The accuracy of electronic working length determination

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Abstract

Hoer D, Attin T. The accuracy of electronic working length determination. *International Endodontic Journal*, **37**, 125–131, 2004.

Aim To determine *in vivo* the accuracy of two impedance quotient apex locators under clinical conditions.

Methodology Electronic working length determination was carried out before extraction in 79 human teeth with 93 root canals. In 51 root canals, the determination was performed using the apex locator Justy II® (Hager & Werken, Duisburg, Germany); in 42 canals, the apex locator Endy 5000® (Loser, Leverkusen, Germany) was used. A root canal instrument was fixed at working length with composite material prior to extraction followed by the exposure of a radiograph. After histological preparation of the apical region, the teeth were examined under a light microscope. The distance of the file tips to the target intervals 'minor foramen – major foramen' and 'apical canal constriction' was determined. These values were compared with the calculated working lengths, determined by radiographic assessment. The data were statistically analysed by a paired *t*-test.

Results For both apex locators and both target intervals, no significant differences between the electronic and radiographical assessments were recorded. The probability of determining the area between minor and major foramen was 82.4% for Justy II and 81% for Endy 5000. However, accurate determination of the apical constriction was only successful in 51% (Justy II) and 64.3% (Endy 5000) of canals. Variation of the inaccurate measurements was higher for Endy 5000 than for Justy II.

Conclusions Under clinical conditions, it is possible to determine the region between the minor and major apical foramen with electronic length measuring devices (ELD). However, use of these devices does not result in precise determination of the apical constriction.

Keywords: apex locator, endodontics, working length.

Received 10 December 2002; accepted 15 September 2003

Introduction

The significance of the apical canal constriction in root canal treatment is well recognized, and traditional canal preparation techniques aim to retain it as a natural barrier between the root canal and apical tissues (Tronstad 1991). However, the accurate determination or even estimation of the apical canal constriction is not possible with radiography because of anatomical variations or errors in projection (Surmont *et al.* 1992, ElAyouti *et al.* 2002). With the original specification of apex locators (using one measuring frequency), it was difficult to determine working length, as they only gave precise results in dry root canals (Ushiyama 1983). Modern apex locators, using impedance quotient measurements, are able to determine an area between the minor and major foramen by measuring the impedance between the file tip and the canal fluid with different frequencies. The principle of measurement of these devices is based on the electrical resistance of dentine (Ushiyama 1983). Former *in vivo* studies on the accuracy of electronic apex locators often used the major foramen as a reference point (Pagavino *et al.* 1995, Lauper *et al.* 1996). Other studies used radiographs to control the accuracy of electronic working length determination *in vivo* (Dunlap *et al.* 1998), but the position of the tip of the measuring instrument was not determined in relation to the apical constriction. *In vitro* studies did not include the errors which may have occurred while measuring in the mouth (Czerw *et al.* 1995).

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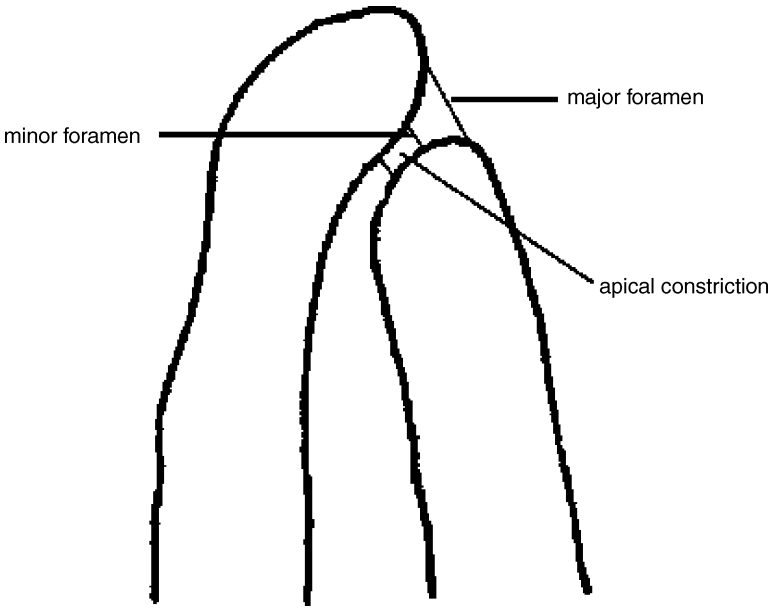

Figure 1 Anatomy of the apical part of the root.

