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Comparative Evaluation of Working Length Determination Using Conventional and Endomotor-Integrated Electronic Apex Locators in the Presence of Different Irrigants: An In Vitro Study

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Abstract

Accurate working length determination is essential for successful endodontic treatment. Electronic apex locators (EALs) are widely used because they provide reliable measurements and reduce dependence on radiographs. The accuracy of these devices may be influenced by the irrigating solutions present within the root canal. While conventional irrigants such as sodium hypochlorite and saline have been extensively studied, limited information is available regarding the effect of herbal irrigants such as neem extract on electronic working length determination. Therefore, this in vitro study aimed to compare the accuracy of a conventional electronic apex locator and an integrated apex locator in the presence of

saline, 3% sodium hypochlorite, and neem extract. Thirty extracted human single-rooted teeth were selected and standardized access cavity preparation was performed. Actual working length was determined using the direct visual method and used as the reference standard. Working length measurements obtained with both apex locator systems were compared under different irrigant conditions. Statistical analysis was performed using repeated measures ANOVA and one-way ANOVA. Significant differences were observed between actual and electronic measurements within all irrigant groups ($p < 0.001$), while no significant differences were found among the irrigants ($p > 0.05$). The integrated apex locator consistently produced measurements closer to the actual working length. Within the limitations of this study, both apex locator systems demonstrated clinically acceptable accuracy, and neem extract showed performance comparable to saline and sodium hypochlorite.

Keywords: Working Length, Electronic Apex Locator, Integrated Apex Locator, Neem Extract, Sodium Hypochlorite, Saline.

Introduction

Successful endodontic treatment depends on thorough cleaning, shaping, and obturation of the root canal system while preserving the integrity of the periapical tissues. Accurate determination of working length is therefore considered one of the most critical steps in root canal therapy. Working length is defined as the distance from a coronal reference point to the point at which canal preparation and obturation should terminate. Instrumentation beyond or short of the apical constriction may result in inadequate debridement, extrusion of debris and irrigants into the periapical tissues, postoperative pain, delayed healing, and treatment failure[1].

Traditionally, radiographic methods have been used for working length determination. Although radiographs provide valuable information regarding root canal anatomy and surrounding structures, they possess several limitations. Radiographs produce a two-dimensional image of a three-dimensional structure and are susceptible to distortion, magnification errors, superimposition of anatomical landmarks, and subjective interpretation. Furthermore, radiographic techniques may not accurately identify the apical constriction, which is considered the ideal endpoint for root canal instrumentation and obturation[2].

To overcome these limitations, electronic apex locators (EALs) have been developed and are now widely used in endodontic practice. Electronic apex locators determine working length by measuring electrical characteristics within the root canal system and have demonstrated high levels of accuracy under various clinical conditions. Modern multifrequency apex locators have significantly improved the precision and reliability of electronic working length determination, thereby reducing dependence on radiographic methods and minimizing radiation exposure[3].

Recent technological advancements have led to the integration of apex locator technology within endodontic motors. Endomotor-integrated apex locators allow simultaneous instrumentation and real-time monitoring of working length, thereby improving clinical efficiency and reducing the risk of over-instrumentation. These systems enable the clinician to continuously monitor file position during canal preparation and may contribute to enhanced treatment outcomes. Despite their increasing use in clinical practice, studies comparing their accuracy with conventional electronic apex locators remain limited[4].

The accuracy of electronic apex locators may be influenced by the presence and nature of irrigating

solutions within the root canal. Endodontic irrigants differ in their chemical composition, ionic concentration, and electrical conductivity, all of which may affect electronic measurements. Sodium hypochlorite is the most commonly used irrigant because of its excellent antimicrobial activity and tissue-dissolving properties. However, its high electrical conductivity has been reported to influence electronic apex locator readings under certain conditions[5]. Saline is frequently used as a control irrigant in studies evaluating apex locator performance because of its relatively stable conductive properties and minimal interaction with measuring devices[6].

In recent years, increasing interest has been directed toward the use of herbal products in endodontics. Neem (Azadirachta indica) possesses antimicrobial, anti-inflammatory, antioxidant, and biocompatible properties that make it a promising alternative irrigant. Previous studies have demonstrated its effectiveness against common endodontic pathogens, including Enterococcus faecalis, which is frequently associated with persistent root canal infections[7,8]. Despite the growing popularity of neem extract in endodontics, limited information is available regarding its influence on electronic working length determination.

