Ex vivo comparison of two electronic apex locators with different scales and frequencies

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Abstract

Hör D, Krusy S, Attin T. *Ex vivo* comparison of two electronic apex locators with different scales and frequencies. *International Endodontic Journal*, **38**, 855–859, 2005.

Aim To compare *ex vivo* the accuracy of two impedance quotient apex locators with different scales and frequencies of the measuring circuit.

Methodology In each root of 193 extracted human teeth, electronic working length determination (ELD) was carried out with a newly constructed measuring unit. In all cases, ELD was performed using the apex locators Justy II® (Hager & Werken, Duisburg, Germany) and Raypex 4® (VDW, Munich, Germany) on the scale points (sp) 0/0.5/1 of each device. A Miller Needle reaching working length was fixed with composite. The corresponding sp and the differences to the other sp were recorded. After histological preparation of the apical region, the teeth were examined under a light microscope. The distances of the Miller Needle tips to the target intervals 'minor foramen–major foramen' and 'apical canal constriction' (apical constriction) were determined for each sp for both devices. The data were statistically analysed by a chi-square test.

Results Precise determination of the target interval 'minor foramen–major foramen' was successful with Raypex 4 in 94.8% (sp 1), 90.7% (sp 0.5) and 72.5% (sp 0) of cases and with Justy II in 59.6% (sp 1), 92.2% (sp 0.5) and 68% (sp 0) of cases. No measurement carried out by Raypex 4 and by Justy II on sp 1 was beyond the major apical foramen. However, on sp 0.5, there were eight measurements for Raypex 4 and four measurements for Justy II beyond the major apical foramen. Overinstrumentation was also recorded for sp 0 in 49 specimens (Raypex 4) and 59 specimens (JustyII). The major apical constriction was met exactly by Raypex 4 in 50.7% (sp 1), 14% (sp 0.5) and 5.2% (sp 0) of cases and by Justy II in 32.1% (sp 1), 23.8% (sp 0.5) and 4.1% (sp 0) of cases. The differences between the determination made with the sp suggested by the manufacturers for Raypex 4 (sp 1) and Justy II (sp 0.5) were not significant ($P > 0.05$) for the target interval 'minor foramen–major foramen' and significant ($P \leq 0.05$) for the apical constriction. The differences between the sp of each device were significant ($P \leq 0.05$) for both target intervals.

Conclusions It is possible to determine the region between the minor and major apical foramen with electronic apex locators *ex vivo*. The best results were obtained using the sp advised by the manufacturers. Raypex 4 gave the best results on sp one without any measurement beyond the apical foramen. Use of ELD does not result in precise determination of the apical constriction.

Keywords: apex locator, endodontics, working length.

Received 19 July 2004; accepted 16 May 2005

Introduction

The importance of working length determination in root canal treatment is well recognized and traditional canal preparation techniques aim to retain the apical canal constriction as a natural barrier between the root canal and apical tissues (Tronstad 1991). Radiographic working length determination is only possible with reference to the radiographic apex. However, although the apical canal constriction (apical constriction) is on average 1 mm short of the radiographic apex, there can be a great variation of this value between 0 and

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3 mm (Green 1956, 1960, Chapman 1969, Dummer *et al.* 1984). This discrepancy means that radiographic working length determination is mostly arbitrary (Hör & Attin 2001). 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 of the measuring instrument and the canal fluid with different frequencies (Hör & Attin 2001, 2004, Gordon & Chandler 2004). The position of the file tip within this interval depends on the electrical resistance of dentine (Ushiyama 1983, Voß & Siebenkees 1994). Accurate determination of the apical constriction with these devices is not possible, but the measuring error for electronic working length determination (ELD) can be limited apically to the major foramen (Hör & Attin 2004); a file tip passing beyond the major foramen is therefore very unlikely. Furthermore, the position of the file tip can be limited coronally to a position apical to the canal constriction (Hör & Attin 2001). A more extensive correction of the results would be possible by an empiric calibration of different scales and devices in extracted human root canals. The question is whether the probability to hit the target interval is different for different devices within an identical root canal. Moreover, does the measurement depend on the frequencies of the measuring circuit and on the use of a particular scale point (sp) on the device's display?

This study was carried out to create a measuring unit for a direct comparison of different electronic devices. With the help of this unit, the accuracy of the devices to determine the target interval should be empirically estimated according to the different sp on the displays *ex vivo*. The results of the clinical measurements were controlled histologically.

