Original Article

Comparative evaluation of working length determined using integrated apex locator and root ZX mini under various irrigating solutions: An *in vivo* study

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Abstract

Background: Electronic apex locators (EALs) are frequently used as adjuvant to radiographs in working length (WL) determination. The introduction of integrated apex locators (IALs) further simplified the root canal treatment by continuous monitoring of the apex while root canal shaping.

Aim: The aim of this study was to evaluate the efficacy of radiographs, EAL, and IAL in determining the WL in the presence of various irrigants.

Materials and Methods: The present *in vivo* study was carried out on 30 patients who were divided into 10 in each group, based on the type of irrigant used; 0.9% saline (Group 1), 0.2% chlorhexidine (Group 2), and 2.5% of sodium hypochlorite (NaOCL) (Group 3). In each group, WL is determined using conventional radiographs, Root ZX Mini (EAL), and CanalPro CL2i (IAL).

Statistical Analysis: Kruskal–Wallis test and Friedman's two-way ANOVA test were used for statistical analysis.

Results: Mean WL was comparably lower with Root ZX Mini, while the WL by CanalPro CL2i and the radiographic method were comparable. In all methods, the type of solutions used did not influence the WL, with a higher mean WL when NaOCL is used as an irrigant. Nevertheless, the above comparisons were not statistically significant.

Conclusion: the irrigation solutions employed in this study had no impact on the performance of apex locators and radiographs.

Keywords: Apex locators; apical foramen; chlorhexidine; periapical radiographs; sodium hypochlorite; working length

INTRODUCTION

Endodontic treatment encompasses various critical steps that determine the outcome, among which, the estimation of accurate working length (WL) was continuously been a challenging task. A precise WL helps in effective canal preparation, by minimizing the extrusion of debris or restorative material into the periapical area.[1] Traditionally radiographs, anatomical knowledge, tactile sensation, and paper points have been used for defining WL. All of the aforementioned techniques, however, have drawbacks but radiographs give a two-dimensional image, subjectivity, picture

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magnification, distortion errors, radiation exposure, and superposition of anatomical components. Teeth with open apex and apical curvature limit the use of tactile perception or absorbent points.[2,3]

A significant advancement in endodontics was the introduction of electronic apex locators (EALs), which sets out as an effective adjuvant for detecting the canal terminus. Custer initiated the research on an electronic method in 1918, and Suzuki revived it in 1942. Sunanda,[4] however, was the one who applied these ideas to create a straightforward device to detect the WL in 1962. Today's major improvements in EALs have greatly increased their accuracy and adaptability. The introduction of an integrated apex locator (IAL), in which the endodontic motor and apex locator (AL) work reciprocally, is more beneficial for WL measurement as it reduces the chairside time of the treatment.[4] However, the performance of ALs varies with the root canal contents and conditions.[5]

Over the decades, sodium hypochlorite (NaOCL) and chlorhexidine (CHX) were the most widespread irrigating solutions used. NaOCL is the gold standard due to its varied properties such as tissue dissolution and antimicrobial efficacy. CHX is one of the widely used irrigating solutions due to its property of substantivity, low toxicity, enhanced antimicrobial properties, acceptable odor and taste, and nonbleaching properties.[6] The current research reveals that the type and concentration of irrigating solution potentially affect the accuracy of EALs in WL measurement.[7,8] However, few studies reported that canal contents did not alter the accurateness of EALs in determining the WL.[9,10]

The advantages and clinical effectiveness of EALs have been the question of numerous studies; however, the majority were conducted *in vitro*. Although the reproducibility of ALs is a great advantage, the information obtained from radiographs is indispensable.[11] A literature search revealed no *in vivo* studies relating to the efficacy of EAL, IAL, and radiographs in estimating the WL in the presence of various irrigating solutions. Thus, the current study aimed to evaluate the efficacy of Root ZX Mini, CanalPro CL2i, and conventional radiographs in WL determination under the presence of normal saline, 0.2% CHX, and 2.5% of NaOCL.

