ORIGINAL RESEARCH

Investigating the Influence of Heat Treatment on Nickel-Titanium Instruments: Assessing Precision in Electronic Apex Locators and Endodontic Motors

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ABSTRACT
Background:Manufacturers have developed numerous nickel-titanium alloys, but there is limited information on the accuracy of integrated Electronic Apex Locators (EAL) when employed in conjunction with various thermal processes for determining the working length. The objective of this study is to employ an integrated EAL and endomotor assembly to evaluate, in an ex vivo setting, the impact of different thermal processes on nickel-titanium instruments.**Methods**:In this investigation, 40 extracted human maxillary incisors were employed. The visual approach served as the method to determine the control for the working length (WL). The WL was gauged throughout the cleaning and shaping procedures, employing rotary files from the Reciproc, Reciproc Blue, Wave One Gold, Twisted File Adaptive, and Hyflex CM systems, all with a 0.25 diameter instrument size.**Results**:The precision of the Electronic Apex Locator (EAL) remains unaffected by heat treatment applied to NiTi rotary instruments, as indicated by a lack of significant impact ($P > 0.051$).**Conclusion**:The utilization of thermal processes did not influence the accuracy of working length (WL) estimation when employing an Electronic Apex Locator (EAL) integrated with the endomotor.
Keywords: Endomotor,instrument,electronic apex locator

INTRODUCTION

Accurate determination of the working length (WL) is a critical factor that significantly influences the success of endodontic procedures.[1] Achieving optimal results hinges on precisely identifying the apical limit, preferably in close proximity to the site of apical constriction. The processes of root canal preparation and obturation necessitate a meticulous approach to ensure strict adherence within the intricate confines of the root canal system.The cement dentinal junction is widely recognized as the optimal endpoint for these procedures. This histological landmark serves as a crucial reference point for clinicians aiming to achieve effective and successful endodontic outcomes. However, despite its acknowledged significance, practical clinical settings present real-world challenges, making the precise identification of the cement dentinal junction often unfeasible.Navigating these challenges requires clinicians to leverage their expertise, employ advanced diagnostic tools, and exercise careful judgment.[2] Achieving an accurate working length is essential not only for successful treatment but also for preserving the overall health and integrity of the tooth undergoing endodontic intervention. The intricate balance between clinical knowledge and practical considerations underscores the complexity of endodontic procedures and emphasizes the need for a nuanced approach to ensure optimal patient outcomes.

Precise determination of the working length (WL) is indispensable for the success of endodontic treatments, as the achievement of optimal outcomes is closely tied to accurately establishing the apical limit near the apical constriction.[3]The inception of Electronic Apex Locators (EALs) for root canal length determination traces back to Suzuki's description in

1942, and their clinical introduction by Sunada in 1965 marked a significant advancement in endodontic technology. Numerous in vitro and in vivo studies have substantiated the commendable accuracy of EALs in determining root canal length. However, the nuanced anatomy of the apical foramen, the diameter of the instrument's tip, and the specific alloy employed can introduce variability in these measurements, as noted by some researchers.In the ongoing quest to enhance the mechanical properties of nickel-titanium (NiTi) instruments, manufacturers have developed a diverse array of NiTi alloys. Through strategic heat and surface treatments, these instruments exhibit heightened flexibility and increased resistance to torsional and cyclic fatigue.[4] Yet, the potential impact of these treatments on the electrical circuit impedance remains an area of investigation, typically evaluated through electrical resistivity measurements using LCR meters.Contemporary endodontic practice has witnessed a notable integration of Electronic Apex Locators into endodontic motors. This integration allows for the simultaneous monitoring of the working length and the progress of root canal preparation. This innovation proves particularly valuable in cases with pronounced curvatures, where changes in working length can occur during the shaping phase. The concomitant use of an EAL serves as a valuable adjunct, ensuring real-time monitoring and enhancing precision throughout the intricate process of endodontic intervention. This synergy of technology not only reflects the evolution of endodontics but also underscores the commitment to achieving the highest standards of accuracy and efficacy in clinical practice.[5]Manufacturers have undertaken significant advancements in the development of nickel-titanium (NiTi) alloys, employing a combination of heat and surface treatments to enhance the mechanical properties of NiTi instruments. These treatments are designed to confer increased flexibility and heightened resistance to torsional and cyclic fatigue, ultimately improving the overall performance of these crucial endodontic tools. However, amidst these strides in material science, the potential ramifications of these treatments on the electrical circuit impedance, a vital aspect in the context of Electronic Apex Locators (EALs), remain an intriguing and evolving area of inquiry.