Materials and methods

The measurements were carried out in 193 single rooted extracted human teeth *ex vivo*. Two apex locators, using the impedance quotient method to determine endodontic working length (JustyII®; Hager und Werken, Duisburg, Germany; Raypex 4 ®; VDW, Munich, Germany), were used. After extraction, the teeth were stored in a thymol solution (1%). An access cavity was prepared with a diamond bur and the root canal orifices were widened with a size 3 Gates-Glidden drill. The root canals were rinsed with a 2% NaOCl solution and the access cavities were dried with cotton pellets. The teeth were positioned in the measuring unit with matrix holder in a way that the root apices were dipped into a bowl filled with isotonic NaCl solution (Fig. 1). The measurements were carried out with Miller Needles size xxf (VDW), which were connected to the measuring file holder and the screw (Fig. 1). Each root canal was measured by both devices on the sp 0, 0.5 and 1 (Figs 3 and 4) on the electronic apex locator (EAL) displays. By turning the screw one full revolution (360°) the needle tip was advanced 1 mm forward into the root canal. The position of the needle tip was recorded for every sp. After the last measurement the needles were fixed with a light curing composite and the teeth were stored in a 1% thymol solution. The root canals and the apical canal constrictions were then exposed by carefully sectioning the root apices in a longitudinal direction. With a diamond bur (S6837; Komet, Lemgo, Germany) in a straight hand-piece, dentine was removed until only a thin layer remained over the root canal. This dentine was then removed with a probe. The topography of the apical constriction and the major foramen was determined under a light microscope at 16× magnification. The distances between the apical constriction, the major foramen and the anatomical apex were measured and the target intervals 'minor foramen–major foramen' and 'apical constriction' were determined (Fig. 2). Finally, the position of the Miller Needle tip in relation to the target

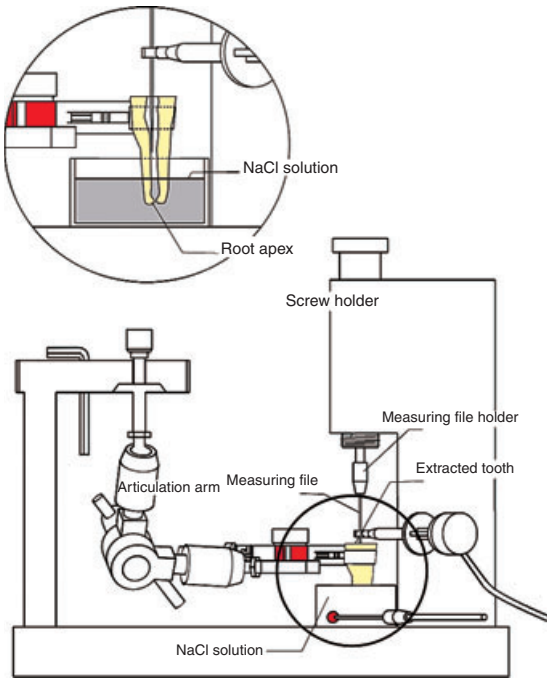

Figure 1 Measuring unit.

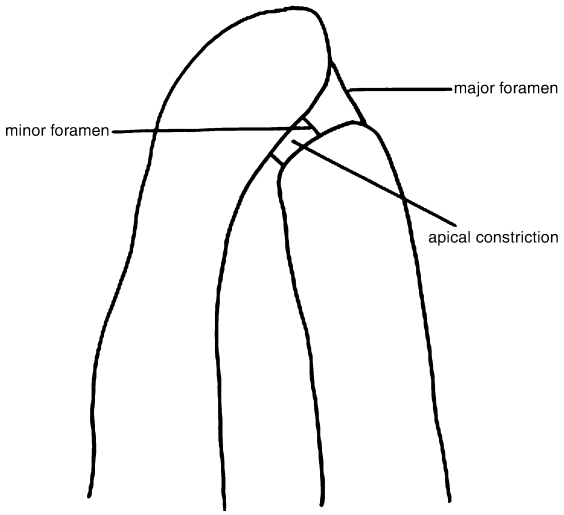

Figure 2 Anatomy of the apical part of the root. If the apical constriction was a slot and not a point, the apical end of the apical constriction was defined as 'minor foramen'. If the apical constriction was a point both expressions defined the same.

Figure 3 Display of Justy II.

