Ex vivo evaluation of the capacity of the Tri Auto ZX to locate the apical foramen during root canal retreatment

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Abstract

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Aim To evaluate *ex vivo* the capacity of the Tri Auto ZX to locate the apical foramen during root canal retreatment.

Methodology The root canals of 62 maxillary and mandibular canines were prepared to a length 1 mm short of the apical foramen, to an apical size 35 using 1% sodium hypochlorite as an irrigant. Once prepared, the length of each tooth was measured directly using a size 15 K-Flexofile introduced in the canal until the tip was visible at the apical foramen. After the file was removed, its length was recorded to a precision of 0.01 mm using a calliper. These direct lengths (DL) became the 'gold standard' for comparison with the electronic lengths (EL) derived from the Tri Auto ZX. After direct measurement, the tooth was measured electronically (EL1) and the canals were filled using lateral condensation of gutta-percha cones and sealer. Seven days later the root filling was removed using solvent, Gates-Glidden burs, and K-files, and new electronic lengths determined (EL2). The electronic lengths (EL1 and EL2) were compared with the DL, and the differences were analysed statistically using the proportions test and Student's *t*-test.

Results At a tolerance limit of ±0.5 mm, EL1 coincided with the DL in 76% of cases. Lengths obtained in the presence of remnant of filling material (EL2) coincided in 81% of cases. The proportions test used to compare these percentages showed no statistically significant difference between EL1 and EL2 ($P > 0.05$). The Student's *t*-test revealed a statistically significant difference ($P < 0.05$) between the means of the differences between DL/EL1 (−0.36 mm) and DL/EL2 (−0.04 mm).

Conclusion The Tri Auto ZX was accurate to ±0.5 mm in more than 80% of teeth following removal of root fillings.

Keywords: electronic apex locator, electronic odontometry, endodontic retreatment.

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Introduction

Determining the apical limits of canal preparation and filling is one important aspect of root canal treatment. Several authors when reporting clinical and/or histological studies obtained a better outcome when root fillings were 1–2 mm short of the radiographic apex of the root or the apical foramen (Sjögren *et al.* 1990, Soares *et al.* 1990).

One method to assess working length is the electronic apex locator (EAL). Because of the influence of canal contents, the readings obtained from the earlier devices made length measurements unreliable (McDonald 1992). With technological advances and an improved knowledge of how electrical properties act along the canal (frequency, capacitance, impedance), the devices have been improved (Inoue 1973, Ushiyama 1983, Yamaoka *et al.* 1989, Kobayashi & Suda 1994).

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The Root ZX (J. Morita Corp., Kioto, Japan) is an EAL that the manufacturers claim is capable of measuring canal length without being affected by canal contents. It has been the subject of several studies that show a high level of reliability (Czerw *et al.* 1995, Shabahang *et al.* 1996, Felippe *et al.* 1997, Pagavino *et al.* 1998, Ounsi & Naaman 1999). After some years, the same company designed the Tri Auto ZX, a handpiece for the mechanical preparation of root canals, with a built-in EAL. The Root ZX was installed in this handpiece (Kobayashi *et al.* 1997), but with smaller dimensions.

In the majority of studies assessing EALs, the length of teeth measured by insertion of a file in the canal as far as the foramen was compared with the lengths measured by the devices before mechanical preparation (Czerw *et al.* 1995, Shabahang *et al.* 1996, Felippe *et al.* 1997, Grimberg *et al.* 1998, Pagavino *et al.* 1998, Ounsi & Naaman 1999).

Few reports have evaluated measurements obtained following preparation or pre-enlargement of the canal (Rivera & Seraji 1993, Mowrey *et al.* 1997, Ibarrola *et al.* 1999). According to some reports, the presence of debris and dentine chips, frequently produced after instrumentation, can affect the precision of EALs (Rivera & Seraji 1993, Ibarrola *et al.* 1999) and thus affect the working length readout.

The purpose of this study was to evaluate *in vitro* the capacity of the Tri Auto ZX to locate the apical foramen following removal of root filling material during root canal retreatment.

