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# The influence of irrigating solutions on the accuracy of the electronic apex locator facility in the Tri Auto ZX handpiece

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## Abstract

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**Aim** To determine the influence of various irrigating solutions on the accuracy of the electronic apex locator facility in the Tri Auto ZX handpiece.

**Methodology** One hundred and forty teeth with single canals and mature apices, scheduled for extraction for either periodontal or prosthetic reasons in 76 patients were used. Following informed written consent local anaesthesia was administered, access cavities were prepared and pulp tissue removed. The teeth were then randomly divided into seven groups according to the irrigating solutions used. The root canal length measurements were completed using the Tri Auto ZX handpiece with automatic reverse function in the presence of one or other of the following solutions: 0.9% saline, 2.5% NaOCl, 3% $H_2O_2$, 0.2% chlorhexidine, 17% EDTA, Ultracaine® D-S or in the absence of an irrigating solution (control). Files were immobilized in the access cavity with composite resin. After extraction, the apical regions of the teeth were exposed and the file tips examined under a stereomicroscope. Distances between the file tips and the apical constriction were measured (mm) and analysed using a one-way ANOVA and *post hoc* Tukey test.

**Results** Mean distances from the apical constriction to the file tip were longer in the 0.9% saline group ($P < 0.05$). There was no statistically significant difference on file tip position between the other solutions.

**Conclusions** Tri Auto ZX gave reliable results with all irrigating solutions apart from in the presence of 0.9% saline.

**Keywords:** handpiece, irrigation solutions, profile, root canal length, Tri Auto ZX.

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## Introduction

The accurate determination of root canal length is one of the important factors that can influence the outcome of root canal treatment (Seltzer *et al.* 1963, Smith *et al.* 1993, Ricucci & Langeland 1998, Ricucci 1998). It is widely accepted that root canal instrumentation and filling should be terminated at the apical constriction, where the periodontal ligament begins and the pulp ends (Kuttler 1955, Christie & Peikoff 1980, Dunlap *et al.* 1998, Ricucci & Langeland 1998, Steffen *et al.* 1999, Gordon & Chandler 2004).

The use of electronic devices to determine root canal length has increased substantially in recent years. The principal design and development of the early apex locators dates back to Suzuki (1942). He carried out research on dogs and discovered that the electrical resistance between the periodontal membrane and the oral mucosa was a constant value of approximately 6.5 kΩ. This principle was introduced into clinical practice by Sunada (1962) and it is on his work that

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the operating principles of resistance-type Electronic Apex Locators (EALs) are based.

Further developments of EALs have resulted in units that operate by measuring changes in impedance across the wall of the root canal and by applying two different frequencies to a file and measuring the difference between them. Studies to determine the accuracy of EALs show that the units are accurate within ±0.5 mm between 83.0% and 93.4% of the time (O'Neill 1974, Suchde & Talim 1977, Inoue & Skinner 1985, Kaufman *et al.* 1989, McDonald & Hovland 1990).

Kobayashi & Suda (1994) introduced the Root ZX apex locator (J. Morita Corp., Kyoto, Japan). This EAL simultaneously calculates the ratio of two different frequencies and, reportedly, the accuracy of the measurement is not affected by vital pulp tissue, sodium hypochlorite or exudate within the canal (Dunlap *et al.* 1998, Jenkins *et al.* 2001, Meares & Steiman 2002).

The accuracy of EALs has been studied in depth and they have been shown to determine root canal length effectively and reproducibly (Fouad *et al.* 1993, Shabahang *et al.* 1996). Even in the presence of root canal irrigants, such as ethanol, local anaesthetic solution and sodium hypochlorite, as well as pus and necrotic tissue, EALs are able to maintain their high level of accuracy (Fouad *et al.* 1993, Dunlap *et al.* 1998).