Although several studies have evaluated the influence of conventional irrigants on apex locator accuracy, evidence regarding the effect of herbal irrigants such as neem extract remains scarce. Furthermore, limited literature is available comparing conventional electronic apex locators and integrated apex locator systems in the presence of different irrigating solutions. Therefore, the present in vitro study was undertaken to evaluate and compare the accuracy of working length determination using a conventional electronic apex locator and an integrated apex locator in the presence of saline, 3% sodium hypochlorite, and neem extract. The null hypothesis tested was that there would be no significant difference in the accuracy of working length determination between the two apex locator systems under different irrigating conditions.

Materials and Methods

Study Design

The study protocol was approved by the Institutional Ethics Committee (Approval No. CKS/IEC-ENDO/2026/28). This in vitro comparative study was conducted to evaluate and compare the accuracy of working length determination using a conventional electronic apex locator (EAL) and an endomotor-integrated apex locator (IAL) in the presence of different intra canal irrigants, namely normal saline, 3% sodium hypochlorite (NaOCl), and 10% aqueous neem extract.

Sample Selection and Storage

Thirty freshly extracted human permanent single-rooted teeth with fully formed apices were selected for the study. Teeth extracted for periodontal or orthodontic reasons were collected and cleaned of adherent soft tissue remnants and calculus using ultrasonic scalers. Teeth exhibiting root fractures, root resorption, open apices, calcified canals, previous endodontic treatment, or extensive carious destruction were excluded from the study.

Following cleaning, the specimens were stored in normal saline until use to prevent dehydration.

Sample Preparation

Standard endodontic access cavities were prepared using high-speed diamond burs under copious water coolant. The coronal portion of each tooth was adjusted when necessary to obtain a stable and reproducible reference point for working length measurements.

A size #10 K-file was introduced into the canal until the tip became visible at the major apical foramen under

magnification. The actual working length (AWL) was established by subtracting 0.5 mm from this measurement and was considered the reference standard.

Experimental Model Preparation

An alginate model was used to simulate the periodontal ligament and provide an electroconductive medium for electronic working length determination. Each tooth was embedded in freshly mixed alginate contained in a plastic mould, leaving the crown portion exposed. The lip clip of the apex locator was inserted into the alginate to complete the electrical circuit. Fresh alginate was prepared whenever required to ensure adequate conductivity throughout the study.

Figure 1: Alginate model used for electronic working length determination.

Group Allocation

The thirty specimens were randomly divided into three groups of ten teeth each according to the irrigating solution used during working length determination:

- Group I (n = 10): Normal Saline
- Group II (n = 10): 3% Sodium Hypochlorite (NaOCl)
- Group III (n = 10): 10% Aqueous Neem Extract

Preparation of Irrigating Solutions

Normal Saline: Commercially available sterile normal saline solution was used as the irrigant.

Sodium Hypochlorite: A 3% sodium hypochlorite solution was used according to the study protocol.

Aqueous Neem Extract: Fresh neem leaves (Azadirachta indica) were thoroughly washed with distilled water and shade-dried. The dried leaves were pulverized into a fine powder. Ten grams of neem powder was mixed with 100 mL of distilled water and heated at 60–70°C for 30 minutes. The solution was filtered using Whatman filter paper to obtain a clear aqueous extract, which was used as the experimental irrigant.

Working Length Determination

Before measurement, the root canals were irrigated with the respective irrigating solution assigned to each group.

Actual Working Length (AWL)

The actual working length was determined by introducing a size #10 K-file into the canal until the file tip was JUST visible at the major apical foramen. The measured length minus 0.5 mm was recorded as the actual working length. The tooth samples were later inserted into alginate moulds.

Conventional Electronic Apex Locator (EAL)

Working length determination was performed using a conventional electronic apex locator. A size #15 K-file attached to the device was advanced into the root canal until the apex locator indicated the apical constriction according to the manufacturer's instructions. The silicone stop was adjusted to the coronal reference point and the length was measured using an endodontic ruler. The recorded value was considered the electronic working length.