Material and methods

Preparation of teeth

Sixty-two maxillary and mandibular human canines with a single canal and fully formed roots were numbered and stored in saline solution – 0.9% solution of NaCl (Texon, Viamão, Brazil) until use. After endodontic access cavity preparation, canal patency was checked with a size 15 K-Flexofile (Dentsply Maillefer, Ballaigues, Switzerland) introduced to the anatomical apical foramen. The incisal edge of each tooth was ground to produce a definitive flat reference point. Teeth were measured using a size 15 K-Flexofile introduced in the canal until the tip was just visible at the apical foramen. The file, held by a needle-holder perpendicular to the incisal edge, was laid against a millimetre ruler, making it possible to obtain the length of each tooth. The canals were then prepared 1 mm short of this length to an apical size 35 under irrigation with 2 mL of 1% sodium hypochlorite (Miyako, São Paulo, Brazil) between each instrument.

Length between the coronal reference point and apical foramen using the direct method (DL)

Once canal preparation was complete, the teeth were measured once more by a direct technique. These measurements became the 'gold standard' for comparison with the electronic measurements. A size 15 K-Flexofile was introduced in the canal so that its tip was just visualized with the help of a magnifying glass (×2.5) at the apical foramen. The rubber stop was moved to the reference point and the length recorded with a 0.01 mm (±0.03) precision calliper (Starret 727-6/150, Itu, Brazil) after its removal from the canal. Each tooth was measured three times by the same operator, the mean of the three lengths obtained being recorded.

Length between the coronal reference point and apical foramen using the EAL (EL1)

To conduct the electronic measurements, the Tri Auto ZX unit was used according to the manufacturer's instructions (J. Morita MFG Corp. 1998). A container with saline soaked sponge was used as the support for an opaque plastic cylinder, perforated on the sides to allow the saline free access. Each of the teeth was fixed at the level of amelo-cemental junction to a perforation existing on the lid of the plastic cylinder, in such a way as to ensure the root was submerged in saline. The labial clip, connected to the negative electrode of the device, was secured to one of the container's surfaces. The file holder, connected to the positive electrode, was attached to a 31 mm long size 15 file. The file was introduced in the canal, which had been previously filled with saline, until an 'apex' reading was obtained. The stopper was placed at a tangent to the reference point (Fig. 1) and the instrument was removed from the canal and measured with the calliper as described previously. Those measurements, corresponding to the electronic measurements obtained after preparation and before root filling, were noted as electronic lengths 1 (EL1).

Root canal filling

The canals were then irrigated with 2 mL of 1% sodium hypochlorite, dried with absorbent paper points, and then filled using lateral condensation of

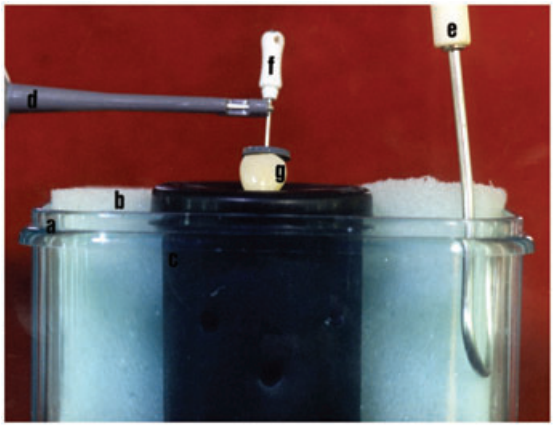

Figure 1 Apparatus used to obtain electronic measurements: (a) plastic container; (b) saline-soaked sponge; (c) perforated plastic cylinder; (d) file holder; (e) labial clip; (f) measuring file; (g) tooth positioned on the plastic cylinder lid perforation.

gutta-percha cones (Tanari, Manacupuru, Brazil) and zinc oxide-eugenol cement (Vigodente, Rio de Janeiro, Brazil). After sealing the access cavity with Cimpat (Septodont, Saint-Maur-des-Fossés, France) the teeth were radiographed in a bucco/palatal direction and then stored in 100% humidity for 7 days. These radiographs (Ultra-Speed; Kodak, Rochester, NY, USA) were exposed with a 50 kV machine (Dabi-Atlante, Ribeirão Preto, Brazil), at 0.4 s exposure time, with a 6 cm focal distance.

