A COMPARATIVE STUDY ON THE DETERMINATION OF WORKING LENGTH IN SINGLE-ROOTED TEETH USING ELECTRONIC APEX LOCATORS

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ABSTRACT

Aim of the study This study aims to evaluate the accuracy of an electronic apex locator (Apex Finder) in determining the working length of root canals in extracted monoradicular teeth. By comparing electronic and manual measurement methods across four experimental groups, the study assesses the clinical reliability and consistency of electronic apex locators. **Materials and methods** A total of 40 single-rooted permanent teeth, extracted for orthodontic reasons, were included in the study. After access cavity preparation and mounting in alginate-supported conformers, working length was determined using manual (Kerr files) and electronic (Apex Finder) techniques. Measurements were verified radiographically. The teeth were divided into four groups based on the scale readings of the Apex Finder: 00, 03, 05, and 07. **Results** The Apex Finder showed a high degree of accuracy, with results coinciding with manual measurements in 90% to 100% of cases. Group III exhibited the highest accuracy, with complete alignment between electronic and manual readings. Minor deviations occurred in the other groups but remained within clinically acceptable limits. **Conclusions** The study demonstrates that electronic apex locators like the Apex Finder can be effective tools for determining root canal working length. Their accuracy, particularly when used in conjunction with manual techniques, supports their integration into routine endodontic practice, reducing dependence on radiographic methods and enhancing procedural efficiency.

Key words: electronic apex locator, working length determination, endodontic measurement accuracy, apex finder device, root canal treatment

INTRODUCTION

We Root canal therapy has undergone a remarkable transformation over the centuries, evolving from primitive and often painful interventions to precise, technology-enhanced procedures that emphasize efficacy, accuracy, and patient comfort. Central to the success of endodontic therapy is the accurate determination of the working length (WL), defined as the distance from a coronal reference point to the point at which root canal preparation and obturation should terminate. Errors in determining the WL can lead to treatment failure due to insufficient cleaning or over-instrumentation of the apical tissues [1].

Historically, endodontic treatment was limited by rudimentary tools and a poor understanding of root canal anatomy. The earliest efforts at root canal therapy relied on manual instrumentation with improvised tools, lacking the anatomical precision or aseptic conditions necessary for consistent success [2]. Over time, developments such as the introduction of gutta-percha and improvements in instrumentation helped standardize clinical procedures [3].

In the 20th century, radiographs became the primary method for estimating WL. However, radiographic techniques have inherent limitations: they produce two-dimensional images of three-dimensional structures, are subject to distortion and interpretation error, and expose patients to ionizing radiation [4]. Furthermore, root curvature, anatomical anomalies, and superimposition can complicate the clinician's ability to interpret radiographs accurately [5].

In recent years, electronic apex locators (EALs) have emerged as a transformative technology in endodontics. These devices work by measuring the impedance or resistance between the periodontium and the oral mucosa, providing real-time feedback on the position of the file within the canal [6]. Advances in circuit design and signal processing have led to the development of multi-frequency EALs that are more accurate and less influenced by canal contents such as irrigants or pulp remnants [7].

The literature strongly supports the integration of EALs into standard practice. Multiple clinical and in vitro studies have demonstrated that EALs can match or even surpass radiographic accuracy in determining WL. For example, studies by Anjaneyulu and Nivedhitha [3] and Kaur et al. [4] confirm that EALs offer reliable length measurements even in complex clinical scenarios.

Modern endodontics increasingly combines EALs with digital imaging for corroboration. The synergistic use of digital periapical radiography and EALs enhances diagnostic confidence and reduces patient exposure to radiation [8]. In comparative studies, EALs have been shown to yield consistent results across different tooth types and clinical settings [9].

In addition, certain studies have explored the role of apex locators in the context of retreatment, where existing filling materials may interfere with conventional methods. Jaiswal et al. [8] found that EALs maintained accuracy even in the presence of gutta-percha and sealers. Similar findings were reported by Cîmpean et al. [15], whose research confirmed that various irrigating solutions have a minimal effect on the functionality of modern apex locators.

Clinical protocols are also evolving. The integration of EALs into everyday endodontic practice requires understanding device calibration, electrode placement, and technique sensitivity. Educational institutions are now incorporating advanced EAL training into dental curricula to ensure future clinicians are well-prepared [10].

Furthermore, technological innovations continue to refine apex locator design. Iandolo [5] highlights how new diagnostic software integrated into apex locator systems can map root canal trajectories more precisely. Similarly, Pisano et al. [13] emphasize that apex locator technology will continue to evolve with the incorporation of artificial intelligence and real-time data analytics.

