Original Article

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Dentistry Section

Influence of Two Forms of Chlorhexidine on the Accuracy of Working Length Determination using Different Generation Apex Locators: An Experimental Study

RAJARAM SUNDARAVARADHAN[1], R ANITHA KUMARI[2], JAYALAKSHMI SOMASUNDARAM[3], CHETHANA S MURTHY[4], L VIJAYALAKSHMI[5], R VIKRAM[6], APEKSHA RAO[7], HARINI J RAJ[8]

ABSTRACT

Introduction: Variations are observed in working-length measurements of root canals in the presence of different irrigants due to differences in electrical conductivity. Chlorhexidine is commonly used as an irrigant in endodontics, primarily in concentrations of 0.2%, 1% and 2%. These solutions are favoured for their broad-spectrum antimicrobial properties, with higher concentrations being particularly effective against a wide range of bacteria, including resistant strains like *Enterococcus faecalis*. Additionally, chlorhexidine gel formulations have been introduced, which offer enhanced lubricating properties and improved retention within the root canal system compared with traditional liquid solutions.

Aim: To determine the influence of 2% chlorhexidine gel, 2% chlorhexidine solution and 2.5% sodium hypochlorite on the accuracy of the 4th-generation Root ZX Mini (J Morita Corp, Tokyo, Japan) and the 6th-generation Canal Pro™ (Coltene/Whaledent, Switzerland) Electronic Apex Locators (EALs).

Materials and Methods: This experimental study was conducted at the Department of Conservative Dentistry and Endodontics, Vokkaligara Sangha (VS) Dental College, Bengaluru, Karnataka, India over six months (January 2021-June 2021). A total of 48 single-rooted premolar teeth were selected. After obtaining ethical clearance, the teeth were randomly divided into three groups based on the irrigant used: Group 1 (G1)—2% chlorhexidine gel; Group 2 (G3)—2% chlorhexidine solution; Group 3 (G3)—2.5% sodium hypochlorite solution. A sample size of 16 teeth per group was used. Under local anaesthesia with rubber dam isolation, access cavities were prepared. Working length measurements were performed using the 4th- and 6th-generation EALs. The coronal access was sealed and the tooth was extracted atraumatically. Actual Working Length (AWL) was determined using Cone- Beam Computed Tomography (CBCT). Inferential statistics were performed using Fisher's-exact test. Statistical analysis was conducted with Statistical Package for the Social Sciences (SPSS) version 20.0.

Results: Accuracy of the Root ZX Mini and Canal Pro™ EALs in the presence of chlorhexidine gel was 81.25% and 93.0%, respectively; in the presence of chlorhexidine solution, the accuracy was 81.25% and 87.5%, respectively; and in the presence of sodium hypochlorite solution, the accuracy was 68.75% and 81.25%, respectively.

Conclusion: The EALs Root ZX Mini and Canal Pro™ showed the highest accuracy in working-length measurements with chlorhexidine gel, followed by chlorhexidine solution and then sodium hypochlorite solution.

Keywords: Chlorhexidine gel, Cone beam computed tomography, Electronic apex locator, Sodium hypochlorite

INTRODUCTION

Successful root canal therapy depends on thorough knowledge of root canal anatomy [1]. Adequate cleaning, shaping and three-dimensional obturation rely on understanding the natural anatomy of the root canals and the variability of their shapes. Root canal anatomy is complex and highly variable, necessitating the use of devices that can be used in conjunction with conventional radiographic techniques to determine the apical termination point for root canal preparation, which is termed the working length. The Glossary of the American Association of Endodontists (AAE) defines working length as, "the distance from a coronal reference point to the point at which canal preparation and obturation must terminate" [2]. A proper understanding of the histological composition and the apical third anatomy of teeth helps determine the ideal apical limit of instrumentation and filling of the root canal. There are various techniques for measuring working length during endodontic treatment, such as tactile sensation, paper points, radiographic techniques, electronic apex locators (EALs) and others, each with its own advantages and disadvantages [3].