The present study was carried out in order to evaluate the accuracy of modern apex locators to determine the apical canal constriction or the area between the minor and major foramen (Fig. 1) under clinical conditions. The results of the clinical measurements were controlled histologically.

Materials and methods

Two apex locators using the impedance quotient method to determine endodontic working length (Justy II®, Hager & Werken, Duisburg, Germany; Endy 5000®, Loser, Leverkusen, Germany), were used in the study. Forty-two patients with 79 teeth (93 root canals), which were to be extracted for periodontal, surgical or orthodontic reasons were included. The patients were between 22 and 70 years old (mean 59.8); 27 women and 15 men participated. After written and verbal information, all subjects gave written consent to participate in the study.

Fifty-one root canals were randomly measured by Justy II (treatment room 1) and 42 root canals by Endy 5000 (treatment room 2). Pulps in 12 root canals measured by Justy II and 8 measured by Endy 5000 were nonvital (tested with CO_2-tester). After local anaesthesia (Ultracain DS® or DS-forte®, Hoechst Marion Roussel, Frankfurt/Main, Germany), a rubber dam was applied and caries and existing restorations were removed. An access cavity was then prepared and the pulp chamber was cleaned; bleeding of the pulp was arrested with a cotton pellet and 3% H_2O_2. The root canal orifices were enlarged with a Gates–Glidden-drill no. 2 or 3 (VDW, Munich, Germany). The root canals were rinsed with 1% NaOCl solution, and the access cavities dried with cotton pellets. The working length was then determined *in vivo* as follows. A size 15 K-file was connected to the apex locator and the lip clip attached. The K-file was inserted, until the apex locator indicated that the file had reached the apical constriction. These values were taken as the apical endpoint according to the manufacturer's instructions, i.e. scale point 1 for Justy II and the yellow LED for Endy 5000. The K-file was fixed in the tooth with a light curing composite (Tetric flow®, Vivadent, Schaan, Liechtenstein) and the tooth was extracted. The extracted tooth was placed on a dental film (Agfa Dentus M2, Heraeus Kulzer, Dormagen, Germany) and a radiograph was taken (65 kV, 0.2 s). The radiographic working length was determined by examining the radiograph with a magnifying glass ($\times$2 magnification). The apical end point of the radiographical working length was set 1 mm short of the radiographical tooth length. The electronic working length determination did not influence this radiographical determination. Then, the root canal and the apical canal constrictions were exposed by carefully sectioning the root apices in a longitudinal direction. With a diamond bur in a straight hand-piece, dentine was removed until only a thin layer of dentine remained over the root canal. The remaining dentine was removed with a probe. The topography of the apical constriction and the major foramen was determined under a light microscope at $\times$16 magnification (Fig. 2). The distances between the