The integration of EALs into endodontic motors has ushered in a transformative era in endodontics. This technological synergy allows for the simultaneous determination of the working length (WL) and the intricate progress of root canal preparation.[6] The concurrent use of an EAL is particularly advantageous, as it addresses the dynamic nature of root canals, especially those characterized by significant curvatures, where alterations in working length can manifest during the shaping phase.In the contemporary research landscape, where the convergence of working length (WL) and the intricacies of biomechanical preparation (BMP) can be monitored in real time, the integration of an EAL with endodontic motors emerges as a practical and preferred approach. This simultaneous monitoring not only provides a comprehensive understanding of the dynamic changes within the root canal system but also empowers clinicians with actionable insights for precise and effective treatment.To delve deeper into the intricacies of this integrated approach, the current research endeavors to conduct ex vivo assessments. The focal points of investigation include unraveling the effects of various thermal processes on NiTi equipment.[7] Additionally, the study aims to explore the influence of the apical preparation diameter on the accuracy of Electronic Apex Locators. By systematically examining these facets, the research seeks to contribute nuanced insights, bridging the gap in our understanding of how thermal treatments and instrument characteristics intersect, ultimately influencing the precision of EALs during the critical phase of biomechanical preparation. This pursuit of knowledge holds promise for refining endodontic practices and advancing the field towards ever greater precision and efficacy.

MATERIALS AND METHODS

To initiate the dental preparations for the current research, a total of 40 extracted human maxillary incisors were carefully selected. Each tooth within the study population exhibited a fully formed apex, ensuring a consistent anatomical feature for analysis. A meticulous verification process, facilitated by periapical radiographs, confirmed the presence of a single canal in each tooth. The curvature of the canals was methodically determined using Schneider's method, resulting in a range between 10 to 30 degrees.Prior to inclusion in the study, all selected teeth underwent a standardization process. This involved establishing a uniform root length of 17 mm for each tooth by precisely removing the dental crowns. The removal of the crowns was executed with precision using a diamond disc, ensuring that the standardized root length was consistently achieved across all specimens.This meticulous preparation and standardization protocol lay the foundation for a robust and controlled experimental setup, allowing for meaningful comparisons and analysis within the defined parameters. The careful selection and preparation of teeth contribute to the reliability and reproducibility of the research findings, ensuring that the outcomes are representative and applicable to the intended scope of the study.

The determination of the control working length (WL) was executed through a meticulous process. Employing a clinical microscope for enhanced precision, a manual stainless steel K-file #10 was utilized in the procedure. The K-file was delicately inserted into the root canal, and its placement was meticulously observed through the clinical microscope.The endpoint for determining the control working length was established when the file was visualized flush with the major foramen. This method ensured that the working length corresponded precisely to the point where the file aligned with the major foramen, providing a visual reference for accurate measurement. The integration of a clinical microscope and a manual stainless steel K-file #10 in this process reflects a commitment to precision and meticulous control in determining the working length, laying the groundwork for the subsequent phases of the research.In the electronic working length measurement phase, the prepared roots were securely affixed within an acrylic box to ensure stability and consistency. Subsequently, they were immersed in a specialized conductive gel formulated for this purpose. The conductive gel was meticulously composed, comprising 0.5% potassium chloride, 2.5% hydroxyethyl cellulose, and a saline solution, as per previously established protocols.This conductive gel serves a crucial role in facilitating electrical conductivity during electronic working length measurements. Its composition is carefully designed to create an optimal environment for the electronic apex locator (EAL) to function effectively. The potassium chloride aids in enhancing conductivity, while the hydroxyethyl cellulose contributes to the gel's consistency and adherence to the root surface.By submerging the roots in this conductive gel, the research protocol ensures a standardized and conducive medium for electronic measurements. This methodology is aligned with established practices in endodontic research, emphasizing precision and control in the electronic working length determination process.