Endodontic retreatment presents unique challenges in WL determination. When addressing previously treated teeth, clinicians must contend with residual filling materials and anatomical alterations. In a 2023 study, the Romanian Journal of Oral Rehabilitation evaluated the reliability of apex locators in retreatment scenarios, finding them to be a dependable alternative even when conventional radiographic methods were compromised [14]. This reinforces the relevance of EALs in complex endodontic scenarios.

The impact of irrigation protocols on the accuracy of EALs has also been a focus of recent investigation. Cîmpean et al. [15] conducted a detailed in vitro evaluation of three apex locator models exposed to various concentrations of sodium hypochlorite. Their findings confirm that while minor variations can occur, modern EALs maintain satisfactory performance across diverse chemical environments, making them robust tools under routine clinical conditions.

Finally, device-to-device comparison studies further validate the credibility of EALs. Gehlot et al. [16] assessed four apex locator models using stainless steel and nickel-titanium hand files. The study concluded that while minor performance differences exist, all devices tested were acceptably accurate, supporting their clinical interchangeability and dependability.

In conclusion, the determination of working length remains a cornerstone of endodontic therapy, and modern innovations such as electronic apex locators have significantly enhanced the precision of this critical measurement. Supported by a growing body of evidence and propelled by continuous technological improvement, EALs are shaping the future of root canal treatment, offering clinicians tools that are both accurate and adaptable to the complexities of human dental anatomy [15,16].

MATHERIALS AND METHODS

This study was conducted on a group of 40 permanent, single-rooted teeth that had been extracted for orthodontic purposes. The teeth presented with grade III mobility and were considered non-restorable. Collection was facilitated through dental offices specialized in Orthodontics and Dentofacial Orthopedics. Informed consent was obtained from all patients for the extraction and the use of their teeth as biological material in this research.

Inclusion Criteria:

Intact teeth without carious lesions;

Teeth without extensive wear or abrasion;

Single-rooted teeth.

It was ensured that there were no calcifications or hyaline deposits that might interfere with canal patency and working length determination.

Exclusion Criteria:

Multi-rooted teeth;

Teeth with overhanging coronal restorations;

Teeth with extensive carious lesions;

Teeth with full-coverage crowns.

Principle of the Method

The following techniques and materials were used:

A gypsum base mold was prepared;

Alginate was mixed and poured into the mold;

The extracted teeth and the apex locator probe were embedded in the alginate;

A #10 K-file (25mm, violet handle) was introduced into the canal for WL measurement.

The 40 teeth were randomly divided into four equal groups:

Group I: The endodontic file was advanced until the apex locator displayed a value of 00.

Group II: The file was advanced until the device registered a value of 03.

Group III: Advancement continued until the apex locator showed a value of 05.

Group IV: The file was inserted until the value 07 was indicated on the device.

Working Procedure

The first step in determining the working length of the endodontic canals involved creating an access cavity using rotary instrumentation connected to the high-speed handpiece of the dental unit, alongside manual techniques.

The second stage comprised the actual determination of the working length of the canals, initially using the manual technique via Kerr endodontic files and subsequently confirmed with the electronic method using the Apex Finder device.

The extracted teeth were first placed into alginate material and then embedded into a conformer for structural support during the measurements (Figure 1).

Figure 1. The extracted teeth were first placed into alginate material and then embedded into a conformer for structural support during the measurements

Following the determination of the working length using both manual and electronic techniques, standard radiographic imaging was performed. These radiographs served to compare the accuracy of manual working length determination against that achieved with the electronic apex locator.

Subsequent analysis aimed to determine the relationship between these readings and the actual anatomical apex, thereby assessing the accuracy and reliability of the electronic apex locator under these controlled conditions.

RESULTS AND DISCUSSIONS

The results of this study reflect the variability and precision of electronic working length determination using the Apex Finder across four experimental groups. Each group was defined by the display value recorded on the apex locator at the time of measurement. These groups corresponded to values of 00, 03, 05, and 07 on the Apex Finder display. Ten teeth were randomly assigned to each group and measurements were recorded individually for each tooth.

As shown in Table 1, the vast majority of measurements were consistent with their assigned values, though some minor deviations were observed, particularly in Groups II and IV. These deviations will be further analysed in the discussion section to assess their clinical significance and potential influencing factors.