Electronic length after removal of root filling (EL2)

After 7 days, the coronal seal was removed and a gutta-percha solvent (Eucaliptol; Iodontosul, Porto Alegre, Brazil) was placed on the filling material. Three minutes later, sizes 2 and 1 Gates-Glidden burs (Dentsply Maillefer) were used on the cervical and middle thirds, respectively, to remove the filling material, with concomitant sodium hypochlorite irrigation. The apical third of the root filling was removed using gutta-percha solvent and sizes 25, 20 and 15 K-files used sequentially in an apical direction and calibrated to reach the root canal filling length as obtained previously from the radiograph. When a size 15-file reached the desired length, the canal was irrigated with saline and the tooth placed once more in the plastic container for the second electronic reading (EL2) as described previously (EL1). For those teeth where the EAL did not emit a signal, the measurement was repeated after the file had been introduced more apically to the point where an 'apex' reading occurred. Measurements thus obtained, in the presence of remnants of the filling material, were noted as electronic length 2 (EL2).

The moment the device confirmed the file tip was at the apical foramen (apex reading), the tooth was radiographed in a buccal-palatal direction before and after removal of the file from the canal in order to analyse the relation between radiograph apex-file tip and the presence of filling material remnants, respectively.

Evaluation criteria

Measurements obtained with the EAL before and after root filling (EL1 and EL2) were compared with the original direct measurements (DL). Differences were computed and considered to be acceptable when less than or equal to 0.5 mm. When the DL was greater than the EL1 and/or EL2, the difference received a negative sign indicating that, in the electronic measurement, the file tip was short of the foramen. When the DL was less than the EL1 and/or EL2, the difference was given a positive sign, indicating the file tip had passed beyond the foramen.

Percentages of acceptable measurements for each electronic reading were calculated and compared using the proportions test. The means of differences between DL/EL1 and DL/EL2 were then calculated and compared using Student's *t*-test. The critical value of statistical significance was 5%.

Results

Four teeth were excluded from the study, because of canal obstruction due to filling material compaction and root perforation making it impossible to obtain and compare the second electronic measurement. The final number of teeth was thus 58.

The differences between the tooth lengths, obtained by direct and electronic methods, before root canal filling (DL/EL1) are shown in Table 1. The differences between DL and the electronic lengths measured after the removal of filling material (EL2) are shown in Table 2. These differences were distributed, in different intervals, in relation to the length determined directly (gold standard).

Within the adopted tolerance limits (±0.5 mm), measurements obtained using the device before root canal filling (EL1) were considered acceptable on 76% of cases ($n = 44$). After the root canal filling (EL2), the percentage was 81% ($n = 47$). Using the proportions test (Z) to compare the percentage of acceptable

Table 1 Distribution of the differences between EL1 (before root filling) and direct length. Acceptable measurements (±0.5 mm) are underlined

					n=19	*n*=19		
					–0.43	**–0.24**		
					–0.42	**–0.23**		
					–0.40	**–0.22**		
					–0.40	**–0.21**		
					–0.40	**–0.21**		
					–0.40	**–0.21**		
					–0.40	**–0.20**		
					–0.39	**–0.18**		
					–0.38	**–0.18**		
					–0.38	**–0.18**		
					–0.36	**–0.13**		
				n=07	**–0.36**	**–0.12**		
				–0.71	**–0.35**	**–0.11**		
				–0.70	**–0.33**	**–0.10**		
				–0.67	**–0.32**	**–0.09**	*n*=04	
				–0.63	**–0.30**	**–0.09**	**+0.20**	
	n=02	*n*=02	*n*=02	–0.53	**–0.28**	**–0.02**	**+0.17**	*n*=02
n=01	–1.43	–1.12	–0.88	–0.52	**–0.26**	**–0.02**	**+0.05**	**+0.42**
–1.60	–1.26	–1.04	–0.80	–0.51	**–0.26**	**–0.01**	**+0.02**	**+0.27**
–1.50	***–1.25***	***–1.00***	***–0.75***	***–0.50***	***–0.25***	*0.00*	***+0.25***	***+0.50*** **(mm)**