MATERIALS AND METHODS

The present *in vivo* study has obtained Ethical Clearance for study from the Institutional Review Board (no: PMVIDS and RC/IEC/ENDO/PR/544-22) and has registered for the Clinical Trial Registry of India with (no: CTRI/2023 / 07/055346). The present study followed all the ethical standards in accordance with the guidelines provided by the Declaration of Helsinki. Upon the elucidation of the study procedures, subjects signed the consent form. The anonymity and discreetness of subjects were upheld. The study fulfills the Strengthening the Reporting of Observational Studies in Epidemiology guidelines.

The sample size was estimated using the G*Power software based on the previous literature, wherein at an effect size of 0.624, 95% confidence interval, and a power of 0.80, the estimated sample size is 30 (with 10 in each group). Subjects in the age group of 20–40 years, requiring endodontic treatment for single-rooted anterior teeth with apical periodontitis and irreversible pulpitis, and who gave consent were involved in the study. Participants with compromised medical history, teeth with open apices or internal resorption, curvatures, fractured teeth, and calcified canals were excluded from the study.

The tooth was anesthetized using 2% lignocaine with 1:200,000 adrenaline and isolated using a rubber dam. An access cavity was established using Endo Access Burs, with #2–4 Gates-Glidden drills, the coronal portion of each canal was flared, and the pulp was removed with a barbed broach [Figure 1]. A K-file #10 size (Mani Inc., Tochigi, Japan) was submissively inserted up to the apical foramen to evaluate canal patency. Based on the irrigating solution used, all the patients were randomly split up into three groups of 10 each.

Subjects in Group 1 received 0.9% of normal saline, 0.2% CHX in Group 2, and 2.5% of NaOCL in Group 3. Canals were irrigated using a 23-Gauge side-vented needle. Following the irrigation, the WL was determined in each group using three methods: radiographic method, Root ZX Mini AL [Figure 2a], and CanalPro CL2i AL [Figure 2b].

Working length determination by radiographic method (Ingle's method)

A periapical radiograph was attained after inserting a file into the canal that was 1 mm shorter than the tooth's real length as determined by a preoperative radiograph. The

Figure 1: Armamentarium used in the study

distance between the file end and the apical foramen was measured and the difference is adjusted accordingly to get the actual length. To corroborate with the cementodentinal junction, 1 mm was deducted from the tooth's corrected length and is now noted as the radiographic WL.

Working length determination by apex locators

We used the Root ZX Mini and the CanalPro CL2i in accordance with the directions provided by the manufacturer. The electrode was attached to the file, and the clip was placed on the patient's lip. Up until the display signaled that the minor diameter had been attained, the file insertion was advanced. The rubber stop on the file shaft was positioned on the reference point after determining the apical limit. The distance between the instrument's tip and the rubber stop was measured, and the measurement's value was noted before the instrument was carefully withdrawn.

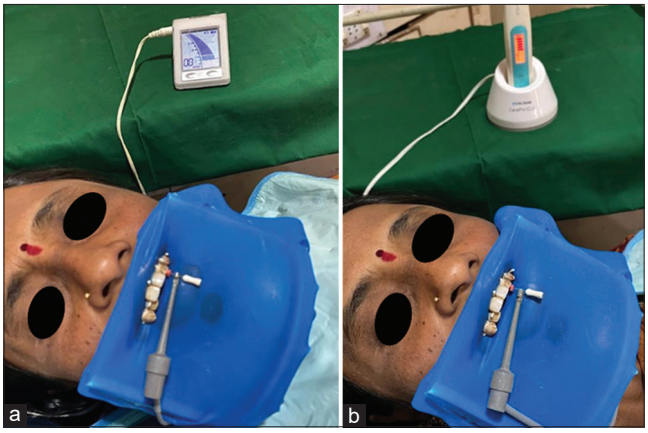

Figure 2: Recording of working length using root ZX mini and CanalPro CL2i. (a) Working length (WL) determination using Root ZX mini and, (b) WL determination using CanalPro CL2i