The introduction of EALs has greatly simplified working-length measurement during endodontic treatment. Newer-generation apex locators have been reported to perform better than conventional apex locators in endodontic treatment under different clinical situations, such as immature teeth and perforations. Differences across generations of apex locators in their mechanism of action and their working efficiency have been illustrated in comparative studies [4,5]. It has also been reported that the presence or absence of irrigants and the nature of the irrigants in the root canal system significantly influence the accuracy of EALs. Effects of various irrigants, such as saline, hydrogen peroxide, sodium hypochlorite, EDTA and chlorhexidine, have been investigated to evaluate variations in EAL accuracy [6]. Chlorhexidine is a potent antimicrobial agent used in endodontic treatment, both as a root canal irrigant and as an intracanal medicament. It has also been formulated as a lubricant gel, with advantages such as biocompatibility and water solubility, encouraging its use during instrumentation [7]. Very few studies have evaluated the accuracy of different generations of EALs in the presence of gel or liquid-type endodontic irrigants to determine how variations in their electrical conductivities affect working-length measurement [6]. Thus, this study aims to evaluate the influence of gel and liquid forms of chlorhexidine and sodium hypochlorite irrigants on the accuracy of the 4th- and 6th-generation EALs for measuring the working length of teeth in vivo and to compare with

measurements obtained from CBCT scans post-extraction. The null hypothesis is that there is no difference in the accuracy of the 4th- and 6th-generation EALs in the presence of chlorhexidine gel, chlorhexidine solution and sodium hypochlorite solution.

MATERIALS AND METHODS

An experimental study was conducted at the Department of Conservative Dentistry and Endodontics, VS Dental College, Bengaluru, Karnataka, India over six months (January 2021-June 2021). Ethical clearance was obtained from Kempegowda Institute of Medical Sciences (Ethical ref. no.: KIMS/IEC/D121/D/2021).

Inclusion and Exclusion Criteria: A total of 48 non carious, single-rooted maxillary and mandibular premolars from patients aged 18-40 years, scheduled for orthodontic extraction, were selected for the study. Teeth with endodontic treatment, metallic restorations, external root resorption, perforations, fractures, or lesions were excluded.

Sample size calculation: Assuming an alpha error of 0.05 and to achieve 80% statistical power, the sample size was calculated as 16 teeth per group. Informed consent was obtained and patients were randomly allocated using a digital randomiser into three groups based on the irrigant used for the measurement of working length:

- Group 1 (G1): 2% chlorhexidine gel
- Group 2 (G2): 2% chlorhexidine solution
- Group 3 (G3): 2.5% sodium hypochlorite solution

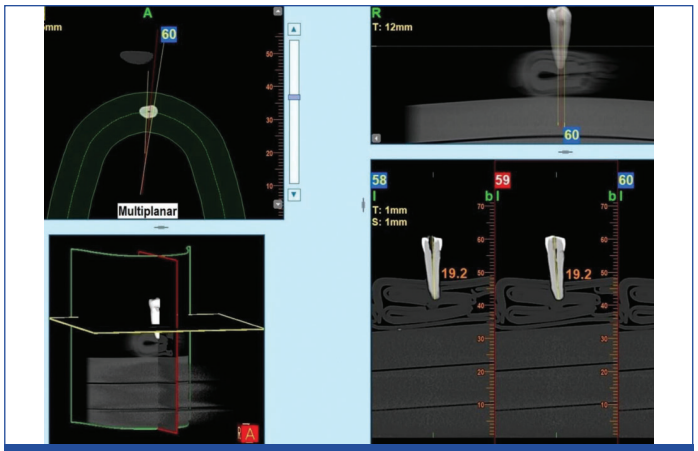
Study Procedure

The tooth was isolated with a rubber dam under local anaesthesia. Endodontic access opening was prepared with a #2 Endo Access Bur (Dentsply Sirona), after which coronal preflaring of the root canal was performed using 25/0.8 HyFlex CM orifice shapers (Coltene/Whaledent, Switzerland). Pulp tissue and debris were extirpated with hand files, followed by irrigation with 2.5% sodium hypochlorite using a side-vented 30-gauge needle. The canal was rinsed with saline and dried with paper points. Two millilitres of 95% ethyl alcohol were introduced inside the canal for 10 seconds, followed by removal of excess alcohol with paper points to dry the root canal system completely before measuring the working length with the allocated irrigant or gel [8]. The tooth was then irrigated with the irrigant corresponding to the assigned group.

