International Endodontic Journal

doi:10.1111/j.1365-2591.2009.01636.x

A tactile method for canal length determination in teeth with open apices

A. ElAyouti, E. Dima & C. Löst

Department of Conservative Dentistry and Endodontology, University of Tübingen, Tübingen, Germany

Abstract

ElAyouti A, Dima E, Löst C. A tactile method for canal length determination in teeth with open apices. *International Endodontic Journal*, **42**, 1090–1095, 2009.

Aim To present a tactile method for working length determination in teeth with open apices and to determine its accuracy and repeatability.

Methodology Ninety teeth with 129 root canals were prepared to create open apices. The correct working length (CWL) for each canal was determined by introducing a file into the root canal until it was visible at the apex. Consequently, the tactile working length (TWL) was determined by the 'Tactile Method' using a K-file that was bent at the tip. Two operators repeated the measurement once in each root canal. The accuracy of the TWL was determined by comparing the TWL with the CWL. The mean of the absolute differences and the corresponding 99% confidence interval (CI) were calculated. Both the repeatability and inter-operator agreement of the tactile method were determined by performing paired analysis of the differences between repeated measurements and the two operators.

Results Overall, 97% (CI: 91–99) of the TWL were within 0.5 mm from the CWL, the mean of absolute differences was 0.1 mm (CI: 0.1–0.2). The maximum difference between repeated measurements was 0.2 mm and between the two operators was 0.6 mm.

Conclusions The tactile method may provide an accurate determination of canal length in teeth with open apices.

Keywords: accuracy and repeatability, inter operator agreement limits, open apex in immature teeth, simulated root resorption, tactile methods, working length determination.

Received 14 April 2009; accepted 17 August 2009

Introduction

The term 'open apex' is used to indicate the presence of an exceptionally wide root canal at the apex. Open apices typically occur in immature teeth when root development ceases as a sequel of pulp necrosis. Whilst trauma is regarded as the main cause of open apices in immature anterior teeth, caries may also lead to open apices in both anterior and posterior immature teeth. In fully developed teeth causes of open apices include extensive apical resorption, root-end resection and overinstrumentation.

Correspondence: Ashraf ElAyouti, Department of Conservative Dentistry and Endodontology, University of Tübingen. Osiandestraße 2–8, 72076 Tübingen, Germany (Tel.: 0049 7071 29 83498; fax: 0049 7071 29 5656; e-mail: ashraf.elayouti@med.uni-tuebingen.de).

There are many problems associated with the treatment of teeth with open apices; the short thin-walled roots increase the risk of fracture and have an unfavourable crown-root ratio; the extensive apical resorption, facilitated by the thin-walled dentine and long-standing infection, impedes accurate canal length determination; the wide and often apically divergent canals necessitate tailored canal filling techniques to achieve an optimal seal (Gutmann & Heaton 1981, Morse *et al.* 1990, Kerezoudis *et al.* 1999, Mackie & Hill 1999, Allen & Mackie 2003, Dominguez *et al.* 2005, Bogen & Kuttler 2009).

Successful root canal treatment occurs when overinstrumentation and overfilling are avoided and filling materials confined to the limits of the canal (Ricucci 1988, Ricucci & Langeland 1988, Shabahang *et al.* 1999, Holland *et al.* 2007). Accordingly, accurate working length determination is essential in achieving

optimal healing. Unfortunately, open apices pose many difficulties to contemporary methods of canal length determination.

Radiographic methods known for their inherent interpretation difficulties are even more challenging in open apices where dentinal walls frequently end at different levels and have irregular margins. Consequently, the apical end of the canal that is circumferentially surrounded by dentine is located a few millimetres short of the radiographic apex, which results in overestimation of the radiographic working length (Baggett *et al.* 1996).

Apex locators have been shown to be highly accurate in locating the apical foramen and constriction (Gordon & Chandler 2004, Kim & Lee 2004). Unfortunately, in open apices they give incorrect measurements (Hülsmann & Pieper 1989, Ebrahim *et al.* 2006, Herrera *et al.* 2007, Tosun *et al.* 2008) because wide root canals (e.g. >size 60), associated with open apices, adversely influence the function of apex locators. In wide canals, the electronic working length is shorter than the actual canal length (Wu *et al.* 1992, ElAyouti *et al.* 2005).

