Influence of heat treatment of nickel–titanium instruments on the accuracy of an electronic apex locator integrated with endodontic motor

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Abstract

Context: Manufacturers have produced a wide variety of nickel–titanium (NiTi) alloys, but the available literature is limited on the accuracy of some integrated electronic apex locators (EAL) used with different NiTi heat treatments in working length (WL) determination.

Aim: This study aims to evaluate ex vivo, the influence of different heat treatments of NiTi instruments, and the diameter of the apical preparation on the accuracy of an EAL used during root canal preparation using an integrated EAL and motor unit.

Materials and Methods: Nineteen extracted human mandibular incisors were included in the study. The WL control was determined by the visual method. Instruments of Mtwo, Reciproc, Reciproc Blue, WaveOne Gold, Twisted File Adaptive, and Hyflex CM systems, with diameters from 0.25 mm to 0.50 mm, were used to measure WL during root canal preparation. The electrical resistivity of instruments with a diameter of 0.25 mm from each system was evaluated using an Inductance, Capacitance, and Resistance (LCR) meter.

Statistical Analysis Used: Data were statistically analyzed using Fisher’s exact test and Kruskal–Wallis test.

Results: The different heat treatments and different diameters did not influence the precision of the EAL (P > 0.05).

Conclusion: The heat treatment and the diameter of the apical preparation did not influence the accuracy of WL determination by an EAL integrated with the endodontic motor.

Keywords: Apical foramen; nickel–titanium alloy; odontometry; root canal therapy

INTRODUCTION

Working length (WL) determination is essential for the success of endodontic treatment, where the best prognosis is obtained when the correct determination of the apical limit is established close to the apical constriction.[1-3]

Electronic apex locators (EALs) used to determine root canal length were first described by Suzuki in 1942[4] and introduced clinically by Sunada in 1965.[5] In vitro and in vivo studies showed good accuracy of these devices in determining root canal length,[6-9] although some authors report that the anatomical diameter of the apical
foramen\textsuperscript{[10]} instrument’s tip diameter and kind of alloy could interfere in measurements\textsuperscript{[11-13]}.

To improve the mechanical properties of nickel–titanium (NiTi) instruments, manufacturers have produced a wide variety of NiTi alloys. Heat and surface treatments produce instruments with greater flexibility and resistance to torsional and cyclic fatigue\textsuperscript{[13-15]}. It is not known if these treatments could intermeddle in the impedance of the electrical circuit and are usually measured by electrical resistivity using LCR meters.

Currently, some endodontic motors have an integrated EAL that allows simultaneous monitoring of the WL and root canal preparation. As changes in work length may occur during the shaping phase in the root canal with severe curvatures\textsuperscript{[16]} the concomitant use of EAL is desirable.

Despite knowing that the diameter of the instrument used can influence the accuracy of some integrated EALs\textsuperscript{[1]} there are no studies evaluating the influence of different NiTi heat treatments on this WL determination.

Thus, the present study aimed to evaluate \textit{ex vivo}, the influence of different heat treatments of NiTi instruments, and the diameter of the apical preparation on the accuracy of an EAL used during root canal preparation using an integrated EAL and motor unit.

**MATERIALS AND METHODS**

**Teeth preparation**

The present study was approved by the Institutional Research Ethics Committee (CAAE12293119.6.0000.0075). Nineteen extracted human mandibular incisors with fully developed apex, with a single canal confirmed by periapical radiograph and curvature angle range between 10° and 30°, determined according to Schneider’s\textsuperscript{[17]} were previously standardized at 17 mm root length by dental crowns removal using a diamond disc (KG Sorensen, São Paulo, Brazil) and stored in distilled water at 37°C.

**Control working length determination**

WL was determined visually using a clinical microscope (Zeiss, Oberkochen, Germany) and a manual stainless steel K-file #10 (Dentsply Maillefer, Ballaigues, Switzerland). The file was inserted into the root canal until it was visualized flush with the major foramen to determine the control WL. [Figure 1].

**Electronic working length measurement**

The roots were fixed in an acrylic box and then submerged in a conductive gel composed of 0.5% potassium chloride, 2.5% hydroxyethyl cellulose, and saline solution, as previously described\textsuperscript{[6]}.

![Figure 1: Clinical microscopy image of the hand file visualized flush to the major foramen to determine the WL control (top and side views). WL: Working length](image)

**VDW Gold RECIPROC motor (VDW, Munich, Germany), which has an integrated EAL, was used to measure WL electronically.**

NiTi systems with #25 tip diameter and heat treatments were used: HyFlex CM size 25.04 (Coltene, Altstätten, Switzerland), Twisted file Adaptive size 25.06 (Axis/SybronEndo, Orange, CA, USA), WaveOne Gold Primary size 25.07 (DentsplyMaillefer, Ballaigues, Switzerland), Reciproc R25 size 25.08 (VDW, Munich, Germany), and Reciproc Blue R25 size 25.08 (VDW, Munich, Germany). Instruments with larger diameters were also evaluated: WaveOne Gold Medium size 35.06 (Dentsply Maillefer, Ballaigues, Switzerland), Reciproc Blue R40 size 40.06 (VDW, Munich, Germany), WaveOne Gold Large size 45.05 (Dentsply Maillefer, Ballaigues, Switzerland), and Reciproc Blue R50 size 50.05 (VDW, Munich, Germany).

The root canals were rinsed with 15 mL of 2.5% sodium hypochlorite and electronic WL was determined when the file reaches the position where the orange LED light appeared on the endodontic motor display. Then, the silicone stopper was adjusted on the occlusal reference, and the length was measured using an endodontic ruler (Dentsply Maillefer, Ballaigues, Switzerland). Measurements were performed in triplicate for each instrument.

