An ex vivo comparison of root canal length determination by three electronic apex locators at positions short of the apical foramen

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Objective. The aim of this study was to evaluate the precision of working length determination of 3 electronic apex locators (EALs): Root ZX, RomiApex D-30, and Ipex at 0.0 mm, at the apical foramen (AF), and at 1.0 mm short of the AF.

Methodology. Thirty-eight mandibular premolars had their real lengths previously determined. Electronic measurements were determined at 1.0 mm, followed by measurements at 0.0 mm, performed in triplicate.

Results. Precision of devices at 1.0 mm and 0.0 mm were: 94.7% and 97.4%, respectively (Root ZX); 78.9% and 97.4% (RomiApex D-30); and 76.3% and 97.4% (Ipex). Although no statistical differences were observed between the EALs at 0.0, at 1.0 mm Root ZX performed significantly better than the others.

Conclusion. The EALs had acceptable precision when measuring the working length at the AF. However, when used at levels short of the AF, only Root ZX did not suffer a significant negative effect on precision. **(Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010;110:e57-e61)**

Ideally, endodontic treatment should be limited to the root canal system. To assure that these limits are not surpassed, the length of the canal should be carefully monitored throughout each step of its preparation, maintaining effective control of the working length during the biomechanical instrumentation procedure. Several different techniques have been used to determine the location of the apical foramen. These techniques involve mathematical, radiographic, and electronic methods.[1] Electronic apex locators (EALs) are particularly useful when the apical portion of the root canal system is superimposed radiographically by anatomic structures.[2] Moreover, EALs are extremely useful in cases where the apical foramen does not coincide with the anatomic root apex, which occurs in 41.0% of all posterior teeth and 34.4% of all anterior teeth.[3,4]

The cementodentinal junction (CDJ), the clinical and anatomic landmark where the pulp and periodontal tissue meet, is universally accepted as the limit for biomechanical preparation and obturation in endodontics. However, the CDJ cannot be precisely determined radiographically.[5] Present-day EALs are able to determine the CDJ with precision >90.0%.[6] This degree of accuracy was only reached after drastic improvements were implemented since the first EAL was described by Custer[7] and after the concept was revisited by Sunada.[8] Current devices incorporate concepts such as impedance, resistance, and capacitance together or independently, enabling the EALs to precisely determine the position of the endodontic instrument within the root canal system.[1]

Root ZX (J. Morita, Tokyo, Japan), developed by Kobayashi and Suda,[9] is one of the most widely used EALs. This device, a third-generation EAL, represents 95% of all EALs currently chosen by professionals.[10] The Root ZX uses the impedance ratio method, by simultaneously registering the impedance ratio at 2 different frequencies.[11,12] Since its launch, Root ZX has received considerable attention from the scientific media, and owing to its excellent performance, it is now regarded as the gold standard against which new EALs are evaluated.[6,13-25] A fourth generation of EALs, using a combination of multiple frequencies instead of 2, has recently been developed.[1,10] RomiApex D-30 (Romidan, Kiryat-Ono, Israel), a fourth-generation EAL launched in 2005 and evolved from the Bingo 1020 (Forum Technologies, Kiryat-Ono, Israel), has shown

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precision rates of 92.5%.[6] Another representant of the new-generation EALs is the Ipex (NSK, Tochigi, Japan), which was recently launched and has not yet had its precision evaluated.

Fourth-generation EALs measure capacitance and resistivity simultaneously to precisely determine the apex location. However, these concepts can only be computed simultaneously when the circuit is closed, that is, when the tip of the instrument reaches the apical foramen. Until then, only the capacitance is used by the device to determine the position of the instrument.[1] Consequently, it is clear that the tip of the instrument has to reach the foramen before the resistivity increases, which improves the clinical safety of the EALs. Several studies evaluating EALs do not take into account the effect of penetration depth on the precision of the measurements. Penetration depths varying from 1.0 mm short of the apical foramen to beyond this anatomic structure have been reported.[6,13-25]

Accordingly, considering the great popularity of the EALs among general practitioners and specialists, together with the importance of correct working length determination, the aim of the present study was to evaluate the precision of 2 recently launched EALs and compare their performance with the Root ZX, both at levels 1.0 mm short of the apical foramen (−1.0 mm) and at the apical foramen (0.0 mm).

