ORIGINAL RESEARCH PAPER

Endodontics

KEY WORDS: AI Endomotor, Root ZX 2 Apex Locator, Tri Auto ZX2+ Endomotor.

COMPARATIVE EVALUATION OF WORKING-LENGTH DETERMINATION USING DIFFERENT APEX LOCATOR SYSTEMS: AN EX-VIVO STUDY

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ABSTRACT

This study evaluated the working-length (WL) determination accuracy of two integrated apex locators (AI endomotor, Tri Auto ZX2+) and one external locator (Root ZX 2) compared to CBCT. Using 60 extracted single-rooted teeth in conductive alginate, device measurements to the 0.0 mark were recorded and compared against CBCT using One-way ANOVA. Results revealed a maximum mean difference of only 0.12 mm between CBCT and the tested devices, with no statistically significant variance among any of the groups ($p = 0.995$). Ultimately, all three devices proved highly reliable and equally accurate to CBCT for WL determination.

INTRODUCTION

Accurate root canal working length (WL) determination is essential for successful endodontic therapy. Imprecise measurements can lead to under-instrumentation or over-instrumentation.(1) 2D radiographs were the standard, but inherent limitations—such as anatomical superimposition and distortion—prompted the widespread adoption of electronic apex locators (EALs). (2)Standalone devices like the Root ZX 2(Dentaport ZX) have since become the clinical benchmark for precise, radiation-free WL determination. (3)

Recent advancements have introduced endomotors with integrated EALs, such as the Tri Auto ZX2+ and AI endomotor. While these systems provide continuous, real-time apical monitoring to streamline workflows, their accuracy compared to established external EALs requires validation. In ex-vivo studies, CBCT serves as the non-destructive, three-dimensional "gold standard" for establishing actual anatomical canal lengths, effectively overcoming the limitations of conventional imaging.(2,4)

The primary aim of this study was to evaluate and compare the accuracy of WL measurements obtained using AI endomotor, Tri Auto ZX2+ endomotor, and the Root ZX 2 apex locator against actual canal lengths determined by CBCT.

MATERIALS AND METHODS

The required sample size was calculated using G*Power software (version 3.1.9.7). Based on a significance level of 0.05 and a statistical power of 0.90, the total sample size was determined to be 60 specimens.

Sixty extracted single rooted teeth (Fig:1) were utilized for this ex vivo study. To establish a stable coronal reference point, the occlusal surfaces of the teeth were flattened. Following preparation, the actual WL for all 60 samples was recorded utilizing CBCT. This CBCT measurement served as the absolute reference. Group 1: Actual Working Length (Fig:2).

To simulate a clinical electrical circuit. Tooth was embedded in a plastic container filled with a conductive alginate medium. 0.9% saline solution was utilized as the root canal irrigant. A lip electrode was embedded directly into the conductive alginate, and device reference cables were connected in accordance with the manufacturer recommendations.

The specimens were subsequently tested using three different electronic devices to form the experimental groups:
Group 2: Root ZX 2 standalone apex locator (Fig:4)
Group 3: Tri Auto ZX2+ endomotor with integrated apex locator (Fig:5)
Group 4: AI endomotor with integrated apex locator (Fig:2)

For each respective device, an endodontic file was attached as per the manufacturer's guidance. The file was advanced slowly and apically into the canal until the device's display indicated the apex (the 0.0 mark). Once the apex was located, silicone rubber stopper was carefully adjusted and the file was removed to measure the length in millimeters using an endodontic ruler.

To ensure precision, this process was repeated three times for each tooth with each device. The mean of these three measurements was calculated and recorded as the final device working length reading for that specific tooth.

RESULTS

Data from a total of 60 samples were analyzed, with an equal distribution of 15 samples per group.

Intergroup Comparison

An intergroup comparison (Table 1) utilizing a One-way ANOVA test revealed no statistically significant differences in WL when all four groups were compared with one another ($p = 0.995$). The highest mean working length (Graph 1) was recorded in Group 1 (21.49 ± 2.75), followed by the Group 2 (21.47 ± 2.73) and Group 3 (21.41 ± 2.66). The Group 4 demonstrated the lowest mean working length (21.37 ± 2.61).

Pairwise Comparison

Pairwise comparisons (Table 2) carried out using Tukey's post hoc test demonstrated no statistically significant differences when the groups were evaluated in pairs. The highest mean difference (Graph 2) recorded was between the 1 and 4 Groups (0.12, $p = 0.8$), followed by the 1 and 3 Groups(0.08, $p = 0.86$), and the 1 and 2 Groups (0.03, $p = 0.95$).