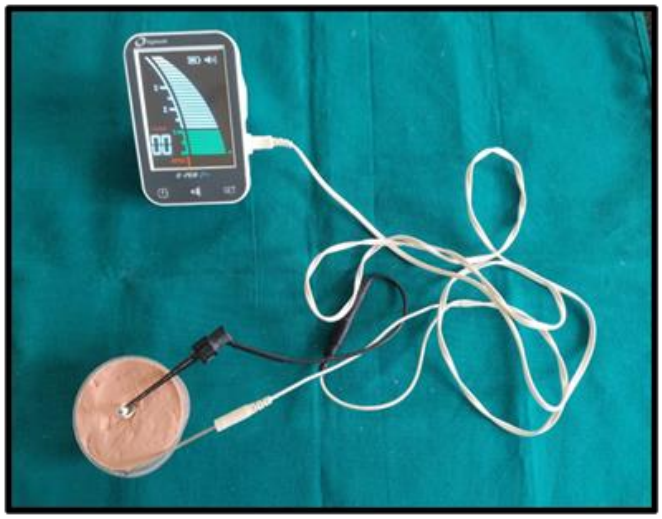


Figure 2: Working length determination using a conventional electronic apex locator.

Endomotor-Integrated Apex Locator (IAL)

Working length was also determined using the endomotor-integrated apex locator. A size #15 K-file connected to the integrated apex locator was advanced into the canal until the device indicated the apical constriction. The working length displayed by the device was recorded for each specimen.

Figure 3: Working length determined using endomotor-integrated apex locator

Statistical Analysis

The collected data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) software version 20.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics including mean and standard deviation were calculated.

Within each irrigant group, comparisons among actual working length, conventional electronic apex locator measurements, and integrated apex locator measurements were performed using repeated measures analysis of variance (ANOVA) followed by appropriate post hoc pairwise comparisons. Intergroup comparisons among saline, sodium hypochlorite, and neem extract were performed using one-way ANOVA. A p-value less than 0.05 Was Considered Statistically Significant.

Results

Table 1: Within-group comparison of working length measurements under different irrigant conditions

Irrigant	Comparison	Measurement 1 (Mean ± SD)	Measurement 2 (Mean ± SD)	Mean Difference (mm)	p value
Saline	AWL vs EAL	20.53 ± 1.29	20.08 ± 1.28	0.45	<0.001*
	AWL vs IAL	20.53 ± 1.29	20.29 ± 1.24	0.24	0.001*
	IAL vs EAL	20.29 ± 1.24	20.08 ± 1.28	0.21	0.006*
NaOCl	AWL vs EAL	20.96 ± 3.26	20.28 ± 3.23	0.68	<0.001*
	AWL vs IAL	20.96 ± 3.26	20.76 ± 3.26	0.20	<0.001*
	IAL vs EAL	20.76 ± 3.26	20.28 ± 3.23	0.48	<0.001*
Neem	AWL vs EAL	19.70 ± 2.47	19.23 ± 2.43	0.47	<0.001*
	AWL vs IAL	19.70 ± 2.47	19.53 ± 2.43	0.17	<0.001*
	IAL vs EAL	19.53 ± 2.43	19.23 ± 2.43	0.30	<0.001*

Repeated measures ANOVA; *statistically significant

Repeated measures ANOVA revealed statistically significant differences among the actual working length(AWL), electronic apex locator (EAL), and integrated apex locator (IAL) measurements within all irrigant groups ($p < 0.001$). With saline, the mean actual working length was 20.53 ± 1.29 mm, which was significantly higher than the mean EAL value (20.08 ± 1.28 mm) and the mean IAL value (20.29 ± 1.24 mm). Similarly, with sodium hypochlorite, the mean actual working length (20.96 ± 3.26 mm) was significantly greater than the EAL (20.28 ± 3.23 mm) and IAL (20.76 ± 3.26 mm) measurements. With neem irrigant, the mean actual working length (19.70 ± 2.47 mm) was also significantly higher compared to EAL (19.23 ± 2.43 mm) and IAL (19.53 ± 2.43 mm). In all irrigant groups, IAL values were consistently closer to the actual working

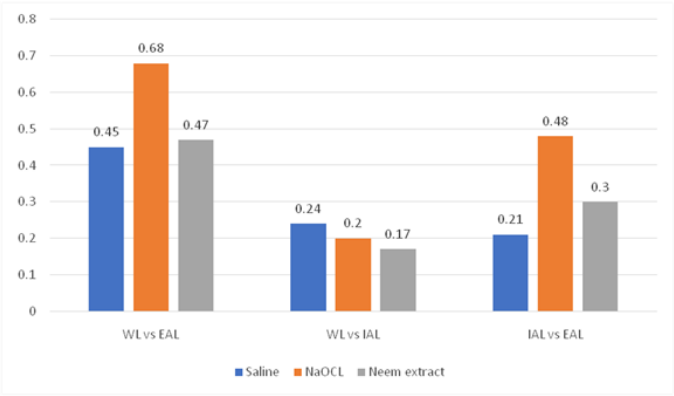
length and significantly higher than EAL values. (Table 1) (Figure 1)