Table 1: Mean comparison of working length between different methods

Group	WL method	*n*	Mean±SD	Test statistic	*P*
Group 1	Radiographic	10	20.0000±1.50923	1.336	0.513
	Root ZX mini	10	19.4500±1.64063		
	CanalPro CL2i	10	20.1000±1.46818		
Group 2	Radiographic	10	20.4500±1.80201	3.931	0.140
	Root ZX mini	10	19.9500±1.42302		
	CanalPro CL2i	10	20.5500±1.51749		
Group 3	Radiographic	10	20.5500±1.57145	2.741	0.254
	Root ZX mini	10	20.1000±1.37032		
	CanalPro CL2i	10	20.8000±1.00554		

Friedman's Two-way ANOVA test, $P \leq 0.05$ considered statistically significant.
SD: Standard deviation

Statistical analysis

Statistical analysis was done using the Statistical Package for Social Sciences (SPSS) version 21 (IBM, Armonk, NY, USA). The normality of the sample was assessed using the Shapiro–Wilk test and it was observed to be a nonuniform distribution, thus nonparametric tests were applied. To compare the mean difference in WL between groups, Kruskal–Wallis test was applied and a comparison between the method of WL estimation within each group was done using Friedman's two-way ANOVA. The study findings were observed significant for $P \leq 0.05$.

RESULTS

Table 1 represents the mean comparison of WL as determined by radiographic and EALs in each group. Among the group that received the normal saline as an irrigant, no significant variance was seen among the three methods ($P = 0.513$). Nevertheless, the mean WL was comparably lower with Root ZX Mini (19.45 ± 1.64), while the WL by CanalPro CL2i (20.1 ± 1.46) and radiographic method (20.00 ± 1.50) was almost comparable. A similar nonsignificant difference between the three methods was also noticed among the groups that received CHX ($P = 0.140$) and NaOCL ($P = 0.254$) as an irrigant, with comparably lower mean WL with Root ZX Mini EAL (19.9 ± 1.42 and 20.1 ± 1.37, respectively). Further, *post hoc* analysis also revealed no significant values in mean WL between each method in all three groups.

Table 2 represents the mean comparison of WL based on the type of irrigant used in each method. In the radiographic method, the type of irrigant solutions used did not significantly influence the WL ($P = 0.602$), though the mean WL was comparably lower (20.0 ± 1.50) among

Table 2: Mean comparison of working length between groups according to determination method

WL determination method	Groups	*n*	Mean±SD	Test statistic	*P*
Radiographic method	Group 1 (saline)	10	20.0000±1.50923	1.015	0.602
	Group 2 (CHX)	10	20.4500±1.80201		
	Group 3 (NaOCL)	10	20.5500±1.57145		
Root ZX mini EAL	Group 1 (saline)	10	19.4500±1.64063	1.205	0.547
	Group 2 (CHX)	10	19.9500±1.42302		
	Group 3 (NaOCL)	10	20.1000±1.37032		
CanalPro CL2i EAL	Group 1 (saline)	10	20.1000±1.46818	1.220	0.543
	Group 2 (CHX)	10	20.5500±1.51749		
	Group 3 (NaOCL)	10	20.8000±1.00554		

Kruskal–Wallis test, $P \leq 0.05$ considered statistically significant. WL: Working length, SD: Standard deviation, CHX: Chlorhexidine, NaOCL: Sodium hypochlorite, EALs: Electronic apex locators

the teeth that received saline as an irrigant, while the mean WL with CHX (20.45 ± 1.80) and NaOCL (20.5 ± 1.57) was almost similar. When ALs were used, a similar lower mean WL was seen with the saline group (19.45 ± 1.64 and 20.1 ± 1.46, respectively) in comparison to the other canal irrigants. Nonetheless, none of the comparisons were statistically significant. Moreover, *post hoc* analysis also revealed no significant influence of irrigating solutions on the various methods of WL determined.

DISCUSSION

The Root ZX mini and the CanalPro CL2i are two compact ALs that have been recently familiarized. The Root ZX mini, a 3rd-generation AL, is considered to be the gold standard and is based on the "ratio method" that uses dual frequency and proportional impedance.[12] Root ZX Mini is designed to be easily portable and also emphasized that they are less sensitive to intracanal contents. This EAL also features automated calibration, shock resistance, and three programmed memory settings.[13] Its operation, precision, and reproducibility were reported as comparable to that of Root ZX.[14] However, there is little information about the Root ZX mini's *in vivo* accuracy in identifying the proper WL in the literature.