Paper point techniques may be used to determine canal length in open apices (Baggett *et al.* 1996) and to check or adjust the electronic working length (Rosenberg 2003). These techniques require the canal to be completely dry and the periapical tissues to be relatively moist (i.e. not excessively dry or moist). In open apices, the control of moisture is difficult because the contact area to the inflamed periapical tissues is large, and excess moisture is common, which results in measurement error. Moreover, to obtain accurate measurements when using tactile techniques the periapical tissues must be located at the same level of the apical terminus, a condition that may not be fulfilled in open apices, because the periapical tissues may grow down the canal up to a distance of 3 mm (Baggett *et al.* 1996) and result in short measurements.

The aim of the present paper was to present a consistent tactile method for working length determination in teeth with open apices, and to determine the accuracy, repeatability and inter-operator agreement of the Tactile Method under simulated clinical conditions.

Materials and methods

The Tactile Method implements a hand instrument to probe the dentinal walls of the root canal. A stainless steel hand file, plugger or spreader can be used. In this study a size 25 K-File was used. The file was bent at the tip (0.5–1 mm) to a 90° angle using an endodontic gauge (Dentsply Maillefer, Ballaigues, Switzerland). The tip of the file was placed in the gauge hole corresponding to the size of the file and bent to be parallel to the gauge surface. The angle of the bent tip was checked to be right angle using a square gauge. Instead of conventional rubber stoppers a small silicon ring was attached to the shaft of the file. The marking line on the silicon ring was used to indicate the direction of the bent tip. The file was slightly curved to facilitate the engagement of the bent tip on the apical edge of dentinal walls (Fig. 1).

Ninety teeth (30 anterior teeth, 30 premolars and 30 molars) with 129 root canals were selected after excluding curved roots (>10 degrees). To simulate immature open apices, the apical 3–4 mm of the roots were removed and the canal was widened with large files and Gates Glidden burs to obtain 0.5–1.5 mm dentinal walls thickness at the apex. Subsequently, apical resorption was simulated by rendering the dentinal walls at the apex irregular using fine diamond round burs and SONICflex ultrasonic tips (Kavo, Biberach, Germany). The differences between dentinal-wall lengths in the same root ranged from 2 to 5 mm.

The correct working length (CWL) was defined to be at the level of the shortest dentinal wall as at this level

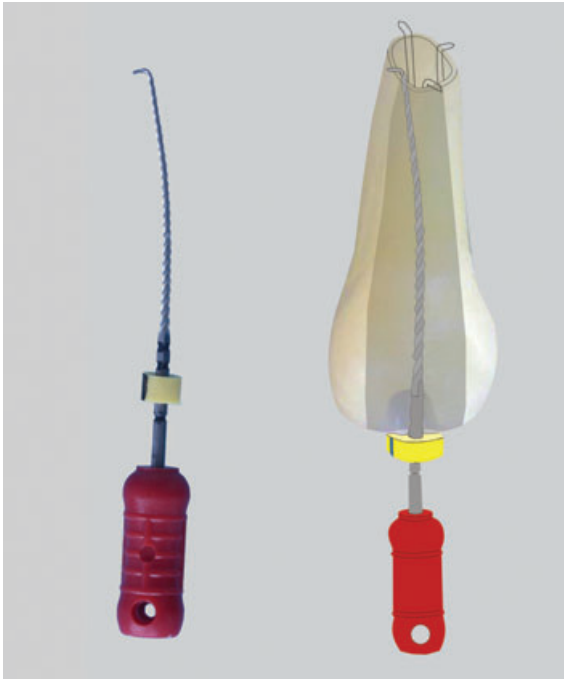

Figure 1 Schematic presentation of the Tactile Method and the measuring file.

the root canal is surrounded by dentine. The CWL for each root canal was determined by inserting a file into the canal to the level of the shortest dentinal wall. A silicon stopper was adjusted to a coronal reference point. The length of the file corresponding to the CWL was measured using a digital micrometer under a stereomicroscope; Stemi (Carl Zeiss, Jena, Germany) at 16× magnification. The roots were then embedded in a low viscosity Impression material (President, Coltène/Whaledent AG, Altstätten, Switzerland) using a 15 mm brass ring. To prevent the impression material from flowing into the canal the apices of teeth were covered with a piece of wax that was removed after the setting of the material. The teeth with the embedded roots were fixed according to their anatomical position in either the madibular or maxillary tooth model (G50; Kavo) of a dental simulation unit (DSEplus; Kavo). The face mask and the antagonist jaw tooth-model of the dental mannequin allowed for simulated clinical conditions by limiting the accessibility of the teeth.