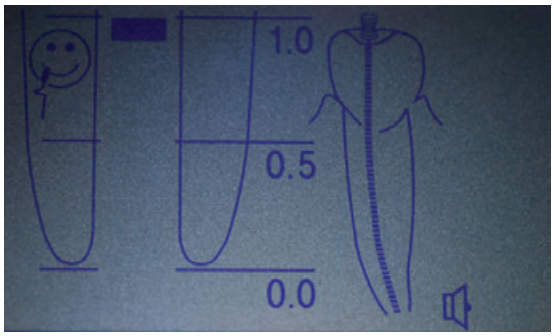

Figure 4 Display of Raypex 4.

intervals was recorded. The virtual positions of the first five measurements for each root canal were calculated with the former noted values. If the Miller Needle tip hit the target interval, the measurement was recorded as a 'success', if not, it was recorded as 'no success'. The value of the distance of the Miller Needle tip to the target interval was negative, if the tip was short of the interval. The value was positive if the tip was beyond the major foramen. The data were statistically compared by the chi-square test (significance was set at $P \leq 0.05$).

Results

Topography of the apical constriction and the major foramen

The mean distance between the anatomical apex and the major foramen was 0.2 mm (±0.23 mm) for all teeth investigated. The distance between the apical constriction and the anatomical apex was 0.91 mm (±0.56 mm). In those cases where the apical constriction was not a point, but like a slot, the apical end (minor foramen) of the apical constriction was taken to calculate the distance to the anatomical apex. The 'traditional' single constriction described by Dummer *et al.* (1984) was found in 93 (48%) cases. A total of 100 (51%) root canals showed a tapered, multiconstricted or parallel constriction (Dummer *et al.* 1984).

Position of the file tip

Figures 5 and 6 show the results for both devices, both target intervals and all sp. The probability of hitting the interval 'minor foramen–major foramen' was 94.8% (sp 1), 90.7% (sp 0.5) and 72.5% (sp 0) for Raypex 4 and 59.6% (sp 1), 92.2% (sp 0.5) and 68% (sp 0) for Justy II. On sp 1, no measurement was beyond the major foramen for both devices. For Raypex 4 there were two measurements (sp 0.5) and 16 measurements (sp 0) beyond the major foramen. Justy II showed two measurements (sp 0.5) and 26 measurements (sp 0) beyond the major foramen. The differences between the devices on the sp suggested by the manufacturers (Raypex 4 sp 1 and Justy II sp 0.5) were not significant ($P > 0.05$). The differences between the different sp of each device were significant ($P < 0.05$). The apical constriction (Fig. 6) was measured exactly by Raypex 4 in 50.7% (sp 1), 14% (sp 0.5) and 5.2% (sp 0) of cases and by Justy II in 32.1% (sp 1), 23.8% (sp 0.5) and 4.1% (sp 0) of cases. The differences between the devices on the sp suggested by the manufacturers (Raypex 4 sp 1 and Justy II sp 0.5) were significant

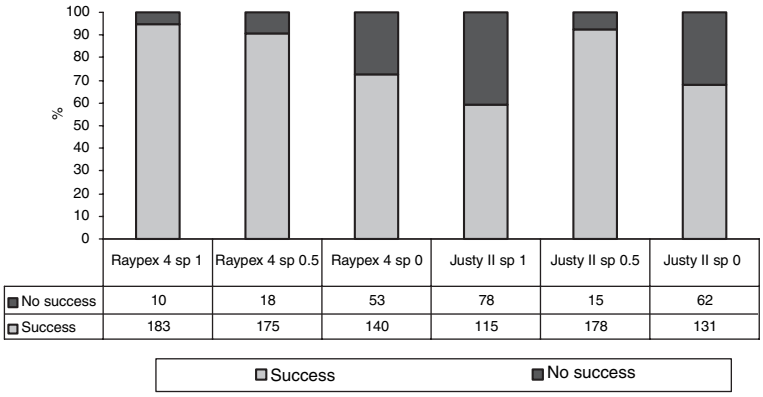

Figure 5 Results for both devices and all scale points (sp) within the target interval 'minor foramen–major foramen'. 'Success' means that the file tip was within the defined target interval.