MATERIALS AND METHODS

Thirty-eight single-rooted human mandibular bicuspids were selected for this study. All teeth were extracted due to orthodontic or periodontal indications, with intact roots and patent apical foramens. Teeth with multiple canals, resorption, fracture, and/or incomplete apex formation were excluded from the study, and only roots classified as Vertucci type I were used.[26]

To remove residual tissues attached to the teeth, specimens were immersed in a 2.5% sodium hypochlorite solution for 4 hours. Calculus and other residues, when present, were removed with the aid of an ultrasonic tip. Then teeth were rinsed under running water and kept in saline solution. Coronal access was performed in a standardized manner with #1013 high-speed round diamond burs (KG Sorensen Ind. e Com., Barueri, Brazil). Once the pulp chamber was exposed, access was finalized with an Endo Z bur (Dentsply-Maillefer, Ballaigues, Switzerland), clearing any remaining portions of the roof or dentin projections. The same bur was used to create plateaus on the occlusal surfaces to better accommodate the endodontic file stops.

The canals were initially explored using hand-held K #15 files (Dentsply-Maillefer). When present, remnants of pulp tissue were gently removed at this time. Subsequently, teeth were numbered and their real canal lengths determined by manually inserting K #15 files into the canals until the instrument tips were visible at the apical foramen, with the aid of a clinical microscope (DF Vasconcellos, São Paulo, Brazil) under ×20 magnifying power. Stops were then set at the coronal references for each tooth and the files removed from the canals. Instrument penetration depths were measured with a precision pachymeter with ±0.01 mm (FNCL; Worker Gage, Esteio, Brazil) and recorded for subsequent comparisons.

All of the steps that follow were performed by a single operator with no knowledge of the real lengths. Throughout the procedures, the teeth were held by a metallic support that allowed freedom of movement for the hands of the operator. The root canal preparation followed the biomechanical principles: Initially, Gates-Glidden burs #5, #4, #3, and #2 (Dentsply-Maillefer) were used in the cervical and middle thirds, with no instrumentation at the apical third. The canal was irrigated with 1.0 mL 2.5% NaOCl at each bur change by means of an endodontic syringe with specific needles (Navi Tip; Ultradent, South Jordan, UT).

After the initial phase of the biomechanical preparation, freshly manipulated alginate (Jeltrate II; Dentsply, Petropolis, Brazil), was loaded into a plastic container, and the metallic support holding the teeth was immersed into the impression material until the apical thirds of the roots were embedded. Then the lip clip electrode was inserted into the alginate. Because this experiment involved the use of fresh alginate, the time frame for measurement of the canals was 30 minutes. Before measuring, 0.5 mL irrigating solution was placed inside the canal, and the excess solution present in the chamber was carefully suctioned to keep the root canal moist.

At this point, the best fitting files were selected, inserted into each canal, and connected to the EALs. For each group of 5 specimens, measurements were conducted in triplicate, alternating the use of the different EALs. Initially, the files were inserted into the canal until the device registered a distance of 1.0 mm from the apical foramen (−1.0); the instrument was then removed from the canal and the penetration depth was measured. At 0.0 mm (at the apical foramen), a similar procedure was followed, but the file was only removed from the canal when the device read "0.0" or "APEX."

The mean values for the 3 measurements at each level were calculated using Excel 2007 (Microsoft Corp., Redmond, WA) and compared with the real length (0.0) and to the real length minus 1.0 mm (−1.0). From these calculations, it was possible to determine the precision of each EAL, considering the discrep-