The Tactile Method

The aim of the Tactile Method is to circumferentially probe the dentinal walls with the bent tip of the file to determine the length of the shortest dentinal wall. A K-File size 25 curved and bent at the tip, as described, was used (Fig. 1). The bent tip was placed against a dentinal wall in the root canal and displaced apically until it engaged the edge of dentinal wall at the apex (Fig. 1). The silicon ring was adjusted to a coronal reference point and the file was then rotated to disengage the bent tip. The same procedure was repeated to circumferentially probe all dentinal walls. When a shorter length was detected the silicon ring was readjusted, the shortest adjusted length of the file represented the tactile working length (TWL). The file length (from the bent tip to the silicon ring) was measured using a digital micrometer under magnification (×16). The length of each root canal was measured by two operators and each operator repeated the measurement once. All measurements were recorded and performed successively on each tooth. The first operator had 1-year experience with the Tactile Method and the second operator had a practical demonstration and practised the method on extracted teeth 1 week prior to the study.

The accuracy of the Tactile Method was determined by comparing the CWL with the TWL of the first operator. The mean of absolute differences (positive values) and the 99% confidence interval (CI) were calculated. A regression analysis was performed to evaluate the influence of tooth type and canal length on the accuracy of the Tactile Method.

The repeatability of the Tactile Method was determined by performing paired analysis of the repeated measurements in each tooth. The coefficient of repeatability that includes 95% of the differences was calculated (Bland & Altman 1986).

The inter-operator agreement was determined by comparing the average of the repeated measurements per tooth. The limits of agreement, which are twice the standard deviations around the mean, were calculated (Bland & Altman 1986).

Results

The accuracy of the Tactile Method within a range of 0.5 mm was 97.7% (126/129 canals). The mean of absolute distances between TWL and CWL was 0.1 mm (99% CI: 0.1–0.2). Box and whiskers plots (Fig. 2) present the distances to the CWL in each root canal. Statistically, there were no differences between anterior teeth, premolars or molars. The length of the canal did not influence the measurements (Fig. 3).

The coefficient of repeatability of the Tactile Method was 0.12 mm, the maximum difference between repeated TWL was 0.2 mm.

The inter-operator agreement upper and lower limits were −0.2 and 0.5 mm, the maximum difference between the two operators using the Tactile Method was 0.6 mm. The readings of the second operator were shorter than those of the first operator in most of the canals (Fig. 4).

Discussion

The accuracy of the Tactile Method, calculated in teeth with simulated open apices, was high (97.7%). It seems that the wide, short and straight root canals used in the present study facilitated the measuring procedure. Nevertheless, the Tactile Method is not feasible in curved canals or in teeth with an apical size smaller than 80, but these clinical situations are uncommon for teeth with open apices.

When Goldberg *et al.* (2002) evaluated 50 teeth with simulated apical resorption they found that the accuracy of Root ZX apex locator was 62.7% (with a tolerance of ±0.5 mm). But, Mente *et al.* (2002) concluded by inspecting 24 cleared teeth that the presence of apical resorption did not affect the accuracy of apex locators. They found that the mean distance to

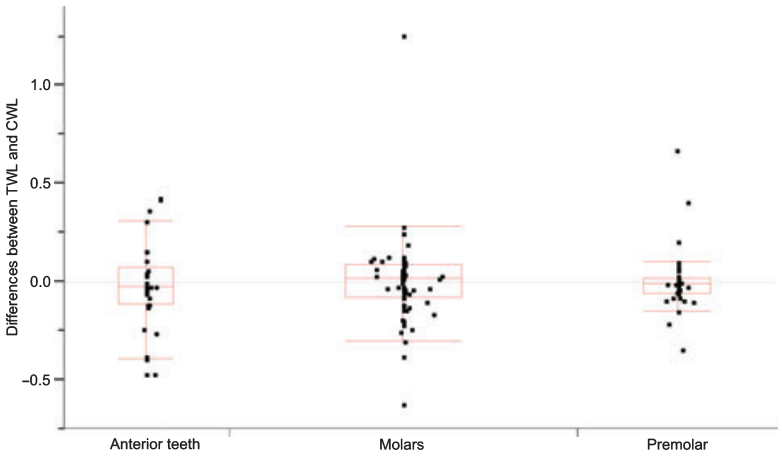

Figure 2 Box and whiskers plot of the differences between tactile working length (TWL) and correct working length (CWL) in each tooth group.

