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ORIGINAL ARTICLE

# The effect of residual calcium hydroxide on the accuracy of a contemporary electronic apex locator

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**Abstract**

***Objective.*** The aim of this study was to evaluate the effect of residual calcium hydroxide [$Ca(OH)_2$] on the accuracy of an electronic apex locator (EAL). ***Materials and methods.*** Working lengths (WLs) of 56 extracted maxillary incisors were determined initially by two different methods. The first method used the 'APEX' reading of the EAL as a reference point, 0.5 mm was subtracted and recorded as $WL_0$. The second method used the '0.5' reading and the score was recorded as $WL_{0.5}$ without subtraction. The roots were prepared to $WL_0$ and divided randomly into three experimental groups ($n = 16$) (1 mm in group A, 2 mm in group B and 4 mm in group C) and a control ($n = 8$). Specimens in all experimental groups were filled with $Ca(OH)_2$ paste. Following its removal, WLs were re-determined with the same methods. ***Results.*** In group C, pre/post WLs were significantly different ($p < 0.05$). No significant difference was observed between the other experimental groups and the control group. ***Conclusion.*** Accuracy of EAL decreased proportionally with the amount of paste remaining at the ±0.5-mm tolerance level. $Ca(OH)_2$ paste remnants may cause incorrect EAL readings.

**Key Words:** *apex locator accuracy, calcium hydroxide, endodontics*

## Introduction

The need for an inter-appointment medication to improve disinfection is a controversial issue in endodontics [1]. Recent studies have demonstrated that the 'more than one' visit protocol with an inter-appointment medication resulted in improved microbiological status of the root canal system compared with a single-visit protocol [2]. Calcium hydroxide ($Ca(OH)_2$) is used extensively in endodontics due to its antibacterial and biological properties [1]. It is used in various clinical situations and is retained in the canal for periods ranging from 7 days for intracanal medication to 6–24 months for apexification [3]. However, $Ca(OH)_2$ must be removed completely to fill the canal with obturating materials [4]. Several studies have reported that $Ca(OH)_2$ pastes are not easily removed from the root canal system, regardless of the technique used, and that paste remnants may thus be present in roots [5–7].

The precise calculation of working length (WL) is an important factor in root canal treatment outcome. WL is defined as 'the distance from a coronal reference point to the point at which canal preparation and obturation should terminate' [8] and the accurate detection of the end-point of the root canal system (apical terminus) is critical [9]. Electronic apex locators (EALs) that use electrical principles to detect the apical terminus [10] provide highly accurate (83–100%) WL determinations [11–14] and EALs are now part of the basic armamentarium used to provide high-quality and predictable root canal treatment [15].

The Mini Root ZX (J Morita Corp., Tokyo, Japan) is a contemporary EAL that is a modified version of the Root ZX (J Morita Corp.), which uses the 'ratio method' [16].

Numerous reports have described materials and factors potentially affecting EAL accuracy [17–21]. However, to date, no published study has evaluated

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the effects of $Ca(OH)_2$ remnants on EAL accuracy in root canal treatment procedures.

The aim of this study was to evaluate the effect of $Ca(OH)_2$ paste remnants on the accuracy of the Mini Root ZX under laboratory conditions. The null hypothesis was that paste remnants would not affect the accuracy of this EAL.

## Materials and methods

Mesiodistal and buccolingual radiographs of 56 freshly extracted maxillary incisors were obtained to determine that they had non-complicated root canal anatomy, single straight root canals, mature root formation and all roots were inspected under an operating microscope at ×12.5 magnification (Opmi Pico; Carl Zeiss, Oberkochen, Germany) to determine any sign of external resorption, crack or fracture along the roots. All crowns were cut-off at the cementoenamel junction to simplify access to the root canal and to provide a stable reference for all measurements. Root canal patency was controlled with a size 10 K-file (Mani Inc., Tochigi-Ken, Japan).