Recently an engine-driven canal preparation system, the Tri Auto ZX (J. Morita Corp., Kyoto, Japan), has been developed (Kobayashi 1995). The Tri Auto ZX is a cordless handpiece with an integrated EAL that is designed for rotary canal preparation with nickel–titanium instruments. In this system, the instrument electrode is installed in the head of the handpiece and is connected to the Root ZX through the handpiece. The rotation speed of the instrument can be adjusted between 150 and 300 rpm. This device does not require calibration because a microprocessor corrects the calculated quotient and the position of the instrument tip can be observed on the panel with the activation of lights. The Tri Auto ZX has three automatic mechanisms: auto-start–stop mechanism, auto-torque-reverse mechanism and Auto-apical-reverse mechanism. The purpose of this system is that the location of the instrument tip is always electronically monitored by the Root ZX during preparation, so the danger of over-instrumentation can be minimized (Kobayashi 1995, 1997, Kobayashi *et al.* 1997).

The function and characteristics of the Tri Auto ZX were extensively described in previous publications (Kobayashi *et al.* 1997, Kobayashi 1997). *Ex vivo* studies have demonstrated that the Tri Auto ZX can accurately measure the root canal length and trigger reversal of file rotation when the instrument reaches a predetermined level (Campbell *et al.* 1998, Grimberg *et al.* 1998). This also occurs when an excess of torque is registered. The apical extent of the instrumentation can be then controlled more safely (Zmener *et al.* 1999).

Irrigation is presently the best method for the removal of tissue remnants and dentine debris during instrumentation (Spangberg & Haapasalo 2002, Haapasalo *et al.* 2005). Use of irrigating solutions also provides gross debridement, lubrication, destruction of microbes and dissolution of tissues (Spangberg & Haapasalo 2002, Haapasalo *et al.* 2005). The effect of irrigating solutions on EALs has been evaluated previously (Fouad *et al.* 1993, Jenkins *et al.* 2001, Meares & Steiman 2002). However, the effect of irrigating solutions on a handpiece with an integrated EAL has not been reported.

The purpose of this *in vivo* investigation was to determine whether the presence of different irrigating solutions had an influence on the accuracy of the Tri Auto ZX auto-apical reverse system.

## Materials and methods

One hundred and forty maxillary and mandibular single rooted teeth with mature apices that had been scheduled for extraction for periodontal, orthodontic or prosthetic reasons in 76 patients were selected. Informed written consent was obtained from each patient before treatment. The patients consisted of 33 males and 43 females with an age range of 18–78 years. Patients with heart pacemakers or those who had a contributory medical history were not included. Teeth with metallic restorations or porcelain-fused-to-metal crowns, that could not be completely removed, were not included. Teeth with open apices were also excluded. The selected teeth were tested with an electric pulp tester (Digitest; Parkell, Farmingdale, NY, USA) and deemed to contain vital pulp tissue.

A standardized periapical radiograph was taken of each tooth. After the administration of local anaesthesia (2% lidocaine with 1 : 100.000 epinephrine; Ultracaine D-S® forte, Aventis, Istanbul, Turkey), each tooth was isolated and the pulp cavity accessed using a tungsten carbide bur rotating in a high-speed contra-angle handpiece under abundant water spray. A flat reference point was prepared on the occlusal surface or incisal edge of the teeth to allow for precise positioning of the instrument. The entrances of the canals were irrigated with saline and dried.

Pulp tissue was removed with barbed broaches and once access was gained, the canal orifice was widened using Gates Glidden drills (Mani Inc., Tochigi, Japan) to facilitate placement of files. The canals were irrigated with saline to remove tissue remnants and dried with paper points. The teeth were randomly divided into seven groups according to the irrigating solutions used. Two millilitres of irrigating solution was used for each tooth. The excess irrigating solution in the pulp chamber was aspirated with plastic syringes (Ayset Plastik San AŞ, Istanbul, Turkey).

The root canal length measurements were completed using the Tri Auto ZX (J. Morita Corp.) with automatic reverse function in the presence of 0.9% saline (group 1), 2.5% NaOCl (group 2), 3% $H_2O_2$ (group 3), 0.2% chlorhexidine (Drogsan, Ankara, Turkey) (group 4), 17% EDTA (Merck Co., Darmstadt, Germany) (group 5) and Ultracaine D-S (group 6) and without irrigating solution as a control (group 7).