Short of foramen (52 samples) | Beyond foramen (six samples)

n, Number of samples in the interval.

measurements produced by the Tri Auto ZX in different situations, no statistically significant difference was evident amongst them ($Z = 0.67$; $P = 0.4981$). However, when comparing the means of the differences between DL/EL1 (−0.36 mm) and DL/EL2 (−0.04 mm), using Student's *t*-test, a statistically significant difference was detected ($P < 0.001$). Therefore, the measurements obtained using the device after removal of root filling (EL2) were nearer to the foramen than those obtained before filling the root canal (EL1).

Radiographs obtained after EL2 measurements showed remnants of filling in all the teeth. On the radiographs taken with the file introduced in the canal, it was not possible to distinguish the end of the instrument in the filling material of 14 teeth, and in 12 of the teeth the position of the instrument was considered doubtful.

Discussion

The method used in this study was similar to that employed in other reports (Felippe & Soares 1994, Kobayashi & Suda 1994, Felippe *et al.* 1997). The extracted teeth were stored in saline solution, because this solution is neutral and kept the teeth hydrated.

Direct lengths (DL) of root canals, used as a reference to analyse electronic measurements, were obtained after preparation of the canal because instrumentation might modify tooth length. Thus, differences between direct and electronic lengths, whenever found, were not a result of preparation but rather of limitations of the EAL or the operator. In addition, when obtaining the DL after mechanical preparation, passage of files as far as the re-established anatomical foramen for canal patency which is essential for EAL function (J. Morita MFG Corp. 1998), may have been affected by compaction of dentine debris (Rivera & Seraji 1993).

In the present study, the device was programmed to detect the apical foramen, which is a reference point that can be determined directly. In this way, there was no need to grind the root apex to visualize the tip of the instrument (as is the case when the constriction has to be located) and it was possible to use the same teeth to

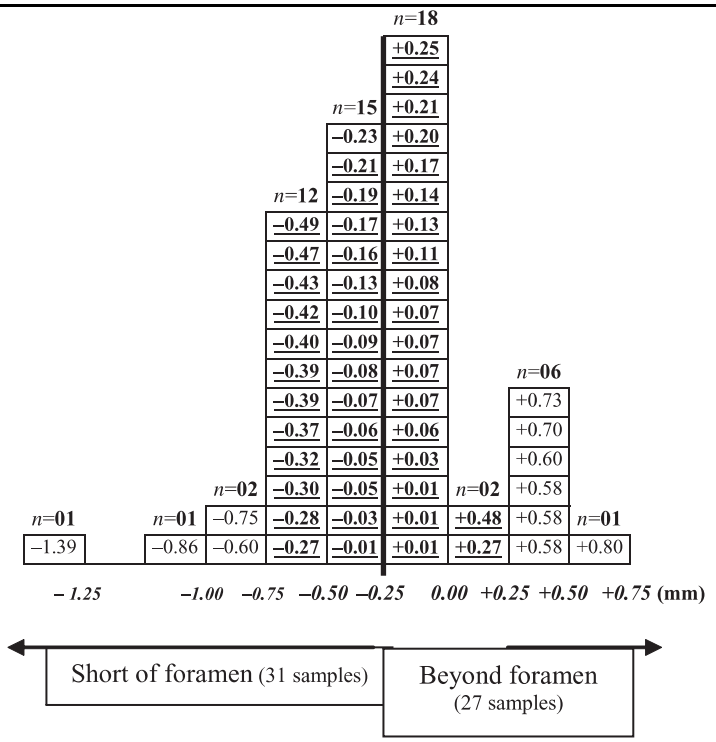

Table 2 Distribution of the differences between EL2 (in the presence of remnants of the filling material) and direct length. Acceptable measurements (±0.5 mm) are underlined

n, Number of samples in the interval.

analyse the device at different times, e.g. before and after root filling.