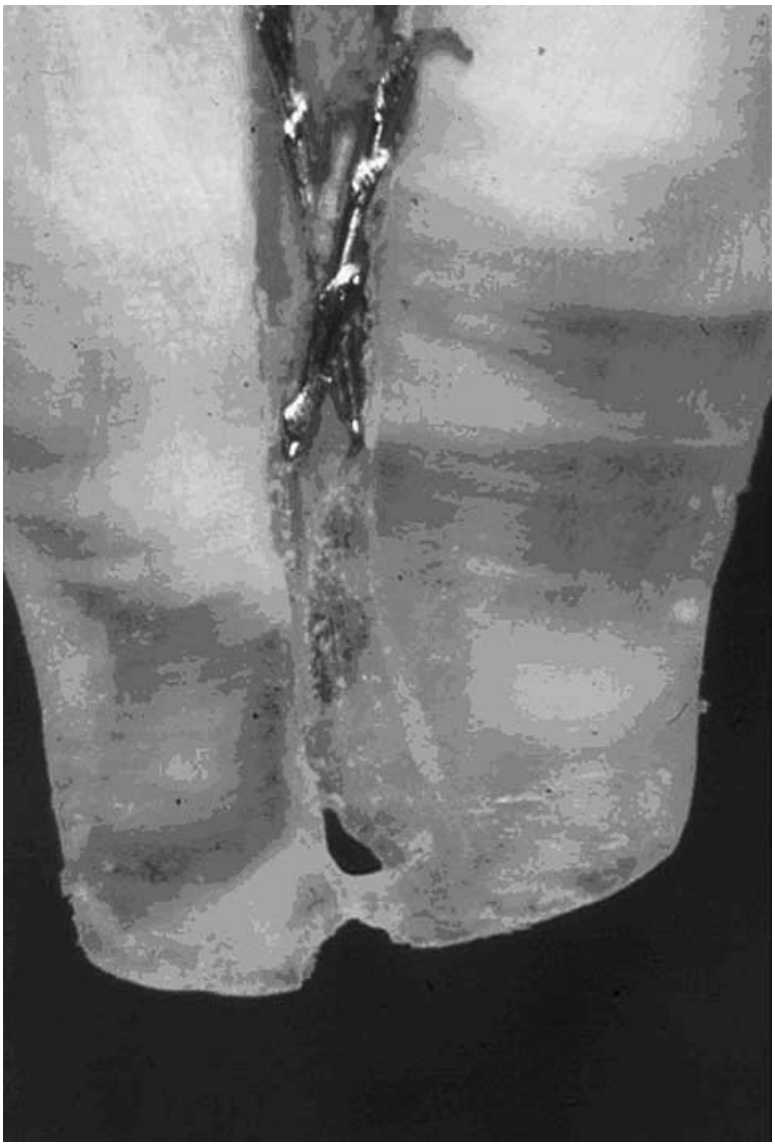

Figure 2 Sectioned root apex in longitudinal direction. File tips are located within the apical constriction.

apical constriction, the major foramen and the anatomical apex were measured and the target intervals 'apical constriction to major foramen' and 'apical constriction' were determined. Finally, the position of the file tip in relation to the target intervals was recorded. If the file tip hit the target interval, the measurement was recorded as success, if not, it was recorded as 'no success'. The value of the distance of the file tip to the target intervals was negative, if the file tip was short of the intervals. The value was positive if the file tip was beyond the target intervals.

The data were statistically compared to the radiographic working lengths by a paired *t*-test (significance was set of $P \leq 0.05$) after verifying the correlation for paired sample tests.

Results

Topography of the apical constriction and the major foramen

Figures 3 and 4 describe the topography of the apical constriction and the major foramen in relation to the anatomical apex for all teeth investigated. The distance between the anatomical apex and the major foramen was 0.24 mm (±0.33 mm). The distance between the apical constriction and the anatomical apex was 1.11 mm (±0.75 mm). All teeth investigated had a constriction (52 root canals showed the constriction as a point, 41 as a line or slot). In those cases where the apical

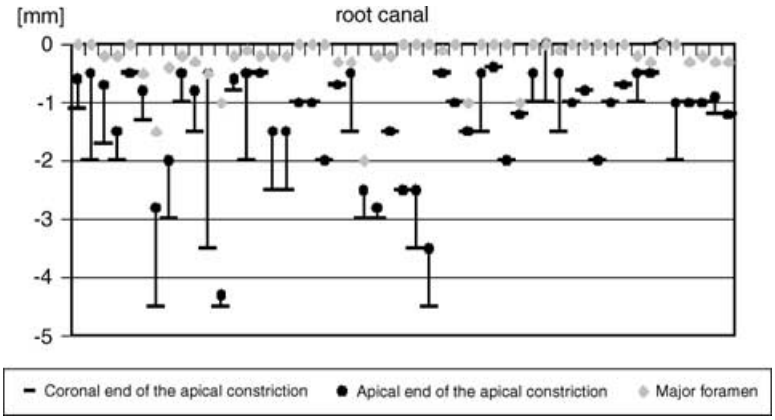

Figure 3 Anatomy of root canals in the 51 roots determined with Justy II. The value 0 shows the anatomical apex, the negative values were located coronally to the apex.