A size 20, 04 taper ProFile NiTi rotary instrument (Dentsply Maillefer, Ballaigues, Switzerland) was mounted in the handpiece. The point at which the auto-apical reverse function triggered was preset on the panel at the 0.5 mm level. When the instrument was introduced into the canal, it began to rotate automatically. The instrument was then advanced down the canal without exerting excessive force and when it reached the predetermined level, the device automatically stopped and rotated in the opposite direction. At this point the rotation was stopped and without moving the instrument in the canal, it was removed from the handpiece and fixed in place with composite resin (Clearfil AP-X; Kuraray Medical Inc., Okayama, Japan). After removal of the rubber dam, the tooth was extracted and placed in a coded specimen cup filled with a solution of 10% formalin for 48 h. After fixation, the teeth were stored in 2.5% NaOCl solution for 48 h and the root surfaces were cleaned to remove all organic debris and deposits.

To observe the apical constriction directly, a window of approximately 3 mm was carefully made in the apical portion of the root using a diamond disk until the root canal was visible (Fig. 1). Judicious removal of the remaining tooth structure to expose the instrument tip and apical anatomy was accomplished with a size 15 scalpel blade (Bard parker, Lincoln Park, NJ, USA). Using a stereomicroscope (SZ-TP; Olympus, Tokyo, Japan), the distance from the apical constriction to the tip of the instrument was measured and recorded in millimetres (mm). If the instrument tip was short of the apical constriction, the measurements were recorded as negative, if the instrument tip had passed the apical constriction, the measurements were recorded as positive and if the instrument tip was flush to the minor apical foramen, the data were recorded as 'zero'. The data were statistically analysed using a one-way ANOVA and *post hoc* Tukey test.

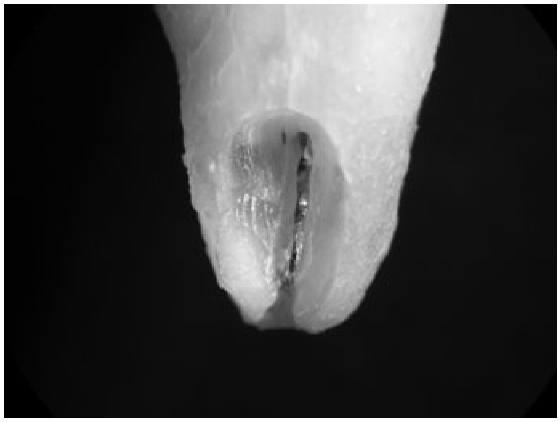

**Figure 1** A window of approximately 3 mm opened in the apex to visualize the point reached by the instrument tip.

## Results

Mean, standard deviation, minimum and maximum distances between the apical constriction and the instrument tip by irrigating solution are shown in Table 1.

Mean age of the patients in groups 1 to 7, respectively, were 45.60 ± 12.01, 52.15 ± 15.53, 53.85 ± 10.26, 56.75 ± 15.18, 52.35 ± 10.20, 58.60 ± 10.54 and 46.70 ± 11.63 years.

The results indicated that the distance of the instrument tip from the apical constriction was significantly

**Table 1** Mean, standard deviation, minimum and maximum distances between the apical constriction and the instrument tip (mm)

| Materials | *n* | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|---|
| Saline (0.9%) | 20 | −1.35[a] | 0.95 | −0.25 | −2.80 |
| NaOCl (2.5%) | 20 | −0.33[b] | 0.30 | 0.00 | −1.20 |
| $H_2O_2$ (3%) | 20 | −0.38[b] | 0.29 | 0.00 | −1.20 |
| Chlorhexidine (0.2%) | 20 | −0.26[b] | 0.30 | 0.00 | −1.25 |
| EDTA (17%) | 20 | −0.36[b] | 0.34 | 0.00 | −1.30 |
| Ultracaine | 20 | −0.32[b] | 0.22 | 0.00 | −0.80 |
| Dry | 20 | −0.29[b] | 0.20 | 0.00 | −0.80 |

Similar letters indicate statistically similar values ($P > 0.05$).