### *Establishment of pre-preparation working lengths*

The roots and the labial clip of the EAL were embedded in an alginate testing model, developed to test apex locators [22]. The Mini Root ZX was used according to the manufacturer's recommendations. A size 10 K-file was placed into the root canal and advanced downward. A rubber stop was fixed to the file with flowable light-curing resin (GrandioFlow; Voco GmbH, Cuxhaven, Germany) when the flashing bars of the EAL reached the 'APEX' level on the screen, and maintained in contact with the flat, horizontal surface of the root. The distance between the fixed stopper and file tip was measured by digital caliper. Measurements were made in triplicate and the average value was recorded. Then, 0.5 mm was subtracted from this initial length and the value was recorded as $WL_0$. After $WL_0$ measurement, another size 10 file was advanced down the canal until '05' was displayed on the EAL screen; measurements were made in triplicate and the average was recorded as $WL_{0.5}$, without subtraction of 0.5 mm.

### *Root canal preparation*

All roots were prepared to $WL_0$ using the ProTaper system (Dentsply Maillefer, Ballaigues, Switzerland). S1, S2 and F1–F3 files were used with an endodontic motor (X-Smart; Dentsply Maillefer) according to the manufacturer's recommendations. The F3 file (ISO tip size #30, apical taper size 9%) was the master apical file (MAF) for all roots. Root canals were irrigated with 2.5% NaOCl between each instrument change. Final irrigation was performed with 3 mL 17% EDTA solution for 1 min, followed by 3 mL 2.5% NaOCl and 3 mL distilled water. The root canals were dried with paper points. The roots were divided randomly into three experimental groups (A–C; $n$ = 16 each) and a control group ($n$ = 8). For each group, measurements were made in triplicate and the average value was used for analysis. An experienced operator blinded to pre-preparation measurements performed all WL re-measurements.

- Group A: Specimens were filled with $Ca(OH)_2$ paste (DiaPaste; Diadent, Almere, The Netherlands) using application tips according to the manufacturer's recommendations. Digital radiographs were taken using a special appliance that fixed the distance between the sensor and radiograph tube to check $Ca(OH)_2$ paste content in the root canals. All samples were sealed with a temporary filling material (Cavit G; 3M ESPE, St. Paul, MN). Roots were stored at 37°C and 100% humidity for 10 days. Then, the temporary filling material was removed and the paste in the root canal was removed using stainless-steel hand files (Master instrument for removing Ca $(OH)_2$ in '1 mm group' was #40 H-File) to 1 mm less than the recorded $WL_0$. The residual $Ca(OH)_2$ paste level was also confirmed by digital radiography. Roots in group A were divided randomly in two sub-groups for EAL re-measurement.

  *Sub-group A1* ($n$ = 8): An F3 file attached to the EAL was advanced down the canal until the flashing bars reached 'APEX' on the screen. The distance between the fixed stopper and file tip was measured by digital caliper. Next, 0.5 mm was subtracted from the average value and the result was recorded as $AWL_0$.
  *Sub-group A2* ($n$ = 8): The procedure was the same as for sub-group A1, but the file was advanced downward until the device displayed '05'. The average value was recorded as $AWL_{0.5}$.

- Group B: Using the same procedures as applied in group A, paste in the root canal was removed to at least 2 mm less than the recorded $WL_0$ (Master instrument for removing $Ca(OH)_2$ in '2 mm group' was #50 H-File). The roots were divided randomly into two sub-groups.

  *Sub-group B1* ($n$ = 8): Procedures were applied as in sub-group A1 and scores were recorded as $BWL_0$.
  *Sub-group B2* ($n$ = 8): Procedures were applied as in sub-group A2 and scores were recorded as $BWL_{0.5}$.

- Group C: Procedures were applied as in group A. Paste was removed to at least 4 mm less than the recorded $WL_0$. (Master instrument for removing $Ca(OH)_2$ in '4 mm group' was #70 H-File) The roots were divided randomly into two sub-groups.

Table I. Mean and standard deviation of experimental groups in millimeters.