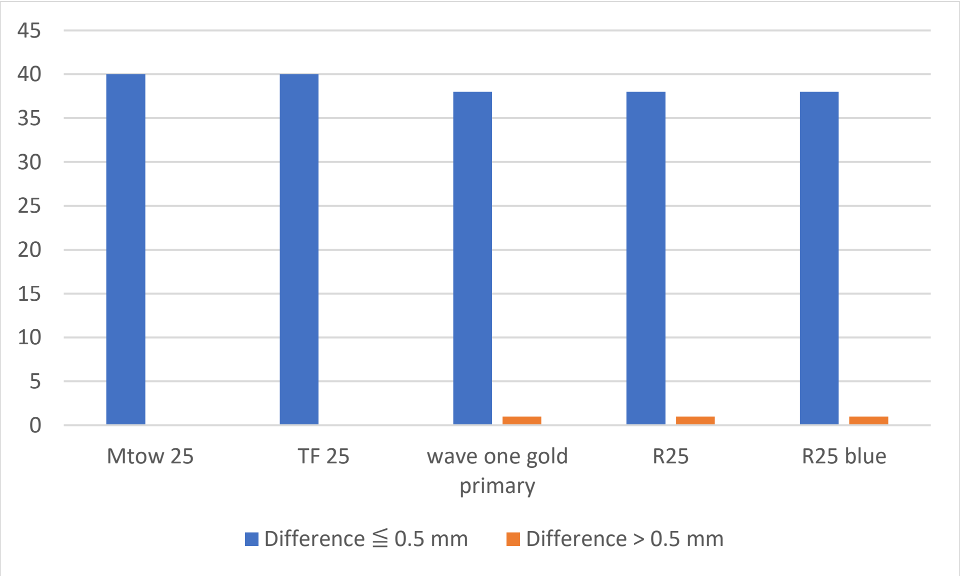
RESULTS

The data presented in Table 1 reveals that there is no statistically significant variation in Electronic Apex Locator (EAL) accuracy when measuring the working length across different groups ($P > 0.05$). Specifically, instruments subjected to various thermal treatments, while maintaining an identical tip diameter of 0.25 mm, did not yield any notable differences in EAL accuracy that reached statistical significance. These results emphasize the consistency of EAL performance across the diverse thermal treatments applied to the instruments, reaffirming the robustness of EAL accuracy in this experimental context.

Table1: Accurate and inaccurate results obtained using 0.25 mm diameter instruments with different heat treatments

	Difference ≦ 0.5 mm	Difference > 0.5 mm
Mtow 25	40	0
TF 25	40	0
Wave one gold primary	38	1
R25	38	1
R25 blue	38	1

Figure1: Accurate and inaccurate results obtained using 0.25 mm diameter instruments with different heat treatments



The presented data displays the mean electrical resistivity values of various instruments, all featuring the same tip diameter of 0.25 mm. Notably, the HyFlex CM instruments exhibited the highest mean electrical resistivity value, measuring 0.144, while the Reciproc Blue instruments registered the lowest value at 0.054. A comprehensive analysis across all heat treatments revealed a statistically significant difference, particularly highlighting the distinction between the CM group and the other groups ($P < 0.05$).These findings underscore the variability in electrical resistivity among the different instruments, with the statistical difference emphasizing the influence of heat treatments on this electrical property. The observed range of resistivity values suggests that the specific characteristics and compositions of the instruments, particularly in the context of heat treatments, play a significant role in determining their electrical properties. The dissimilarity between the HyFlex CM and Reciproc Blue instruments, as well as the statistical significance identified, adds a layer of insight into the nuanced electrical behaviors of these instruments under different thermal treatments.