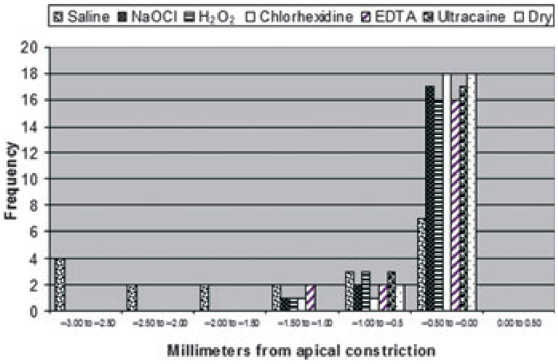


**Figure 2** Frequencies of experimental measurements of the distance between the apical constriction and the instrument tip.

greater in the saline group ($P < 0.05$). The absence of an irrigating solution or the presence of NaOCl, $H_2O_2$, chlorhexidine, EDTA and ultracaine within the canal had no significant effect on the accuracy of the Tri Auto ZX ($P > 0.05$).

The frequencies of measurements of the distance between the apical constriction and the instrument tip are shown in Fig. 2.

The Tri Auto ZX measurements were accurate 85% of the time within ±0.5 mm the apical constriction apart from the saline group where the accuracy was 35%.

When the apical portions of the teeth were visualized, the tip of the instruments was not beyond the apical constriction in any of the groups. Therefore, over-instrumentation was not observed when the Tri-Auto ZX device was used.

## Discussion

A number of methods have been used to evaluate electronic root canal length measuring instruments. Many clinical studies have determined the accuracy of the EALs with radiographic techniques (Busch *et al.* 1976, Trope *et al.* 1985, Kaufman *et al.* 1989), whereas, in other studies, instruments were used clinically and following tooth extraction, the actual lengths of canals were measured (O'Neill 1974, Berman & Fleishman 1984). Laboratory models have also been introduced to test the accuracy of the instruments in a more controlled manner (Nahmias *et al.* 1987, Tinaz *et al.* 2002, Plotino *et al.* 2006).

The position of the apical constriction cannot be accurately determined by radiographs (Dummer *et al.* 1984, Ricucci 1998). Several reports have shown that the location of the apical constriction varies, usually in a range of 0.5–3.0 mm from the radiographic apex (Kuttler 1955, Green 1960). Recently, overestimation of the working length was demonstrated to occur in more than half of premolar teeth, although the radiographic working lengths were apically located 0–2 mm short of the radiographic apex (ElAyouti *et al.* 2001). This can be explained by the anatomical variances that are known to occur in root apices (Kuttler 1955, Burch & Hulen 1972, Dummer *et al.* 1984). Apical foramina are not at the root tip in 87% of mandibular premolars or in up to 98% of maxillary premolars (Burch & Hulen 1972). ElAyouti *et al.* (2002) demonstrated that the frequency of radiographic working length measurement that passed beyond the apical foramen was 51%. Studies have reported that the apical foramen is often located laterally rather than at the root tip (Kuttler 1955, Burch & Hulen 1972, Dummer *et al.* 1984, ElAyouti *et al.* 2002). An apical foramen that is located short of the radiographic apex on the buccal or lingual aspect of the root makes it difficult to identify the position of the apical foramen radiographically. Therefore, the testing of EALs when using radiographs can be problematic and is not a suitable method, especially in premolars.

In addition, *in vivo* radiographic assessment of instrument position alone has been shown to be arbitrary (Chunn *et al.* 1981) and results from such studies can be questioned. In a recent study, Williams *et al.* (2006) reported that when the instrument was short, it was actually closer to the apical foramen than it appeared radiographically. When the instrument was long, it was actually longer than it appeared radiographically. Studies involving tooth extraction to examine directly the relation between the instrument tip and apical constriction require that each instrument is fixed securely *in situ* with an appropriate material. Repositioning an instrument to its measured length after extraction of the tooth may be inaccurate because of differences in the path of the instrument and the effect of parallax on relative position of rubber stop and reference point (Arora & Gulabivala 1995, Pilot & Pitts 1997).

*Ex vivo* models for investigating EALs have been developed in which extracted teeth were immersed in various media with similar electrical resistance to the periodontium. The advantages of these *ex vivo* models were their simplicity, ease of use and the ability to have strict control over the experimental conditions tested. Furthermore, a greater number of canals can be tested over a shorter period of time than could have been achieved by clinical means. The disadvantages of laboratory models are this inability to simulate conditions *in vivo* (Fouad *et al.* 1993). *Ex vivo* studies use electroconductive materials (alginate, agar and saline) to simulate the clinical situation. Some of this media can leak through the apical foramen and may cause premature readings (Czerw *et al.* 1994). It appears that some *ex vivo* experimental models give greater accuracy than can be achieved clinically (Czerw *et al.* 1995). Therefore, the results of laboratory studies could not be directly extrapolated to the clinical situation.