Table 1. Working Length Values Recorded

Tooth	Lot 1 (00)	Lot 2 (03)	Lot 3 (05)	Lot 4 (07)
1	00	03	05	07
2	00	03	05	07
3	00	03	05	07
4	00	03	05	07
5	01	03	05	07
6	00	04	05	07
7	00	03	05	07
8	00	03	05	07
9	00	04	05	09
10	00	03	05	07

Group I

The distribution of correct and deviated measurements in Group I is visually represented in Figure 2, using a pie chart format for clarity and comparative assessment.

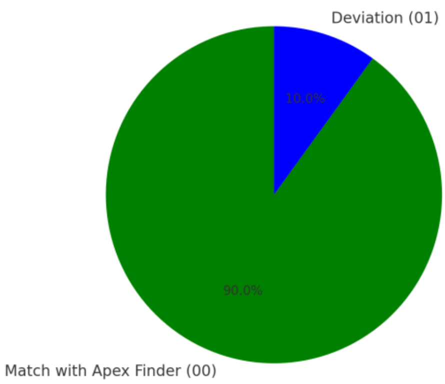

Figure 2. Accuracy of Apex Finder in Group I – Distribution of measurements where electronic values matched or deviated from manual working length determination.

After completing the procedures, the display on the Apex Finder indicated a value of 00. This result was consistent in 9 out of the 10 teeth in Group I, confirming a high level of accuracy in electronic measurement at this reference point.

Thus, for the first group of teeth, the measurements demonstrated that in 9 of the 10 teeth studied, the manually determined working length coincided with the value indicated by the Apex Finder, namely 00. In only one case, a different value of 01 was recorded. The accuracy of the Apex Finder in the case of Group I was calculated at 90%.

Group II

The distribution of correct and deviated measurements in Group II is visually represented in Figure 3, using a pie chart format for clarity and comparative assessment.

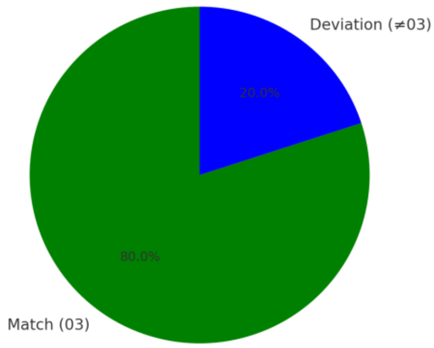

Figure 3. Accuracy of Apex Finder in Group II – Distribution of measurements where electronic values matched or deviated from manual working length determination.

After completing the procedures, the display on the Apex Finder indicated a value of 03 for most of the teeth in Group II. This result was consistent in 8 out of the 10 teeth, while deviations with values of 04 were recorded in the remaining 2 cases.

Thus, in Group II, 8 of the 10 teeth studied had a manually determined working length that matched the value indicated by the Apex

Finder (03). Deviations were minimal and appeared in only 2 cases. The accuracy of the Apex Finder in this group was calculated at 80%.

Group III

The distribution of correct and deviated measurements in Group III is visually represented in Figure 4, using a pie chart format for clarity and comparative assessment.

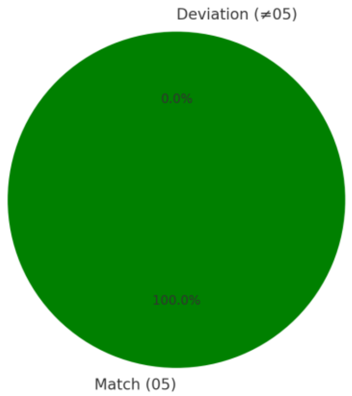

Figure 4. Accuracy of Apex Finder in Group III – All measurements were consistent with manual working length determination.

In this group, the Apex Finder consistently indicated a value of 05 across all 10 teeth. There were no deviations between the manual and electronic working length determinations.

This perfect match across all samples in Group III demonstrates the reliability of the electronic measurement in this range. Therefore, the Apex Finder showed an accuracy of 100% in this group.

Group IV

The distribution of correct and deviated measurements in Group IV is visually represented in Figure 5, using a pie chart format for clarity and comparative assessment.

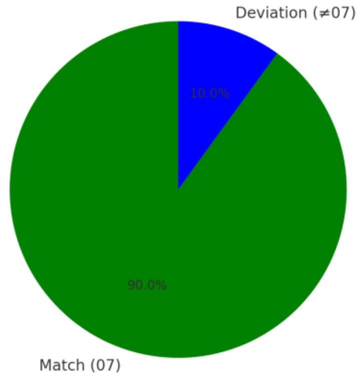

Figure 5. Accuracy of Apex Finder in Group IV – Distribution showing a single deviation from the expected measurement.