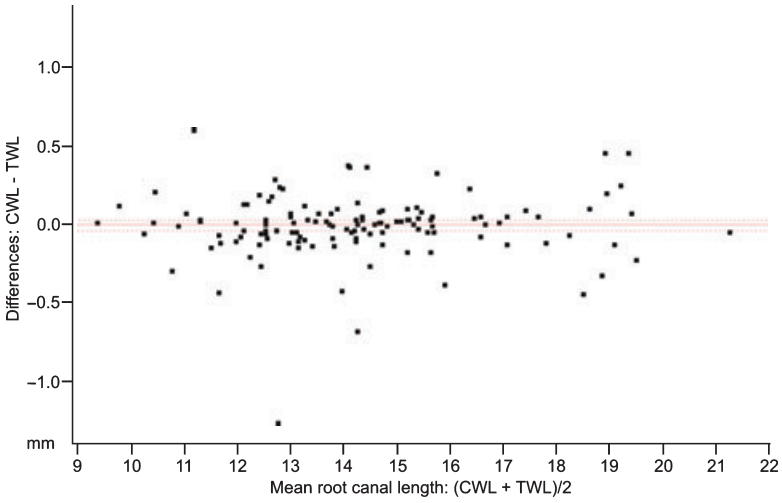

Figure 3 Paired analysis of the differences between correct working length (CWL) and tactile working length (TWL) in relation to root canal length.

the acceptable working length in teeth without resorption (0.26 mm) was similar to that with resorption (0.29 mm). Apical resorption is one factor that may affect the electronic working length in open apices, but the associated wide root canals (size 60 and more) is another factor. Although, different studies have showed that wide canals may not affect the accuracy of apex locators (Nguyen *et al.* 1996, Lee *et al.* 2002), it must be emphasized that the maximum size of the examined canals was 60, which is not comparable with the large sized canals associated with open apices. Other studies examining apex locators in canals with larger sizes (> 60) showed that wide canals do result in short electronic measurements (Wu *et al.* 1992, ElAyouti *et al.* 2005). Hülsmann & Pieper (1989) found that apex locators did not function in teeth with open apices, but after apexification apex locators determined the canal length correctly.

Radiographic methods may lead to overestimation of the canal length (Stein & Corcoran 1992, ElAyouti *et al.* 2001, Williams *et al.* 2006). The main reason is the fact that the apical foramen is frequently (92%) located short of the apex (Burch & Hulen1972) and the length of measuring file appears radiographically shorter than its actual length (Stein & Corcoran 1992). In teeth with open apices the radiographic interpretation of canal length is even more difficult due to the altered apical anatomy and the missing periodontal ligament space at the apex.

The paper point techniques (Baggett *et al.* 1996, Rosenberg 2003) may deliver accurate measurements provided that the periapical tissues exist at the same

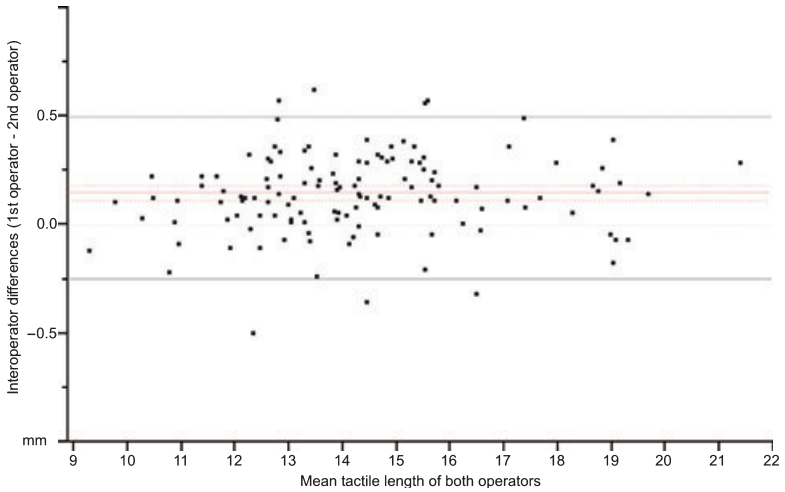

Figure 4 Plot of inter-operator agreement showing the limits of agreement and the differences between the first and second operator in each canal.