Ibarrola *et al.* (1999) suggested that preflaring of root canals would increase the accuracy of the EAL. For this reason, the canals in the present study were preflared with Gates Glidden drills. Every precaution was taken to prevent movement of the tip relative to the root tip. Furthermore, careful instrument cementation with composite resin, sectioning, tooth extraction and subsequent laboratory processing were conducted to prevent loss or distortion of the root tip.

Meredith & Gulabivala (1997) reported that there was a clear increase in series resistance with increasing distance from the radiographic apex for dry canals (22.19–92.07 kΩ) and these figures were markedly higher than for those containing deionized water (9.32–12.10 kΩ) and sodium hypochlorite (7.46–8.92 kΩ). Measurement of changes in resistance was therefore easier in dry root canals and it is likely that this is why commercial EALs perform better in dry canals (Meredith & Gulabivala 1997).

The majority of EALs are not affected by irrigants within the root canal (Arora & Gulabivala 1995, Jenkins *et al.* 2001, Meares & Steiman 2002). Jenkins *et al.* (2001) reported that the Root ZX was a useful and accurate device for the determination of canal lengths, when the commonly used irrigant solutions were used, such as saline, $H_2O_2$, peridex, EDTA, NaOCl, xylocaine and RC Prep.

Currently, there is a trend towards a combined method of checking the working length electronically during root canal preparation with a mechanical handpiece. Steffen *et al.* (1999) used a combination of EALs (Root ZX and Justy, Yoshida, Tokyo, Japan) with mechanical preparation handpieces (Canal Leader, SET, Olching, Germany). Under the condition of their laboratory study, they suggested that the clinical use of this combination could be recommended.

Smadi (2006) compared the radiographic extent of root canal filling with the working length determined with EAL (Tri Auto ZX) alone or in combination with radiograph and did not find any statistical difference in the extent of root canal filling. In a recent laboratory study (Carneiro *et al.* 2006), the working length determined using the Tri Auto ZX was shorter than the actual length. However, the distances achieved were considered clinically acceptable. Carneiro *et al.* (2006) used the 1- and 2-mm auto-reverse function of the Tri Auto ZX and found that its accuracy at 1 mm was more reliable than at 2 mm.

The results of the present study show that the Tri Auto ZX with automatic reverse function can be used safely in the presence of NaOCl, $H_2O_2$, chlorhexidine, EDTA, ultracaine and in the absence of any irrigating solution. However, the use of saline as an irrigating solution with the Tri Auto ZX adversely affected canal length determination.

The accuracy of the Root ZX apex locator was determined in the presence of NaOCl, EDTA, saline, chlorhexidine, xylol and in dry canals in a previous laboratory study (Kaufman *et al.* 2002). The results indicated that chlorhexidine and NaOCl can be used safely in determination of canal length with the Root ZX. In the presence of EDTA and saline, measurements were closer to the actual length, whilst those carried out in dry canals were shorter. This difference in their study was statistically significant. The present results that the use of 0.9% saline adversely affected the measurement sensitivity of the device are in contrast to that of Kaufman *et al.* (2002). This difference can be explained by the differences in the test conditions (*ex vivo* and *in vivo*) and/or also different devices (Root ZX and Tri Auto ZX with automatic reverse function).

According to the results obtained in the present study, the Tri Auto ZX measurements were accurate 85% of the time within ±0.5 mm of the apical constriction except in the saline group. The accuracy of the automatic reverse function of the Tri Auto ZX gave results similar to those obtained in previous studies (Campbell *et al.* 1998, Grimberg *et al.* 1998, 2002).

## Conclusions

The results of this study indicated that the Tri Auto ZX's working length measurement sensitivity is adversely affected by the presence of 0.9% saline in single-canalled teeth.

The Tri Auto ZX can be used reliably with other irrigating solutions. Over-instrumentation beyond the apical constriction was not observed when the Tri Auto ZX was used.

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