The working length of each tooth was measured using #15 K-files (Mani) and both the 4th- and 6th-generation EALs. Measurements were recorded and each EAL was used according to the manufacturer's instructions to determine the minor apical foramen.

In the G1 group, chlorhexidine gel was introduced directly from the syringe using a 27-gauge needle. The apical part of the canal was filled with chlorhexidine gel using a #10 K-file in a counterclockwise motion. In the G2 and G3 groups, 3 mL of 2% chlorhexidine and 2.5% sodium hypochlorite solutions, respectively, were introduced into the canal 1 mm short of the apex using a 30-gauge side-vented needle and excess fluid was removed with a cotton pellet. Three measurements were taken for each apex locator from a fixed coronal reference point. The reference point was fixed with a stop on the file shank after the first measurement to ensure reproducibility. The terminal point was fixed for the Root ZX mini (J Morita Corp, Tokyo, Japan) when its flashing bar reached the level representing "00" on the LCD screen. Similarly, the terminal point for the CanalPro™ apex locator (Coltene/Whaledent, Switzerland) was fixed when the reading reached the "APEX" mark on the display screen. The apical reference point was fixed at the apical constriction; thus, 0.5 mm was subtracted from the obtained value and recorded as the working length. A measurement was considered credible if the reading remained stable and repeatable for at least three consecutive measurements [9].

The file was removed from the root canal and the orifice was sealed with temporary restorative material. The tooth was later extracted carefully with minimal damage to the coronal and radicular portions. The extracted teeth were soaked in 5.25% Sodium Hypochlorite (NaOCl) for 2.5 hours, followed by storage in 10% formalin. For CBCT evaluation, the extracted teeth were embedded in wax blocks according to groupings and scanned using the implant Cone-beam Advanced Technology (i-CAT) Cone-Beam 3D imaging system (Imaging Sciences International, Hatfield, PA, USA) [10]. The tube voltage was 120 kVp with a current of 3.8 mA and an exposure time of 40 s. The images were examined by the second investigator, who was blinded to the group allocation, using the scanner's proprietary software (Xoran Version 3.1.62; Xoran Technologies, Ann Arbor, MI, USA). The recorded images were processed using CTAn v1.14.4 software to calculate quantitative parameters and construct visual 3D models. Sagittal scans were used for CBCT evaluation, using multiplanar reformatted sections to select the best sagittal view for calibration. The slices were first formatted to position the root canal of each tooth vertically to visualise the tooth cusp, pulp chamber, apical foramen and the complete view of the root canal pathway. The distance between the predetermined coronal reference point and the minor apical constriction was measured from the CBCT sections and designated as the AWL [Table/Fig-1].



[Table/Fig-1]: CBCT section of Actual Working Length (AWL) measured.

STATISTICAL ANALYSIS

The values obtained from the apex locators were compared with the CBCT readings to determine whether they were short, at the apical constriction (acceptable), or long, with a tolerance limit of ±0.5 mm and were subjected to statistical analysis [11]. Data were analysed using SPSS 20.0 (SPSS Inc., Chicago, IL), with a significance level of $p < 0.05$. Inferential statistics were performed using Fisher's-exact test to determine differences between the groups.

RESULTS

According to [Table/Fig-2], acceptable results within a 0.5 mm tolerance were obtained with chlorhexidine gel in 15 samples (93%), chlorhexidine solution in 14 samples (87.5%) and sodium hypochlorite in 13 samples (81.25%) for Canal Pro™ (6th-generation EAL). Working length measurements were short with chlorhexidine gel in one sample, chlorhexidine solution in one sample and sodium hypochlorite in three samples. The working length measurement was long only in chlorhexidine solution in one sample. Acceptable results within a 0.5 mm tolerance were obtained with chlorhexidine gel in 13 samples (81.25%), chlorhexidine solution in 13 samples (81.25%) and sodium hypochlorite in 11 samples (68.75%) for Root ZX mini (4th-generation EAL) as shown in [Table/Fig-3]. Working length measurements were short with chlorhexidine gel in three samples, chlorhexidine solution in one sample and sodium hypochlorite in five samples. The working length measurement was long only in chlorhexidine solution in two samples.