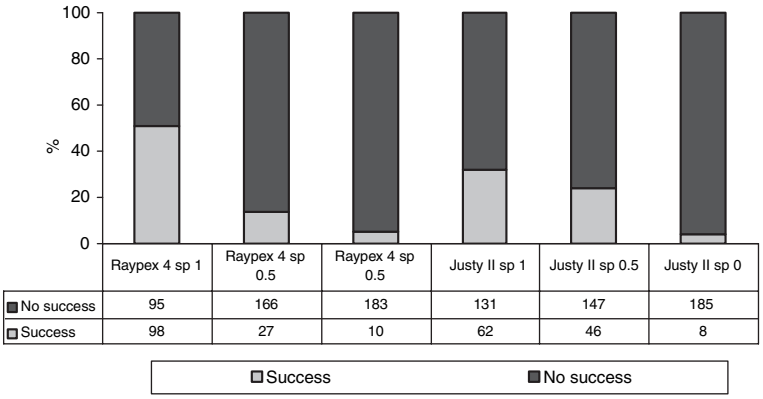

Figure 6 Results for both devices and all scale points (sp) within the target interval 'apical canal constriction'. 'Success' means that the file tip was within the defined target interval.

($P \leq 0.05$) for the apical constriction. The differences between the different sp of each device were also significant ($P \leq 0.05$) for both target intervals for the apical constriction.

Discussion

The results of the topography and anatomy of the apical constriction and the major foramen in the present study are consistent with former studies (Green 1956, 1960, Chapman 1969, Dummer *et al.* 1984). Some of the 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, as in clinical use pushing the file in teeth with necrotic pulps beyond the apical foramen may lead to a transportation of bacteria and toxins into the apical tissue. Furthermore, a Miller Needle size 4f (VDW) was used and not an endodontic instrument for measuring. As the Miller probe is a noncutting instrument, damaging the apical constriction during measurement was avoided. Nguyen *et al.* (1996) showed that electronic length determination (ELD) was not influenced by the size of the measuring instrument used. Moreover, the risk of damaging the apical canal constriction is higher with a root canal instrument than with a probe. Previous laboratory studies showed that electronic apex locators were able to detect a point between the apical constriction and the major foramen, depending on the resistance of the dentine (Voß & Siebenkees 1994). In the present study, the interval 'minor foramen–major foramen' was defined as a target interval to evaluate whether the examined apex locators were able to hit this interval *ex vivo*. The variation of the needle tip within this interval depends on the resistance of dentine (Voß & Siebenkees 1994). This resistance cannot be measured clinically, as there is a great variation within the tooth from the crown to the apex. Therefore, an accurate determination of the apical canal constriction itself is not possible with the present apex locators (Hör & Attin 2004). The target interval 'apical constriction' was chosen to confirm this fact.

The devices are not different in the measuring circuits, both determine the impedance between the needle tip and the canal fluid by calculating the impedance quotient. The frequencies of the current circuits used are different (Justy II: 500Hz and 2 kHz; Raypex 4: 400 Hz and 8 kHz). Furthermore, the display of the Justy II is linearly separated and works with a mechanical needle. The display of the Raypex 4 is separated logarithmically and works digitally (Figs 3 and 4). This could be the reason for a higher accuracy in the range of the apical part of the root canal for Raypex 4. Whilst the linear instrument measures constantly in the whole root canal, the logarithmic display can be divided into more sensitive parts in the apical area of the root canal. Better results for the present generation of apex locators can only be achieved by an empiric calibration of the displays with a great number of extracted teeth measured *ex vivo*, as in the present study. The positions of the file tips have to be compared for different devices and different sp. On the one hand, this procedure shows the probability to hit the target intervals. On the other hand, it is very important that the position of the file tip is not beyond the major foramen. This might result in an overinstrumented and overfilled root canal. The results of the study showed that Raypex 4 on sp 1 fulfilled this challenge best. The results of Justy II on sp 0.5 were similar, but there were two measurements beyond the major foramen. Previous studies often used target intervals ±0.5 or ±1 mm around the apical constriction or the major foramen. These studies reached higher success rates for determination of the apical constriction or the major foramen, as 'success' was defined for a file tip around the apical constriction or the major foramen and not as an exact goal (Czerw *et al.* 1995, Lauper *et al.* 1996, Vajrabhaya & Tepmongkol 1997, Pagavino *et al.* 1998).

Conclusions

The type of display and the measuring frequencies used by electronic apex locators had an influence on the results of ELD. Although the apex locators in this study function with an identical measuring circuit there are differences between the devices. It is possible to electrically determine the interval 'minor foramen–major foramen' with high success rates *ex vivo*. Determination of the apical constriction does not lead to acceptable results. Apex locators and their displays should be calibrated on extracted teeth *ex vivo* before clinical use.

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