The electronic measurements were compared with controls WL and according to a previous study\textsuperscript{[9]} when the difference between the values was ≤0.5 mm, the measurement was considered accurate (score 0), whereas differences >0.5 mm were considered inaccurate (score 1).

**Electrical resistivity analysis**

Electrical resistivity of all instruments with tip ISO #25 (n = 3) used for electronic WL measurement was evaluated using a 4263B LCR Meter (Hewlett-Packard, California, USA), placing their probes on the noncutting intermediate rod and tip of the instrument. The voltage used was 1000 mV with a frequency of 1 kHz, and values were obtained in milliohms (mΩ).
Statistical analysis
Fisher’s exact test was used to evaluate the inter and intragroup differences in the values obtained by comparing the different heat treatments or tip diameters.

Kruskal–Wallis test was used to evaluate electrical resistivity values between groups. The software used for analysis was BioEstat 5.3 (Mamirauá Institute for Sustainable Development, Belém, Brazil), and the significance level was 5%.

RESULTS

Electronic working length measurement
Table 1 shows no statistical difference in EAL accuracy was observed using instruments with different heat treatments and the same tip diameter of 0.25 mm ($P > 0.05$).

Table 2 shows no statistical difference in EAL accuracy was found when comparing instruments of the same system but with different tip diameters ($P > 0.05$).

Electrical resistivity
Table 1 shows the mean electrical resistivity values of different instruments with the same tip diameters (0.25 mm). The highest values were found for HyFlex CM instruments (0.144) and the lowest for Reciproc Blue instruments (0.054). When comparing all heat treatments, results show a statistical difference between the CM group and the others ($P < 0.05$).

DISCUSSION

This study aimed to evaluate the influence of heat treatment and tip diameter of endodontic instruments on the accuracy of an EAL integrated into an endodontic motor. Based on the results of the present study, the heat treatments evaluated (M-Wire, R-phase, Gold Wire, Blue Wire, and CM Wire) and tip diameters analyzed (0.25 mm, 0.35 mm, 0.40 mm, 0.45 mm, and 0.50 mm) showed no influence in the accuracy of the EAL during root canal preparation. Therefore, the null hypothesis was accepted.

One of the factors, the success of endodontic treatment depends on the correct determination of the WL. However, the WL may change during the root canal preparation, mainly in curved conditions. The use of endodontic motors with EAL together presents the advantage of monitoring the WL during root canal preparation, and previous studies reported their suitable accuracy for WL determination being that in some cases showed better accuracy than to conventional radiographic method.

Ex vivo studies are widely used in the literature to assess the accuracy of EALs. Duran-Sindreu et al. compared in and ex vivo models to measure the accuracy of EALs and found no difference. In addition, ex vivo studies are simple, easy to reproduce, and standardize, and can control sample variability and experimental conditions more accurately. We used a conductive 2.5% hydroxyethyl cellulose gel as previously described that is easy to manufacture and standardizes the conductive medium. As in the previous studies, sodium hypochlorite was used as an irrigation solution simulating clinical use.

EALs act as electricity conductors in the electrical circuit to measure WL using the difference between resistance and capacitance (impedance) inside the root canal. Endodontic instruments are manufactured with electroconductive materials and when it reaches the apical constriction region, there is a change in impedance values that is transformed into WL measurements in millimeters from the apical foramen. NiTi alloys with different heat treatments change the alloy constitution varying percentage of different crystalline phases (austenite and martensite) that influences the mechanical properties of the instruments.

Regarding the influence of the alloy on the EAL precision, although Gehlot et al. reported no differences between stainless steel and NiTi alloys, Ferreira et al. demonstrated no influence of different metal alloys on the EAL accuracy. However, there are no studies evaluating the influence of different heat treatments of NiTi endodontic instruments on the accuracy of EALs. Results of this study suggest that NiTi alloy heat treatment did not affect the accuracy of the EAL device ($P = 0.17$).

Concerning electrical resistivity, in the present study, HyFlex CM instruments showed higher values because according to Faulkner et al. the crystalline structure of NiTi can also influence electrical resistivity values since the resistivity of the martensite phase is 14.7% higher than that of the austenite phase. CM Wire presents a greater percentage of crystals in the martensite phase in their crystalline
Table 2: Accurate and inaccurate results obtained using instruments of the same system with different diameters

| Difference (mm) | Gold wire–WaveOne Gold | Blue wire–Reciproc blue |
|----------------|------------------------|-------------------------|
| ≤0.5           | 25.07 35.06 45.05 P     | 25.08 40.06 50.05 P     |
| >0.5           | 1 3 1 2 2              |                          |

structure compared to that in other alloys.[13] Although CM alloys present greater resistivity, no significant differences were found in the WL measurements.

This study also evaluated the influence of the tip diameter of the instrument used to determine WL, showing it did not affect the accuracy of the EAL. Altenburg et al.[1] found lower accuracy of EALs integrated into endodontic motors when using instruments 25.02 and 30.02 compared to that instruments with larger tip and taper (15.05, 20.06, 20.07, 25.06, 25.08, 30.05, and 30.09) and the reason could be because the instrument does not touch a part of the wall preventing the reading of the capacitance.

CONCLUSION

Within the limitations of this study, the type of heat treatment of the NiTi alloy of mechanized instruments and the tip diameter do not influence the EAL accuracy.

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Conflicts of interest
There are no conflicts of interest.

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