DISCUSSION

This study was undertaken with the overarching goal of investigating how two critical factors—heat treatment and the tip diameter of endodontic instruments—might influence the accuracy of an Electronic Apex Locator (EAL) when integrated into an endodontic motor. A meticulous examination of the study's results, which encompassed a range of heat treatments (including M-Wire, R-phase, Gold Wire, Blue Wire, and CM Wire) and various tip diameters (ranging from 0.25 mm to 0.50 mm), revealed a noteworthy outcome. Surprisingly, no significant impact on the accuracy of the EAL during root canal preparation was identified in relation to these factors. Consequently, the null hypothesis, asserting the absence of a substantial effect of these variables on EAL accuracy, was upheld.[8,9]The accuracy of determining the working length (WL) is pivotal for the overall success of endodontic treatments. The dynamic nature of root canal preparation, especially in curved conditions, introduces the possibility of changes in the initially determined WL. The integration of endodontic motors with Electronic Apex Locators emerges as a valuable technological advancement in this realm. This integration allows practitioners to monitor the working length in real-time throughout the root canal preparation process. Significantly, previous research has indicated that these integrated systems exhibit not only suitable accuracy for working length determination but, in some cases, surpass the precision offered by conventional radiographic methods.

Beyond affirming the efficacy of integrated endodontic systems, the current study sheds light on the nuanced relationship between heat treatments, variations in tip diameter, and the accuracy of Electronic Apex Locators. These findings contribute to the evolving understanding of optimal endodontic practices, emphasizing the role of technology in enhancing precision and efficiency during crucial phases of root canal procedures.[10]

The precise determination of the Working Length (WL) stands as a pivotal factor that significantly impacts the overall success of endodontic therapy. Particularly in curved root canals, the WL may experience variations during the Biomechanical Preparation (BMP) phase. Recognizing these dynamic changes and ensuring accurate WL calculations become paramount for achieving successful endodontic outcomes. In this context, the concurrent utilization of endodontic motors alongside Electronic Apex Locators (EALs) emerges as a strategic advantage. This integrated approach enables continuous monitoring of the WL throughout the entire root canal preparation process, allowing clinicians to adapt and refine their techniques in real-time.The precision of Electronic Apex Locators is a subject of frequent scrutiny within the scientific literature, often explored through meticulous ex vivo investigations. In the present study, the precision of EALs was systematically assessed using a conventional 2.5% hydroxyethyl cellulose gel designed to facilitate electrical conductivity. Significantly, the choice of sodium hypochlorite as an irrigation solution mirrored actual clinical conditions, introducing a realistic element to the experimental setup. Opting for an ex vivo model was a deliberate decision, as it affords researchers enhanced control over sample variability and experimental conditions. Ex vivo studies are highly valued for their simplicity, reproducibility, and standardization, allowing for a meticulous examination of the various factors at play in a controlled environment.[11]In adhering to contemporary research methodologies, this study contributes valuable insights to the understanding of EAL accuracy, particularly in the context of different thermal treatments and tip diameters. The emphasis on precision in WL determination underscores its critical role in achieving successful outcomes in endodontic procedures, highlighting the evolving landscape of technology and methodologies in advancing the field.Certainly! Let's delve deeper into the complex interplay between the calculation of Working Length (WL) using Electronic Apex Locators (EALs) and the influence of NiTi alloy composition changes resulting from different thermal treatments.

In the realm of endodontics, Electronic Apex Locators serve as indispensable tools for precisely determining the location of the apical constriction during root canal procedures. These devices operate by exploiting the electrical properties inherent to the root canal system. As the endodontic instrument, typically made from Nickel-Titanium (NiTi) alloy, navigates toward the apical constriction, variations in electrical impedance occur. These impedance changes are integral to the functioning of EALs, and they are intricately tied to the positional information of the instrument within the root canal.Now, the choice of NiTi alloy for endodontic instruments is deliberate due to its unique properties, such as flexibility and resistance to cyclic fatigue.[12] However, the composition of NiTi alloys can be altered through thermal treatments, resulting in changes to the percentage of different crystalline phases, including martensite and austenite. These alterations in the alloy's crystalline structure have a profound impact on the mechanical characteristics of the endodontic instruments.The mechanical properties, in turn, influence how the instrument interacts with the electrical circuit in EALs. The impedance values within the circuit are sensitive to the proximity of the instrument to the apical constriction. As the instrument approaches this critical point, the impedance changes are translated into precise WL measurements, providing real-time feedback to the clinician.Understanding the nuances of NiTi alloy composition and its response to thermal treatments is pivotal in optimizing the design and functionality of endodontic instruments. Researchers and practitioners must consider these material properties to ensure the reliability and accuracy of EALs during root canal procedures.This holistic comprehension of the science behind EALs contributes to advancements in endodontic technology, ultimately enhancing the precision and success of root canal treatments.