Table 2: One-way ANOVA comparing working length measurements among different irrigants

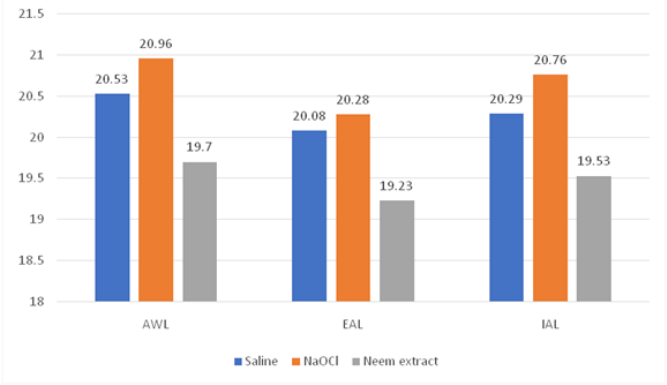
Measurement method	Saline (Mean ± SD)	NaOCl (Mean ± SD)	Neem (Mean ± SD)	F value	p value
AWL	20.53 ± 1.29	20.96 ± 3.26	19.70 ± 2.47	0.669	0.521
EAL	20.08 ± 1.28	20.28 ± 3.23	19.23 ± 2.43	0.519	0.601
IAL	20.29 ± 1.24	20.76 ± 3.26	19.53 ± 2.43	0.640	0.535

One-way ANOVA

One-way ANOVA revealed no statistically significant difference in working length measurements among the three irrigants for any of the measurement methods ($p > 0.05$). The mean actual working length was 20.53 ± 1.29 mm in the saline group, 20.96 ± 3.26 mm in the sodium hypochlorite group, and 19.70 ± 2.47 mm in the neem group ($F = 0.669$, $p = 0.521$). Similarly, the mean electronic apex locator values were 20.08 ± 1.28 mm, 20.28 ± 3.23 mm, and 19.23 ± 2.43 mm for saline, sodium hypochlorite, and neem irrigants respectively ($F = 0.519$, $p = 0.601$). The integrated apex locator measurements also did not differ significantly among irrigants, with mean values of 20.29 ± 1.24 mm for saline, 20.76 ± 3.26 mm for sodium hypochlorite, and 19.53 ± 2.43 mm for neem ($F = 0.640$, $p = 0.535$). (Table 2) (Figure 2)



Graph 1: Mean differences in working length measurements between actual working length, electronic apex locator, and integrated apex locator under different irrigant conditions



Graph 2: Comparison of mean working length values obtained using actual measurement, electronic apex locator, and integrated apex locator under different irrigant conditions

Discussion

Working length determination remains one of the most critical procedures in endodontic therapy because the success of cleaning, shaping, and obturation depends largely on accurate localization of the apical terminus. Contemporary endodontic practice increasingly relies on electronic apex locators because of their ability to provide rapid, reproducible, and highly accurate measurements while minimizing dependence on radiographic methods. Recent systematic reviews and umbrella reviews have confirmed that modern electronic apex locators demonstrate high levels of accuracy and may provide measurements comparable to, or even superior to, conventional radiographic techniques under a variety of clinical conditions[9,10].

The present study compared the accuracy of a conventional electronic apex locator and an integrated apex locator in the presence of three different irrigating solutions: normal saline, 3% sodium hypochlorite, and 10% aqueous neem extract. The results demonstrated that both systems produced clinically acceptable working length measurements. However, the integrated apex locator consistently yielded values that were closer to the

actual working length than those obtained with the conventional electronic apex locator.

The improved performance of the integrated apex locator observed in the present study may be attributed to technological advancements incorporated into contemporary endodontic motors. Integrated systems combine apex location and instrumentation into a single platform and continuously monitor file position during canal preparation. Multi frequency impedance analysis, improved signal processing, and real-time feedback mechanisms enable these devices to compensate for variations in intra canal conditions and provide more stable measurements. Connert et al.[11] demonstrated that contemporary apex locator systems possess excellent accuracy when evaluated using micro-computed tomography, supporting the findings of the present investigation. Similarly, recent evidence synthesized in systematic reviews has concluded that modern electronic apex locators are capable of accurately identifying the apical constriction under diverse experimental and clinical conditions[9,10].