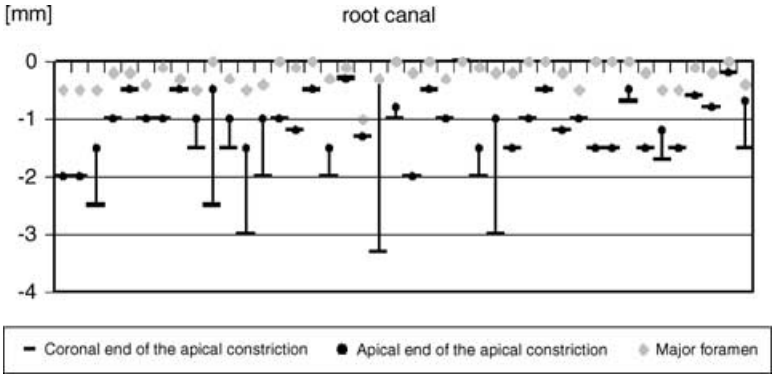

Figure 4 Anatomy of root canals in the 42 roots determined with Endy 5000. The value 0 shows the anatomical apex and the negative values were located coronally to the apex.

constriction was not a point, but like a slot, the apical end of the constriction (=minor foramen) was taken to calculate the distance to the apex (Fig. 1).

Position of the file tip according to electronic and radiographical working length determination

Figures 5 and 6 show the position of the file tips according to electronic and radiographical working length determination in relation to the respective target interval for both apex locators. Forty-two of 51 (82.4%) file tips electronically measured by Justy II were found within the target interval 'apical constriction to major foramen'. For this target interval, the Endy 5000 had an accuracy of 81% (34 of 42 file tips). Seventy-one per cent (66 of 93) of the working lengths calculated by radiograph were within this interval. For the Justy II the maximum distance between the file tip and the major foramen was 4.5 mm. In none of the cases did the file tip lie beyond the major foramen. For the Endy 5000, one file exceeded the major foramen by 0.1 mm, and the maximum distance to the major foramen was 3.5 mm.

The probability of hitting the interval 'apical constriction to major foramen' was 81.7% for all electronic length measurements and 71% for working lengths determined by radiograph. The apical constriction was identified exactly in 57% of all electronically determined working lengths (Justy II = 51%; Endy 5000 = 64.3%). For all teeth, determination by radiograph led to a correct assessment of the apical constriction in 43%.

In nonvital teeth, the interval 'apical constriction to major foramen' was met electronically in 17 of 20 cases (85%). For those teeth, correct assessment of the apical constriction could be recorded in 45% (9 of 20 teeth) of the cases. No statistical analysis was carried out as the sample of nonvital teeth was too small.

Working length determination with the Justy II resulted in nine measurements, which were out of the target interval 'apical constriction to major foramen'. The mean distance between the tip of the file and the target interval was −0.13 mm (±0.39 mm). Twenty-five

