lee 2004). For determination of working lengths in this study with both EALs, a minimum of two files were used in the respective root canals. This initial instrumentation of the canal might have contributed to the discrepancies of the results between the EALs. For the clinical application of EALs it could be recommended to control and re-evaluate the working length continually throughout the instrumentation of the root canals.

The findings of this study have shown that the apical constriction is not consistent with the major foramen. This result is in accordance with the studies of Pineda & Kuttler (1972) and Dummer *et al.* (1984). In previous studies testing the accuracy of frequency-dependent EALs, the major foramen at a tolerance of ±0.5 mm or ±1.0 mm was used as a reference (Lauper *et al.* 1996, Vajrabhaya & Tepmongkol 1997, Dunlap *et al.* 1998, Pagavino *et al.* 1998). The results of the present study demonstrate that the tip of the file was beyond the major foramen in eight cases for the Root ZX and in four cases for the Raypex® 5. This was inspite of the fact that the EALs were used according to the manufacturers' instructions to determine the apical constriction.

As a consequence for the clinical working length determination, the files should only be advanced until the display indicates the minor diameter. This is to avoid the files passing through the major foramen and overestimating the working length. To reduce overpreparation a withdrawal of the instruments of 0.5 mm might be helpful and could be recommended.

Conclusions

Under clinical conditions the tested EALs identified the apical constriction in range of ±0.5 mm with high degree of accuracy. Exact determination of the apical

constriction was however only possible in three cases. The results obtained from different EALs for the same teeth were also not in agreement and showed discrepancies from 0.03 to 1.18 mm.

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