Variables	Accuracy	Chlorhexidine gel	Chlorhexidine solution	Sodium hypochlorite
Tolerance limit of ±0.5 mm	Short	1 (6.25%)	1 (6.25%)	3 (18.75%)
	Accurate	15 (93%)	14 (87.5%)	13 (81.25%)
	Long	0	1 (6.25%)	0
χ^2 value	23.52			
p-value	0.0001*			

[Table/Fig-2]: Accuracy of Canal Pro™ (6th generation apex locator) in the presence of different intracanal irrigants with a tolerance limit of ±0.5 mm.
p<0.05 is statistically significant; 6th Generation apex locator Fisher's-exact test reported a statistically significant difference in accuracy category between the three groups (p<0.05).

Variables	Accuracy	Chlorhexidine gel	Chlorhexidine solution	Sodium hypochlorite
Tolerance limit of ±0.5 mm	Short	3 (18.75%)	1 (6.25%)	5 (31.25%)
	Accurate	13 (81.25%)	13 (81.25%)	11 (68.75%)
	Long	0	2 (12.5%)	0
χ^2 value	42.37			
p-value	0.0001*			

[Table/Fig-3]: Accuracy of Root ZX mini (4th generation apex locator) in the presence of different intracanal irrigants with a tolerance limit of ± 0.5 mm.
p<0.05 is statistically significant; 4th Generation apex locator-Fisher's-exact test reported a statistically significant difference in accuracy category between the three groups (p<0.05).

On comparison of the accuracy of EALs, Canal Pro™ (6th-generation EAL) produced the most accurate results, statistically significant in Group 1. Root ZX mini (4th-generation EAL) showed statistically significant results with chlorhexidine gel and chlorhexidine solution than with sodium hypochlorite solution.

DISCUSSION

The null hypothesis of the present study was rejected as there were variations in the accuracy of working length of the teeth in the presence of different irrigants for both generations of apex locators. It was observed in the present study that chlorhexidine gel, when used as an irrigant, produced the most accurate working length measurements with the 6th-generation EALs. The 4th-generation apex locator produced more accurate results when used with chlorhexidine gel and chlorhexidine solution compared to sodium hypochlorite solution. The results were in accordance with the studies by Jha P et al. and Shin HS et al., [12,13]. The electrical conductivity of various irrigants such as sodium hypochlorite solution, chlorhexidine gel, chlorhexidine solution and saline was studied. It was observed that the electrical conductivity of 1% sodium hypochlorite solution (NaOCl) was four times higher than physiologic saline [13].

It was also reported that the electrical conductivity of chlorhexidine liquid is much lower than that of other liquid irrigants and is similar to that of gel irrigants [13]. Shin HS et al., reported that the gel form of irrigants showed higher accuracy than the liquid form in measuring the AWL, whereas the liquid form had higher accuracy in locating perforations in root canal systems. Gel is largely liquid but behaves as a solid due to a three-dimensional cross-linked network within the liquid and exhibits no flow in a steady state. The electrical conductivity of gel depends on its three-dimensional structure, the concentration of ions and water content [13]. Both irrigant forms can be extruded from the root canal systems, but the possibility and amount of extrusion are greater for liquid irrigants than for gel-type irrigants. This could explain why the liquid form showed lower accuracy than the gel form in measuring the AWL of the teeth [13]. This study also demonstrated the ability of Canal Pro™ (6th-generation EAL) to modulate the electrical conductivity of the endodontic irrigant, as the results obtained with each irrigant were accurate and comparable with the AWL measurements obtained from the CBCT scans.