| | Test sample groups | | | | | | Control groups | |
|---|---|---|---|---|---|---|---|---|
| | 1 mm $Ca(OH)_2$ | | 2 mm $Ca(OH)_2$ | | 4 mm $Ca(OH)_2$ | | $Ca(OH)_2$ free | |
| | Sub-group A1 ($AWL_0$) | Sub-group A2 ($AWL_{0.5}$) | Sub-group B1 ($BWL_0$) | Sub-group B2 ($BWL_{0.5}$) | Sub-group C1 ($CWL_0$) | Sub-group C2 ($CWL_{0.5}$) | $CG_0$ | $CG_{0.5}$ |
| Sample number | 8 | 8 | | 8 | 8 | 8 | 8§ | 8§ |
| Preop. $WL_0$ | 14.77 ± 0.85 | | 15.20 ± 1.50 | | 14.50 ± 0.69* | | 14.62 ± 1.13 | |
| Preop. $WL_{0.5}$ | | 14.49 ± 0.73 | | 14.56 ± 1.02 | | 15.48 ± 1.00* | | 14.60 ± 1.10 |
| Postop. $WL_0$ | 14.84 ± 0.91 | | 14.89 ± 1.62 | | 13.81 ± 0.63* | | 14.71 ± 1.11 | |
| Postop. $WL_{0.5}$ | | 14.21 ± 0.94 | | 14.20 ± 0.83 | | 14.97 ± 0.92* | | 14.58 ± 0.99 |

Preop, Preoperative; Postop, Postoperative.
*In columns show the significance ($p < 0.05$).
§The same eight samples were used in the control group for both $CG_0$ and $CG_{0.5}$ measurements.

*Sub-group C1* ($n = 8$): Procedures were applied as in sub-group A1 and scores were recorded as $CWL_0$.
*Sub-group C2* ($n = 8$): Procedures were applied as in sub-group A2 and scores were recorded as $CWL_{0.5}$.

- Control group ($n = 8$): Samples were prepared to $WL_0$ and left empty. Measurement procedures were applied as in sub-groups A1 and A2 and scores were recorded as $CG_0$ and $CG_{0.5}$, respectively.

Statistical analyses were performed using SPSS software (ver. 13.0 for Windows; SPSS Inc., Chicago, IL). The Shapiro–Wilk normality test and Levene's variance homogeneity test were applied to the data. The data were normally distributed, with homogeneity of variance among groups. Repeated-measures analysis of variance was applied to the data. Pearson's chi-squared test was applied to evaluate the accuracy percentage of data. Measurements made before root canal preparation ($WL_0$ and $WL_{0.5}$) and after $Ca(OH)_2$ placement were compared for each specimen. The accuracy percentages of sub-groups were analyzed with ±0.5 mm tolerance to $WL_0$ and $WL_{0.5}$ for each specimen.

## Results

In group C (4 mm $Ca(OH)_2$), mean $CWL_0$ and $CWL_{0.5}$ values were significantly lower than $WL_0$ and $WL_{0.5}$ values, respectively ($p < 0.05$; Table I). No significant difference was observed between the other experimental groups and the control group ($p > 0.05$; Table I).

The accuracy percentage of $WL_0$ measurements at the ±0.5-mm tolerance level was significantly greater in group A (1 mm $Ca(OH)_2$) than in group C (4 mm $Ca(OH)_2$; $p < 0.05$; Table II). No significant difference in $WL_{0.5}$ measurements was observed among groups ($p > 0.05$; Table II).

## Discussion

In root canal treatment procedures, the complete removal of $Ca(OH)_2$ paste from root canals is difficult [7]. Re-determination of WL may also be required at each appointment. Radiographic techniques may be used alone, but the combined use of radiographic and electronic methods has been suggested to improve accuracy [15,23]. However, the use of $Ca(OH)_2$ may make visualization of the file tip difficult on radiographs because most $Ca(OH)_2$ pastes are radio-

Table II. The accuracy percentages of all test and control groups at the ±0.5 mm tolerance level.

| | Test sample groups | | | | | | Control groups | |
|---|---|---|---|---|---|---|---|---|
| | 1 mm $Ca(OH)_2$ | | 2 mm $Ca(OH)_2$ | | 4 mm $Ca(OH)_2$ | | $Ca(OH)_2$ free | |
| | Sub-group A1 ($AWL_0$) | Sub-group A2 ($AWL_{0.5}$) | Sub-group B1 ($BWL_0$) | Sub-group B2 ($BWL_{0.5}$) | Sub-group C1 ($CWL_0$) | Sub-group C2 ($CWL_{0.5}$) | $CG_0$ | $CG_{0.5}$ |
| Percentages | 88% | 88% | 63% | 75% | 13% | 50% | 100% | 100% |

opaque like the file tip; thus, the use of EAL tools alone may be sufficient in such cases. No evaluation of the effect of $Ca(OH)_2$ remnants on EAL accuracy has been reported.