The tolerance limit of ±0.5 mm was employed in the present study because the foramen has variable forms (Gutierrez & Aguayo 1995) and some difficulty was experienced in visualizing the exact point where the tip of the file reached the cervical border of the foramen, even with magnification. In addition, the relation between the rubber stop/reference point, rubber stop/calliper, and file tip/calliper was difficult to control visually. When repeating the measurements (three times) in DL, seldom were the same lengths obtained exactly (differences less than 0.09 mm). In this way, very small differences (≤0.5 mm) between DL and EL1 and EL2 may have been caused by the experimental model, and not through lack of precision of the EAL.

The tooth lengths obtained from the Tri Auto ZX, following preparation and before root canal filling (EL1), were coincident (±0.5 mm) with the lengths obtained through the direct technique in 76% of cases. Other reports show between 85 and 100% coincidence (Czerw *et al.* 1995, Shabahang *et al.* 1996, Felippe *et al.* 1997, Grimberg *et al.* 1998, Pagavino *et al.* 1998, Ounsi & Naaman 1999). As already mentioned, these previous experiments were conducted in canals prior to instrumentation. In the present study, however, measurements were obtained following preparation, and the reduced accuracy could be attributed to the presence of debris and dentine chips resulting from preparation (Rivera & Seraji 1993). In addition, the different measuring devices used in the present study and those referred to previously might also explain the discrepancy. It should be emphasized that in only six cases did the Tri Auto ZX give measurements longer than the direct ones, the differences always being <0.5 mm. In the remaining 52 teeth, the measurements were shorter than those obtained by the direct method. Extrapolated to clinical practice, these results are promising, as a 0.5–1.0 mm shortening of the length given by the device would allow instrumentation to be conducted within the canal, preventing periapical injury from instruments.

Measurements obtained from the Tri Auto ZX in the presence of filling material remnants (EL2) coincided with direct measurements (±0.5 mm) in 81% of

cases. This is a high percentage of correct readings, comparable with results conducted on canals without previous instrumentation (Czerw *et al.* 1995, Shabahang *et al.* 1996, Felippe *et al.* 1997, Grimberg *et al.* 1998, Pagavino *et al.* 1998, Ounsi & Naaman 1999).

Contrary to EL1, which presented a trend towards shorter measurements than the direct ones, the EL2 for 27 teeth was greater than the DL. The difference between these measurements was <0.5 mm for 20 teeth. In those teeth where the tip of the file passed more than 0.5 mm beyond the foramen ($n = 7$), an analysis of radiographs obtained after recording the EL2 showed in the majority of them, filling material had been pushed through the apical foramen. It seems that in such cases the measuring file had to go beyond the extruded material before the device could signal the foramen.

A size 15 file was employed for measurements, because in a clinical situation, the file introduced to the root canal would be of this size or smaller size in order to avoid extrusion of filling material.

From a comparison of percentages of acceptable measurements obtained before and after root filling, the proportions test revealed no significant differences. So, from a clinical point of view, in both situations the device acted in a similar manner. However, in comparing the mean of differences between DL and EL1 (−0.36 mm) and DL and EL2 (−0.04 mm), the Student's *t*-test revealed a statistically significant difference, in spite of both means being within the tolerance limits. Probably, the presence of filling material remnants in the apical foramen explained why EL2 was close to DL: the device could only signal the arrival of the file tip at the foramen when the file had passed the gutta-percha remnants or beyond.

Based on radiographs taken when obtaining the EL2, an attempt was made to analyse the relation between radiographic apex and file tip. In many teeth (26), the actual position of the file tip was masked by the remnants of the filling material. To obtain the tooth length using the radiographic method, it would be necessary to eliminate more material from the apical zone. Otherwise, the results of this study show that it was not necessary to completely remove the filling material to obtain the tooth length using the Tri Auto ZX. This could be seen as an advantage offered by EALs in cases of endodontic retreatment, as it would help provide the apical limit for cleaning and shaping with greater safety, and at the same time reduce the need for multiple radiographs.

Conclusion

The Tri Auto ZX was accurate to ±0.5 mm in more than 80% of teeth when used following removal of root filling *in vitro*.

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