level of canal terminus and that moisture control is possible within the canal as well as from the periapical tissues. Baggett *et al.* (1996) calculated an accuracy of 95% for the paper point technique when all measurements within ±1 mm from the radiographic apex were considered accurate. Nevertheless, the accuracy of the paper point techniques remains to be determined in relation to the actual canal length, which is a more valid reference than the radiographic length.

Root canal treatment of teeth with open apices is more common in anterior rather than posterior teeth. Even so, molars and premolars were included in this study because there are clinical situations that necessitate the treatment of a posterior tooth with an open apex, for example, treatment of infected resected teeth (Bogen & Kuttler 2009), necrotic immature teeth (Gutmann & Heaton 1981) or teeth with extensive apical resorption (Kerezoudis *et al.* 1999).

Whilst carbide burs have been used to simulate apical resorption (Goldberg *et al.* 2002), in the present study ultrasonic tips were also used to render the irregularities of the dentine walls smooth. Indeed, the apical anatomy of open apices may deviate from the simulated form, and therefore clinical studies are still necessary to validate the accuracy of the Tactile Method.

The file used for the Tactile Method was curved to allow an easy and reproducible engagement of the bent file tip on dentinal wall margins. Also, the use of a small silicon ring instead of conventional stoppers facilitated the manoeuvring of the instrument without interfering with the coronal reference point. The size of the file used was 25; this provided enough instrument stiffness to probe the dentinal walls. However, instruments with larger sizes may also be used in wider root canals.

The minor differences between repeated measurements (0.2 mm) showed that repeating the measurement in the same canal was not necessary. Clinically, this high repeatability may not be attainable because it is impractical to measure the length of the file with a digital micrometer under magnification, and therefore clinically, repeated measurements may still yield more accuracy. Notably, the high repeatability was also observed in the measurements of the second operator who learned the Tactile Method 1 week prior to the study, this demonstrated the consistency of the Tactile Method and the reproducibility of the apical and coronal reference points.

The inter-operator differences were at a maximum of 0.6 mm, whereas the second operator delivered shorter measurements in most of canals. This could be explained by different interpretation of the distance between the bent tip and stopper. This was in agreement with an earlier study that reported the inter-operator agreement limits to be around 0.7 mm when the stopper of a file was adapted to a reference point and the length of the file was measured (ElAyouti & Löst 2006).

Operators who used the Tactile Method for the first time, as the second operator in the present study, experienced difficulties in disengaging of the file tip from dentinal wall. This difficulty can be overcome by curving the file and slightly rotating it on removal out of the canal. Also, a helpful orientation may be provided by adjusting the marking line on the silicon ring to indicate the direction of the bent tip.

Conclusion

In teeth with open apices, the presented Tactile Method may offer an accurate alternative to contemporary methods of working length determination.

References

Allen R, Mackie IC (2003) Management of the immature apex-a clinical guide. *Dentistry Update* **30**, 437–41.

Baggett FJ, Mackie IC, Worthington HV (1996) An investigation into the measurement of the working length of immature incisor teeth requiring endodontic treatment in children. *British Dental Journal* **10**, 96–8.

Bland JM, Altman DG (1986) Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* **1**, 307–10.

Bogen G, Kuttler S (2009) Mineral trioxide aggregate obturation: a review and case series. *Journal of Endodontics* **35**, 777–90.

Burch JG, Hulen S (1972) The relationship of the apical foramen to the anatomic apex of the tooth. *Oral Surgery, Oral Medicine, and Oral Pathology* **34**, 262–8.

Dominguez RA, Munoz ML, Aznar MT (2005) Study of calcium hydroxide apexification in 26 young permanent incisors. *Dental Traumatology* **21**, 141–5.

Ebrahim AK, Wadachi R, Suda H (2006) Ex vivo evaluation of the ability of four different electronic apex locators to determine the working length in teeth with various foramen diameters. *Australian Dental Journal* **51**, 258–62.