Although the use of irrigation solutions help with the removal of materials, the most common method of $Ca(OH)_2$ removal is MAF usage followed by combined NaOCl and EDTA application [24]. Studies have been published about the removal of $Ca(OH)_2$ from root canals and none of them reported the complete removal of $Ca(OH)_2$, especially at the apical region of the root canal [5–7]. It is also impossible to have a standard amount of residue in the root canal with copious irrigation. Although the methodology of the present study did not simulate clinical conditions, we aimed to evaluate the effects of standardized amounts of calcium hydroxide remnants on the accuracy of a contemporary apex locator. Thus, we used the MAF without solution and checked remnant levels in each root by digital radiography.

DiaPaste was selected as the test material. It is a pre-mixed $Ca(OH)_2$ and barium sulfate paste that is packaged in a convenient syringe to eliminate the need for mixing and to provide an ideal vehicle for application. Due to the barium sulfate content, the paste is radio-opaque, facilitating digital radiographic checking. A mixing requirement during preparation makes standardization of the physical properties of paste placed in each sample difficult, and differences in physical properties may directly affect results. Thus, the manufacturer claims that Diapaste is water soluble, which means it is easy to clean and remove (http://www.diadent.com/products/diapaste.htm). Hence, a pre-mixed $Ca(OH)_2$ paste was used in this study.

Previous studies have reported that pre-flaring procedures and measuring file size may affect EAL accuracy. The use of small files to take measurements in root canals with increasing diameters has been shown to lead to inaccuracy [20,25,26]. In this study, size 10 and F3 files were used for pre- and post-preparation EAL measurements, respectively, to prevent inaccuracy due to incompatibility between root canal diameter and instrument size.

In this study, freshly prepared alginate was used as a testing medium. Previous reports have suggested that alginate has good electroconductive properties because it remains around the root and simulates the periodontal ligament (PDL) due to its colloidal consistency [27,28].

Older EALs have proved to be sensitive to root canal contents, particularly in terms of electrolyte composition. However, currently available multi-frequency impedance-type EALs, including the one used in this study, operate accurately even in the presence of electrolytes, such as irrigating solutions, pus, blood or serum exudates [13,29,30]. On the other hand, this type of EAL relies on impedance change along the length of the root to determine the position of the apical terminus [29]. Previous studies have identified factors potentially affecting tooth impedance [31–33], such as dentinal tubule and smear layer sizes [31], chemomechanical preparation and residual root-canal filling materials [29] and apical anatomy [30]. In this study, WLs measured before preparation and after $Ca(OH)_2$ placement were compared in the same roots; thus, the results were not affected by dentinal tubule or anatomical differences. Because roots were left empty in the control group, no paste remnant affected accuracy; in this group, pre- and post-preparation WLs did not differ significantly. Thus, chemomechanical preparation had no significant effect on EAL accuracy.

In this study, two different WL determination methods were used. The first one involved detection of the point at which 'APEX' was displayed on the EAL screen, which mimics the contact of the file tip with the PDL under clinical conditions; 0.5 mm was then subtracted from this measurement. The second method involved detection of the point indicated as '05' on the EAL screen. Previous reports have recommended the first method because the accuracy of EALs in the detection of apical constriction is not sufficient; EALs are capable only of recording the point at which the PDL begins outside the root canal [9]. The second method is very simple, involving no calculation, and avoids the risk of PDL injury. Clinicians who understand the indicators displayed on the EAL can use both methods [18]. Only histological evaluation can determine the precise locations of these two detected points in the root canal. However, within the limits of this study, detection of the '05' point was clearly more accurate than detection of the 'APEX' point when comparing pre- and post-preparation measurements.

In this study, specimens with three levels (1, 2 and 4 mm) of $Ca(OH)_2$ paste remnants were prepared to evaluate the accuracy of a multi-frequency impedance-type EAL. We found significant differences in the group with 4 mm residual paste. Accuracy at the ±0.5-mm tolerance level decreased with increasing amount of residual paste, leading to the rejection of the null hypothesis. Paste remnant amount proportionately affects the accuracy of the Mini Root ZX.

## Conclusion

In root canal treatment procedures, $Ca(OH)_2$ paste remnants may have unfavorable effects on EAL accuracy. These effects may be directly related to the amount of remnants; thus, clinicians must exercise care when measuring WLs using an EAL in these cases.

***Declaration of interest*:** The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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