The 4th-generation EAL also performed similarly under the influence of both gel and solution forms of chlorhexidine, with both forms found to be more accurate than sodium hypochlorite. Shin HS et al., in their in-vitro study, reported that chlorhexidine in different forms produced statistically better accuracy than sodium hypochlorite with the Root ZX mini EAL [13]. Marek E et al., compared the accuracy of Apex Dal and Raypex 5 EALs in the presence of different endodontic irrigants—chlorhexidine gel, chlorhexidine solution and sodium hypochlorite—in an in-vitro environment and reported measurement accuracies of 86.2%, 79.3% and 53.2%, respectively [6]. The results of the present study follow Shin HS et al.,'s findings, stating that measurements taken in the presence of chlorhexidine-based irrigants were consistent [13]. Özsezer E et al., evaluated the performance of Propex mini, a 5th-generation EAL, in the presence of various irrigants, including 2.5% sodium hypochlorite and 0.2% chlorhexidine and reported that the chlorhexidine group was closest to the actual length [14]. These findings were also corroborated by Shin HS et al., who reported that the distance to the apex was smaller when root canals were irrigated with chlorhexidine than when compared with sodium hypochlorite [13].

However, Kang JA and Kim SK; Jenkis JA, Al Hadlaq SM and Chukka RR et al., reported that there was no difference in the accuracy of different EALs in the presence of different irrigants [15-18]. The latest generations of EALs are highly accurate with intelligent technical modifications that increase the efficiency of apex locators in different clinical environments. The use of appropriate endodontic irrigants during the measurement of working length can significantly improve the accuracy of working length measurements across all generations of apex locators. The results of the study suggest the use of chlorhexidine gel as an irrigant with EALs for working length determination in teeth with single canals. The results suggest that the 4th-generation EAL (Root ZX mini) and the 6th-generation EAL (Canal Pro™) are both accurate in working length measurement with liquid and gel forms of chlorhexidine. Various in-vitro and in-vivo studies have shown that CBCT is an effective tool in determining the working length of teeth and was used in our study. It helps in the non invasive evaluation of teeth to determine various anatomical parameters and gain insights before root canal treatment [19].

In the present study, the working length determination was performed under clinical conditions and the accuracy was verified using CBCT after extracting the tooth, thus making the study different and more valid.

Limitation(s)

The present study was conducted with single-rooted teeth, so the same results could not be extrapolated to curved, calcified and wide-open apices of root canals.

CONCLUSION(S)

The gel form of chlorhexidine yielded more accurate values for both EALs, followed by the liquid form of chlorhexidine, with the least accuracy observed with the sodium hypochlorite solution form. The accuracy of the 4th-generation Root ZX mini EAL was less than that of the 6th-generation Canal Pro™ EAL in the presence of sodium hypochlorite. Different irrigants influence the accuracy of different generations of EALs in working length measurement.

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PARTICULARS OF CONTRIBUTORS:
1. Consultant, Department of Conservative Dentistry and Endodontics, VS Dental College, Bengaluru, Karnataka, India.
2. Professor and Head, Department of Conservative Dentistry and Endodontics, VS Dental College, Bengaluru, Karnataka, India; Research Scholar, Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai, Tamil Nadu, India.
3. Chief Scientist, Department of Conservative Dentistry and Endodontics, White Lab, Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai, Tamil Nadu, India.
4. Professor, Department of Conservative Dentistry and Endodontics, VS Dental College, Bengaluru, Karnataka, India.
5. Reader, Department of Conservative Dentistry and Endodontics, VS Dental College, Bengaluru, Karnataka, India.
6. Reader, Department of Conservative Dentistry and Endodontics, VS Dental College, Bengaluru, Karnataka, India.
7. Postgraduate Student, Department of Conservative Dentistry and Endodontics, VS Dental College, Bengaluru, Karnataka, India.
8. Postgraduate Student, Department of Conservative Dentistry and Endodontics, VS Dental College, Bengaluru, Karnataka, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. R Anitha Kumari,
Professor, Head and Research Scholar, Department of Conservative Dentistry and Endodontics, VS Dental College, KR Road, VV Puram, Bengaluru, Karnataka-560004, India.
E-mail: anithamanasi18@gmail.com

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