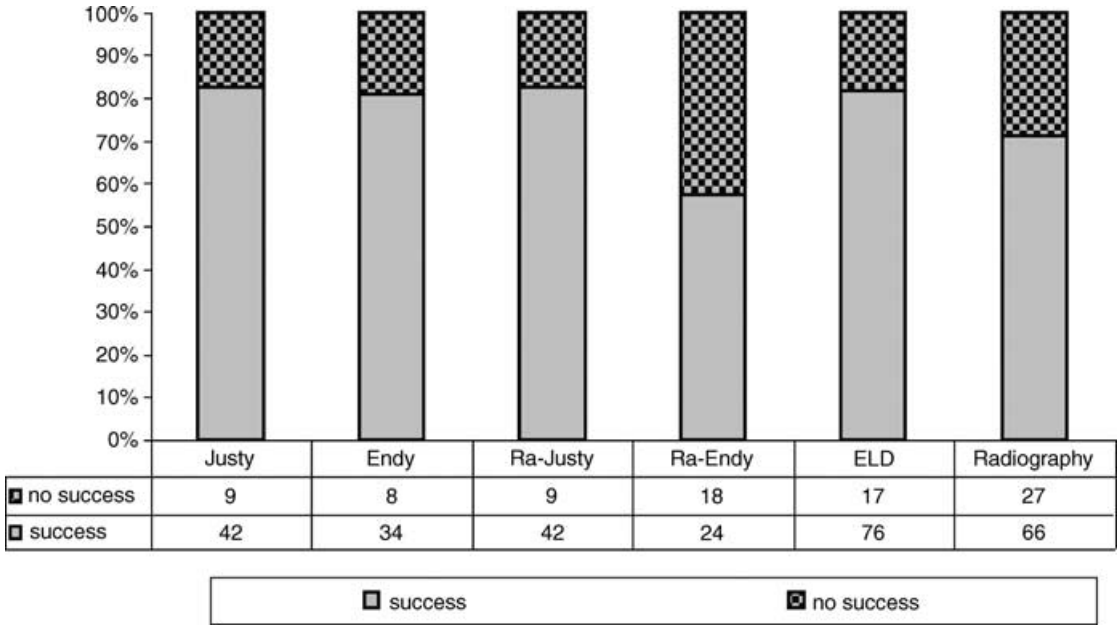

Figure 5 Target interval 'major foramen to coronal end of the apical constriction'. Results for all measurements and both target intervals. 'success' means that the file tip was found under the light microscope within the defined target intervals. 'Ra-Justy' or 'Ra-Endy' describes the position of the file tip to the anatomical apex using radiographical evaluation. The position of the file tip was calculated by the difference of the microscopically measured tooth length and the working length determined by radiograph. Electronic length measuring device (ELD) and radiography summarize all measurements independent of the device used.

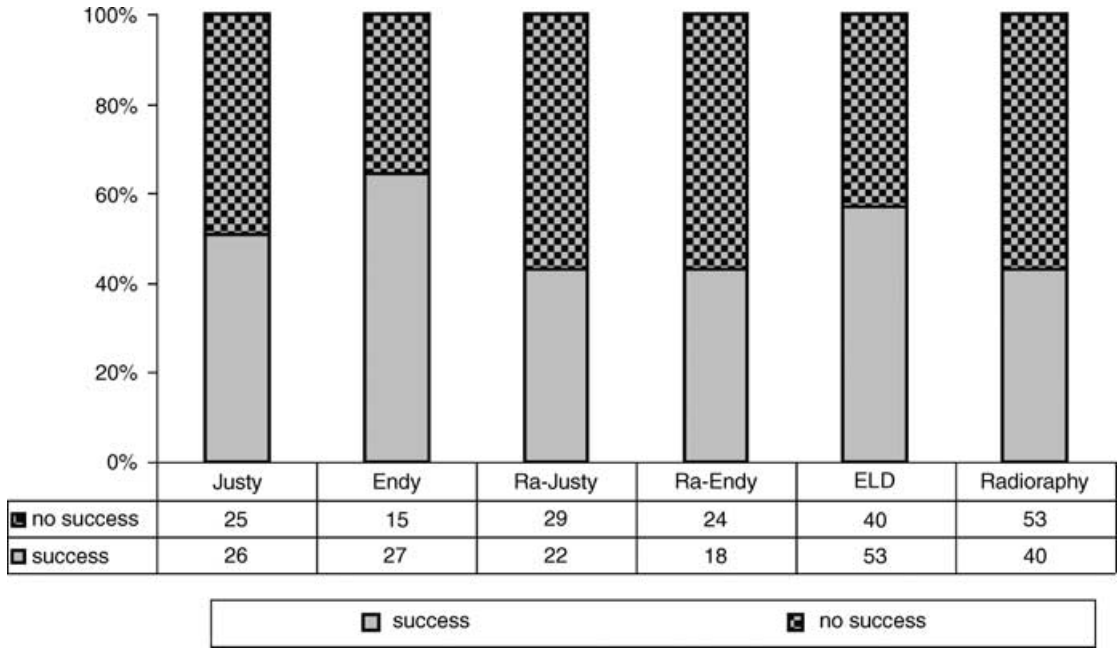

Figure 6 Target interval 'apical constriction. Results for all measurements and both target intervals. 'success' means that the file tip was found under the light microscope within the defined target intervals. 'Ra-Justy' or 'Ra-Endy' describes the position of the file tip to the anatomical apex using radiographical evaluation. The position of the file tip was calculated by the difference of the microscopically measured tooth length and the working length determined by radiograph. Electronic length measuring device (ELD) and radiography summarize all measurements independent of the device used.

measurements performed with the Justy II did not determine exactly the apical constriction with a mean distance of 0.09 mm (±0.65 mm). The comparable radiographical error was −0.1 mm (±0.34 mm) with 9 errors for the first target interval and 0.27 (± 0.6 mm) with 29 errors for the second.