ElAyouti A, Löst C (2006) A simple mounting model for consistent determination of the accuracy and repeatability of apex locators. *International Endodontic Journal* **39**, 108–12.

ElAyouti A, Weiger R, Löst C (2001) Frequency of overinstrumentation with an acceptable radiographic working length. *Journal of Endodontics* **27**, 49–52.

ElAyouti A, Kimionis I, Chu AL, Löst C (2005) Determining the apical terminus of root-end resected teeth using three modern apex locators: a comparative ex vivo study. *International Endodontic Journal* **38**, 827–33.

Goldberg F, De Silvio AC, Manfre S, Nastri N (2002) In vitro measurement accuracy of an electronic apex locator in teeth with simulated apical root resorption. *Journal of Endodontics* **28**, 461–3.

Gordon MP, Chandler NP (2004) Electronic apex locators. *International Endodontic Journal* **37**, 425–37.

Gutmann JL, Heaton JF (1981) Management of the open (immature) apex. 2. Non-vital teeth. *International Endodontic Journal* **14**, 173–8.

Herrera M, Abalos C, Planas AJ, Llamas R (2007) Influence of apical constriction diameter on root ZX apex locator precision. *Journal of Endodontics* **33**, 995–8.

Holland R, Mazuqueli L, de Souza V, Murata SS, Dezan Junior E, Suzuki P (2007) Influence of the type of vehicle and limit of obturation on apical and periapical tissue response in dogs' teeth after root canal filling with mineral trioxide aggregate. *Journal of Endodontics* **33**, 693–7.

Hülsmann M, Pieper K (1989) Use of an electronic apex locator in the treatment of teeth with incomplete root formation. *Endodontics and Dental Traumatology* **5**, 238–41.

Kerezoudis NP, Valavanis D, Prountzos F (1999) A method of adapting gutta-percha master cones for obturation of open apex cases using heat. *International Endodontic Journal* **32**, 53–60.

Kim E, Lee SJ (2004) Electronic apex locator. *Dental Clinics of North America* **48**, 35–54.

Lee SJ, Nam KC, Kim YJ, Kim DW (2002) Clinical accuracy of a new apex locator with an automatic compensation circuit. *Journal of Endodontics* **28**, 706–9.

Mackie IC, Hill FJ (1999) A clinical guide to the endodontic treatment of non-vital immature permanent teeth. *British Dental Journal* **186**, 54–8.

Mente J, Seidel J, Buchalla W, Koch MJ (2002) Electronic determination of root canal length in primary teeth with and without root resorption. *International Endodontic Journal* **35**, 447–52.

Morse DR, O'Larnic J, Yesilsoy C (1990) Apexification: review of the literature. *Quintessence International* **21**, 589–98.

Nguyen HQ, Kaufman AY, Komorowski RC, Friedman S (1996) Electronic length measurement using small and large files in enlarged canals. *International Endodontic Journal* **29**, 359–64.

Ricucci D (1988) Apical limit of root canal instrumentation and obturation, part 1. Literature review. *International Endodontic Journal* **6**, 384–93.

Ricucci D, Langeland K (1988) Apical limit of root canal instrumentation and obturation, part 2. A histological study. *International Endodontic Journal* **6**, 394–409.

Rosenberg DB (2003) The paper point technique, part 1. *Dentistry Today* **22**, 80–6.

Shabahang S, Torabinejad M, Boyne PP, Abedi H, McMillan P (1999) A comparative study of root-end induction using osteogenic protein-1, calcium hydroxide, and mineral trioxide aggregate in dogs. *Journal of Endodontics* **25**, 1–5.

Stein TJ, Corcoran JF (1992) Radiographic ''working length'' revisited. *Oral Surgery, Oral Medicine, and Oral Pathology* **74**, 796–800.

Tosun G, Erdemir A, Eldeniz AU, Sermet U, Sener Y (2008) Accuracy of two electronic apex locators in primary teeth with and without apical resorption: a laboratory study. *International Endodontic Journal* **41**, 436–41.

Williams CB, Joyce AP, Roberts S (2006) A comparison between in vivo radiographic working length determination and measurement after extraction. *Journal of Endodontics* **32**, 624–7.

Wu YN, Shi JN, Huang LZ, Xu YY (1992) Variables affecting electronic root canal measurement. *International Endodontic Journal* **25**, 88–92.