An important objective of the present study was to evaluate whether different irrigating solutions influence electronic working length determination. Irrigants vary considerably in their chemical composition and electrical conductivity, and these characteristics have historically been considered potential sources of measurement variability. Earlier generations of apex locators were more susceptible to conductivity-related interference; however, advances in device design have substantially improved measurement reliability. The absence of significant differences among irrigants in the present study suggests that contemporary apex locator systems are capable of maintaining stable performance despite variations in intracanal conductivity.

Sodium hypochlorite remains the most widely used irrigating solution in endodontics because of its excellent antimicrobial activity and tissue-dissolving properties. Despite its relatively high electrical conductivity, the present findings demonstrated that sodium hypochlorite did not adversely influence working length determination. These observations are consistent with recent systematic reviews evaluating apex locator performance, which concluded that modern devices are significantly less affected by irrigant conductivity than earlier generations[10,12]. Clinically, this finding is important because working length determination is frequently performed while sodium hypochlorite is present within the canal during instrumentation procedures.

A unique aspect of the present study was the inclusion of neem extract as a herbal irrigating solution. The growing interest in plant-derived endodontic materials has led to increased investigation of herbal irrigants as alternatives or adjuncts to conventional chemical agents. Neem (Azadirachta indica) has been reported to possess antibacterial, antifungal, anti-inflammatory, antioxidant, and biocompatible properties, making it an attractive candidate for endodontic applications. Recent reviews have highlighted its effectiveness against Enterococcus faecalis and other microorganisms commonly associated with persistent endodontic infections[13,14].

The present findings demonstrated that neem extract produced working length measurements comparable to those obtained with saline and sodium hypochlorite. This suggests that neem extract provides a suitable environment for electronic apex locator function and does not interfere significantly with impedance-based measurements. The comparable performance observed in the present study supports recent literature emphasizing the potential role of neem as a biologically favorable

irrigating solution in endo dontics [13,14]. Furthermore, the ability of apex locators to maintain measurement accuracy in the presence of neem extract broadens the scope for incorporating herbal alternatives into contemporary endodontic practice.

Another clinically relevant observation from the present study was the consistency of measurements obtained irrespective of the irrigating solution used. This finding reinforces the concept that contemporary apex locator systems are sufficiently advanced to compensate for variations in intracanal conditions and provide dependable measurements during routine clinical procedures. Such reliability may reduce the need for repeated radiographic verification and contribute to reduced radiation exposure while improving procedural efficiency.

The present study was conducted under in vitro conditions and therefore possesses limitations inherent to laboratory investigations. Although the alginate model employed in the study has been widely accepted for evaluating apex locator performance, it cannot fully replicate the complex biological environment encountered in vivo. Factors such as blood contamination, pulpal remnants, periapical tissues, canal anatomy, and patient-related variables may influence electronic measurements under clinical conditions. In addition, only single-rooted teeth were included in the study, which may limit extrapolation of the findings to more complex root canal systems. Future clinical investigations involving larger sample sizes, different tooth types, and additional herbal irrigants are recommended to further validate these findings.

Within the limitations of the present study, both the conventional electronic apex locator and the integrated apex locator demonstrated satisfactory accuracy under all tested irrigating conditions. However, the integrated apex locator consistently produced measurements closer to the actual working length. Furthermore, neem extract exhibited performance comparable to saline and sodium hypochlorite, indicating that its use does not interfere with electronic working length determination and supporting its potential application as a herbal irrigating solution in endodontic therapy.

Conclusion

Within the limitations of this in vitro study, both the conventional electronic apex locator and the integrated apex locator demonstrated satisfactory accuracy in determining working length under all tested irrigating conditions. However, the integrated apex locator consistently produced measurements that were closer to the actual working length, indicating superior agreement with the reference standard.

The type of irrigating solution did not significantly influence electronic working length determination, as comparable results were obtained in the presence of normal saline, 3% sodium hypochlorite, and 10% aqueous neem extract. These findings suggest that contemporary apex locator systems are capable of providing reliable measurements irrespective of the irrigant present within the root canal.

Furthermore, neem extract demonstrated performance comparable to conventional irrigants and did not adversely affect the accuracy of working length determination.

Therefore, neem extract may be considered a potential herbal alternative for endodontic irrigation without compromising the effectiveness of electronic apex locator measurements.

Further in vivo studies with larger sample sizes and more complex root canal anatomies are recommended to validate these findings and assess their clinical applicability.

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