Working length determination with the Endy 5000 resulted in eight measurements, which were out of the target interval 'apical constriction to major foramen'. The mean distance between the tip of the file and the target interval was −0.22 mm (±0.7 mm). Fifteen measurements conducted with the Endy 5000 did not determine exactly the apical constriction with a mean distance of 0.09 mm (±0.61 mm). The comparable radiographical error was −0.21 mm (±0.46 mm) with 18 incorrect measurements for the first target interval and 0.09 mm (±0.79 mm) with 24 for the second.

There was no significant difference between electronic and radiographic determination either for the target interval 'apical constriction to major foramen' ($P = 0.69$) or for assessment of the apical constriction ($P = 0.09$) for the Justy II.

The difference between radiographic and electronic working length determination with the Endy 5000 was also not significant for both target intervals ('apical constriction to major foramen': $P = 0.96$; 'apical constriction': $P = 0.98$).

Discussion

The results of the topography and anatomy of the apical constriction and the major foramen in the present study are closely consistent with previous studies (Green 1956, 1960, Chapman 1969, Dummer *et al*. 1984). Some authors suggested that taking the instrument slightly long and then retracting it may increase the accuracy of readings (Dunlap *et al*. 1998, Lee *et al*. 2002). In the present study, the instructions of the manufacturers of both devices were followed because, in nonvital teeth, pushing the file beyond the apical foramen may lead to a transportation of bacteria and toxins into the apical tissue. Furthermore, a size 15 K-file was used in all cases because Nguyen *et al*. (1996) showed that electronic working length determination is not influenced by the size of the measuring file used. Previous *in vitro* studies have shown that electronic apex locators are able to detect a point between the apical constriction and the major foramen, depending on the resistance of the dentine (Voß & Siebenkees 1994). The interval 'apical constriction to major foramen' was defined as a target interval to evaluate whether the apex locators were able to identify this interval under clinical conditions. The target interval 'apical constriction' was chosen in order to determine whether electronic apex locators could detect accurately the apical constriction, as restriction of the working length to this interval ensures complete removal of pulpal tissue without damaging the periapical tissue (Tronstad 1991). Precise examination of the position of the file tip is only possible if the teeth are examined histologically under a light microscope after extraction. Therefore, an *in vivo* model was used in the present study for evaluating the accuracy of the two apex locators. In this study, the radiographs were exposed following extraction of the teeth. Therefore, evaluation of the radiographs was easier compared to the clinical situation, where superimposition of anatomical structures may impair interpretation. It is assumed that the results of radiographic working length determination under clinical conditions would be poorer than that under the present study. However, taking an additional radiograph with the measuring files *in situ* would have led to unnecessary exposure of the patients to radiation.

The two apex locators determine the working length by measuring the impedance between the file tip and canal fluid using different frequencies. The impedance of the electrode is measured by calculating the quotient of these measurements (Hör & Attin 2001); this impedance is small at the apical constriction and has a higher value at the major foramen. All modern apex locators work with this principle. Former studies (Pallarés & Faus 1994, Lauper *et al*. 1996, Vajrabhaya & Tepmongkol 1997, Dunlap *et al*. 1998, Pagavino *et al*. 1998) defined the major foramen (±0.5 or ±1 mm) as the target interval. The results of those studies are not comparable to the present one, as a file tip beyond the major foramen was not accepted as a success in working length determination. Therefore, those studies resulted in higher success rates than the present study.

It is important to avoid a shortcut of the measuring circuit. Therefore, rubber dam should be used and the access cavity should be dried with a cotton pellet before measuring. The results of this study demonstrate that the use of the Justy II and Endy 5000 device does not result in precise determination of the apical constriction. However, radiographic assessment of working length gave similar results.

Conclusions

Under clinical conditions, the Justy II and Endy 5000 devices were able to identify the interval 'apical constriction to major foramen' with a high degree of success

(81.7%). Accurate determination of the apical constriction was only successful in 57%. Working length determination should be carried out using a combination of an apex locator and radiography.

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