In Group IV, 9 of the 10 measurements matched the expected value of 07, while one case recorded a deviation, registering a value of 09.

This slight variation indicates a high, but not absolute, precision at this display level. The calculated accuracy of the Apex Finder in Group IV was 90%.

Discussion

The findings of this study underscore the growing reliability and applicability of electronic apex locators (EALs) in determining accurate working lengths in endodontics. Across the four experimental groups, the Apex Finder demonstrated an overall accuracy ranging between 80% and 100%, aligning well with existing literature that supports the clinical effectiveness of electronic methods for endodontic measurement [17].

Several studies have indicated that EALs reduce the reliance on radiographic evaluation alone, thereby minimizing radiation exposure and improving procedural efficiency [18,19]. In particular, recent advancements in impedance-based technologies have enhanced the precision of working length determinations even in the presence of irrigants such as sodium hypochlorite, which were previously thought to interfere with measurements [20,21].

Group III displayed a perfect concordance between manual and electronic methods, which may be attributed to canal anatomy and less variation in apical morphology. On the other hand, minor deviations in Groups II and IV suggest potential interference factors such as canal curvature, presence of pulp remnants, or operator sensitivity [22]. Nonetheless, the error margins remained within clinically acceptable limits.

A recent umbrella review confirmed that most modern apex locators perform with a mean accuracy exceeding 85%, particularly in straight canals and under standardized laboratory conditions [23]. The consistency observed in this study supports these conclusions and adds to the body of evidence that validates the inclusion of EALs as a standard tool in endodontic practice.

However, it is essential to acknowledge some limitations. While in vitro models offer controlled environments, they may not fully replicate the challenges encountered in vivo, such as patient movement, varying pulp status, and complex canal systems [24,25]. Furthermore, while alginate and gypsum were useful in simulating periodontal resistance, they cannot perfectly emulate periapical tissues.

Despite these limitations, the data confirm that EALs can be reliable tools, especially when used alongside traditional techniques. The slight variations in readings should not deter clinicians from employing these devices, but rather encourage the adoption of a multi-modal approach to enhance accuracy [26]. Ultimately, the success of root canal therapy is strongly influenced by the precision in determining working length. Inaccuracies may lead to under- or over-instrumentation, increasing the risk of postoperative pain, treatment failure, or periapical pathology [27]. Thus, integrating electronic apex locators can enhance procedural outcomes and patient safety.

The study's conclusions also open the door for further investigations into the influence of file size, canal morphology, and irrigation protocols on the performance of apex locators. Comparative clinical trials in vivo would provide additional validation for the findings presented here [28,29].

In summary, the Apex Finder exhibited excellent consistency, especially in Lot 3, where 100% accuracy was recorded. This reinforces its utility as a precise and reliable tool in the modern endodontic arsenal, capable of complementing and in some cases replacing traditional radiographic techniques when properly used.

The results of the present study confirm the reliability of electronic apex locators in determining the working length of root canals, as evidenced by high accuracy rates across all test groups. These findings align with contemporary literature, which supports the use of apex locators to enhance procedural safety and effectiveness.

Recent scientific contributions, although focused on adjunctive therapies such as plant-based antimicrobials, provide complementary perspectives on improving the biological environment of the root canal system. Their work on the antibacterial properties of Epilobium parviflorum [30] and its role in periapical healing observed through imaging methods [31] reinforces the broader theme of integrating precision diagnostics with biologically favourable treatment approaches. While their focus diverges from direct apex locator performance, the emphasis on therapeutic accuracy and healing outcomes supports the clinical significance of technological innovations like apex finders.

CONCLUSIONS

1. This study evaluated the accuracy of an electronic apex locator (Apex Finder) in determining the working length of root canals in monoradicular teeth extracted for orthodontic purposes. Through a comparison of manually and electronically derived values across four test groups, it was demonstrated that the Apex Finder provided results consistent with manual measurements in 90% to 100% of cases.
2. The highest precision was recorded in Group III, with a perfect match between the electronic and manual determinations. Slight deviations observed in other groups remained within clinically acceptable thresholds. The findings confirm that EALs such as the Apex Finder are effective, reproducible tools in root canal length determination.
3. The clinical significance of this outcome is considerable. Integrating EALs in routine endodontic procedures can reduce dependence on radiographic methods, thus minimizing patient exposure to ionizing radiation. Moreover, their use facilitates real-time feedback and improved procedural accuracy, particularly in cases with challenging anatomies or limited visibility.

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