Monitoring the WL continuously is important, especially in curved canals, as inadvertent use of an endodontic instrument could result in canal straightening, which could have unfavorable implications. To make root canal preparation quick, simple, and accurate, IALs have been developed, wherein an endomotor is built-in along with an AL.[15] These IALs have additional features such as torque control and speed settings.[16] In addition, the automatic apical reverse feature allows for controlled instrumentation by stopping its operation and rotating backward whenever the file tip reaches the preset point.[17]

CanalPro CL2i AL is one such IAL belonging to the 5th generation, which uses two measurement frequencies that are alternated, eliminates noise, and the need for signal filtering, and makes it unaffected by electromagnetic interferences. The CanalPro AL stands out due to its precise apex location, virtual apex function, high-resolution graphic display, and user friendly.[18]

It is thought that these contemporary EALs can function effectively irrespective of irrigation solutions' electroconductivity (NaOCL and saline are highly conducive, while CHX and EDTA are moderately conducive); however, the majority of the research was conducted *in vitro*. Hence, the present study intended to compare the efficacy of the above ALs along with conventional radiographs and the effect of different irrigating solutions in determining the WL through an *in vivo* approach. No unfavorable effects of using 0.9% normal saline, 0.2% of CHX, and 2.5% of NaOCL as an irrigation solution on the efficiency of radiographs, EAL, and IAL in determining the WL were observed. Further, the mean WL was almost comparable between radiographic and CanalPro IAL, while lower with Root ZX Mini EAL.

Some EALS have been observed to be less accurate when used with 0.9% normal saline as an irrigation solution,[8,19] however, other studies reported no influence on the accuracy of EALs[20,21] and on radiographs too.[22] Saline showed a closer value to the actual length in comparison to other irrigants among all the methods of WL determination in a previous study by Soumya and Pradeep.[23] The difference in test conditions and differences in devices might be the reason for these varied results.

Kobayashi[24] and Fan *et al*.[25] reported that high electroconductive solutions such as NaOCl tend toward short measurements as it decreases the electrical impedance. This agrees with other studies, in which the accuracy of different ALs (ProPex, Root ZX, and Sybron Mini) had most of the measurements short of actual WL (AWL) with NaOCl.[8,26] However, in the present study and in a study by Khattak *et al*.,[27] though statistically insignificant, the measurements were comparably higher with NaOCL. This difference might be due to variations in the type of ALs used, the concentration of the solutions used, and the study design.

Since CHX has effective antibacterial qualities and residual effects on the root canal, using it as an irrigation solution has been recommended. In the present study, the WL determined using radiographs and ALs were more consistent with minimal difference only in the group that received CHX as an irrigant. Jha *et al*.,[6] Shin *et al*.,[7] Ozsezer *et al*.,[8] and Khattak *et al*.[27] also obtained the best results in the CHX environment. According to Jain and Kapur, WL determined using Root ZX Mini and ProPex II in the presence of CHX was statistically negligible.[28] Duran-Sindreu *et al*. in their investigation also discovered that the inclusion of CHX had no discernible impact on Root ZX Mini's effectiveness.[29] However, Prasad *et al*.[1] and Mull *et al*.[26] observed a larger deviation from the AWL for both CHX and NaOCL.

Among all the irrigating solutions (saline, CHX, and NaOCL), the WL determined by CanalPro CL2i IAL and the radiographic method was mostly comparable, while Root ZX Mini EAL gave lower values. Nonetheless, the above differences in WL were not statistically significant, signifying that all three methods were equally effective irrespective of the type of irrigant used. Similarly, Soujanya *et al*.[22] also showed that the root length can be accurately measured using conventional radiographs and EALs irrespective of the canal contents. Furthermore, Urooj *et al*.[17] and Chukka *et al*.[30] discovered that in the presence of NaOCl and CHX, both ALs (integrated AL and EAL) were equally accurate in identifying WL at 0.5 mm from the apex.

CONCLUSION

This study has demonstrated that the accuracy of the Root ZX mini and CanalPro CL2i was comparable to that of conventional radiography. The irrigation solutions employed in this investigation had no impact on their performance.

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Conflicts of interest
There are no conflicts of interest.

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