CONCLUSION

The study's scrutiny of various heat treatment approaches yielded a noteworthy finding: the induced variations did not lead to any statistically significant differences. It is crucial to acknowledge and recognize the inherent limitations that accompany this research endeavor. These limitations encompass factors such as the sample size employed, the specific conditions of the experiments, and the protocols governing the diverse heat treatment methodologies applied.In acknowledging the constraints posed by these limitations, the study results consistently pointed towards a lack of substantial divergence in the material's properties and the precision of the apex locator. Despite the constraints, the findings imply a robustness and stability in the performance of the material and the accuracy of the apex locator across different heat treatment scenarios.It is within the scientific ethos to critically assess and acknowledge the constraints of a study, as this transparency enhances the credibility of the findings. Future research endeavors may benefit from addressing these limitations and exploring additional facets to enrich our understanding of the nuanced interactions between heat treatments and the properties of materials, particularly in the context of precision instruments like apex locators.

REFERENCES

1. Ricucci D, Langeland K. Apical limit of root canal instrumentation and obturation, part 2. A histological study. *Int Endod J*. 1998;31(6):394–409.
2. Suzuki K. Experimental study on iontophoresis. *Japan J Stomatol*. 1942;16:411–29.
3. Altenburger MJ, Cenik Y, Schirrmeister JF, Wrbas KT, HellwigE. Combination of apex locator and endodontic motor for continuous length control during root canal treatment. *Int Endod J*. 2009;42(4):368–74.
4. Gordon MP, Chandler NP. Electronic apex locators. *Int Endod J*. 2004;37(7):425–37.
5. Sunada I. New method for measuring the length of the root canal. *J Dent Res*. 1962;41:357–87.
6. Akisue E, Gavini G, De Figueiredo J. Influence of pulp vitality on length determination by using the Elements Diagnostic Unit and Apex Locator. *Oral Surg Oral Med Oral Pathol Oral RadiolEndod*. 2007;104(4):129–32.
7. Akisue E, Gratieri SD, Barletta FB, Caldeira CL, Grazziotin-Soares R, Gavini G. Not all electronic foramen locators are accurate in teeth with enlarged apical foramina: an in vitro comparison of 5 brands. *J Endod*. 2014;40(1):109–12.
8. Chopra V, Grover S, Prasad SD. In vitro evaluation of the accuracy of two electronic apex locators. *J Conserv Dent*. 2008;11(2):82–5.
9. Staffoli S, Grande NM, Plotino G, Özyürek T, Gündog˘ar M, Fortunato L, et al. Influence of environmental temperature, heat-treatment and design on the cyclic fatigue resistance of three generations of a single- file nickel-titanium rotary instrument. Odontology. 2019;107(3):301– 7. doi:10.1007/s10266-018-0399-5.
10. Aggarwal V, Singla M, Bhasin SS. Influence of instrument size and varying electrical resistance of root canal instruments on accuracy of three electronic root canal length measurement devices. Int Endod J. 2017;50(5):506–11. doi:10.1111/iej.12649.
11. Schneider SW. A comparison of canal preparations in straight and curved root canals. Oral Surg Oral Med Oral Pathol. 1971;32(2):271– 5. doi:10.1016/0030-4220(71)90230-1.
12. Caldwell JL. Change in working length following instrumentation of molar canals. Oral Surg Oral Med Oral Pathol. 1976;41(1):114–8.