DISCUSSION

The goal of endodontic therapy is thorough cleaning and shaping and 3-D obturation of the root canal space. The foundational step that dictates the success of these subsequent procedures is the accurate determination of the WL. Defined as the distance from a coronal reference point to the point at which canal preparation and obturation should terminate, the WL dictates the apical limit of all endodontic instrumentation.(5)

Anatomically and histologically, the ideal endpoint for endodontic therapy is the apical constriction (minor apical foramen), where the pulpal tissue transitions into periodontal tissue .(6) Under-estimation of the WL leaves vital or necrotic

tissue remnants and bacterial biofilms in the apical third, which is a primary cause of persistent intraradicular infection and endodontic failure.(7) Conversely, over-estimation damages the periapical tissues, destroys the natural apical stop and increases the risk of extruding infected debris, irrigants or obturation materials into the periapex causing postoperative pain and delayed healing.(8)

Given the critical threshold between success and failure that the apical constriction represents, employing a highly precise, reproducible and clinically practical method for WL determination is of paramount importance in contemporary endodontic practice.

CBCT demonstrated the highest mean working length (21.49 ± 2.75 mm), which can be attributed to its ability to render a three-dimensional representation of the root canal system.(9) However, while CBCT is highly accurate, it is not recommended as a routine substitute for EALs strictly for working length determination due to radiation exposure concerns adhering to ALARA principles.(10)

Conventional 2D radiography projects a three-dimensional anatomical complex into a two-dimensional image, frequently leading to superimposition of adjacent structures and distortion (11)The ideal endodontic endpoint the apical constriction is a histological landmark, not a radiographic one. The apical foramen deviates from the radiographic apex in up to 93% of cases, relying solely on radiographs often leads to working length overestimation and subsequent over-instrumentation.(12) EALs overcome these limitations by utilizing multiple frequencies to measure electrical impedance, allowing them to accurately detect the periodontal ligament and the apical constriction.(13)

Both standalone and integrated apex locators are highly reliable and demonstrate comparable clinical accuracy. Literature confirms that both modalities operate well within the acceptable ±0.5 mm tolerance range. Standalone Apex Locators (Root ZX II) operate independently of rotary instrumentation, making them ideal for initial canal scouting.(14)

Integrated Apex Locators (TriAuto ZX2 Plus, AI Motor) combine the endomotor and apex locator into a single device, allowing for continuous, real-time working length monitoring during active shaping. They feature automated safety mechanisms (auto-stop or auto-reverse) that activate near the apical constriction, significantly reducing the risk of over-instrumentation and apical perforation.

Root ZX 2 apex locator and Tri auto ZX 2 plus integrated apex locator are 3rd generation apex locators which are based on multi-frequency impedence measurement.AI motor integrated apex locator is 4th generation apex locator which uses a multi-frequency ratio analysis with simultaneous impedence measurement at multiple frequencies.(15)

0.9% saline was used because it is chemically neutral, electrically stable, and providing reliable and reproducible results for working length determination. Conductivity level of NaOCl (highest)>0.9 % saline (moderate)>17% EDTA (moderate – low)>distilled water (lowest).(16)

Limitations of the study: Electronic apex locators have their limitations, so should be used in conjugation with other methods like radiographs for better results. Using extracted teeth cannot mimic in vivo conditions.

CONCLUSION

Under the constraints of this ex- vivo study, no statistically significant difference in working length determination was present when CBCT, Root ZX 2, Tri Auto ZX 2plus, and AI motor groups when compared with each other.

Fig 1: Extracted Single Rooted Teeth

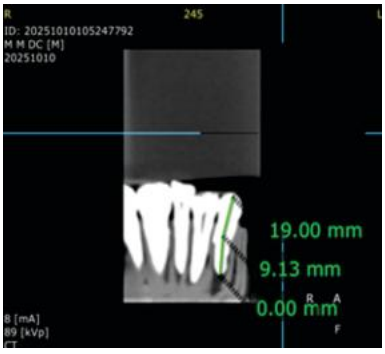


Fig 2:Working Length Measurement by CBCT

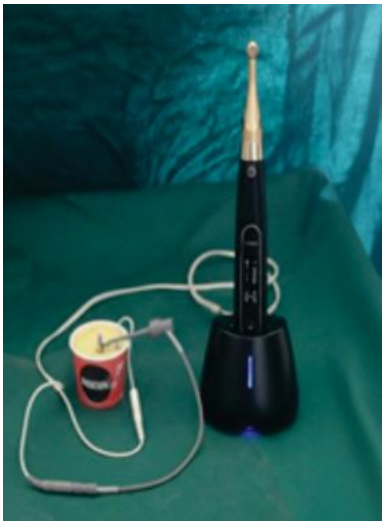
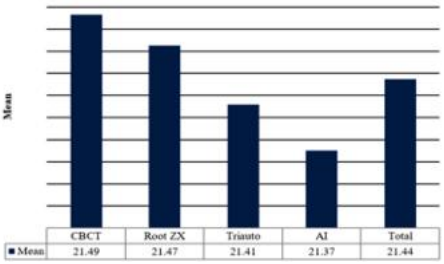


Fig 3: Working Length Measurement by AI Motor Integrated Apex Locator

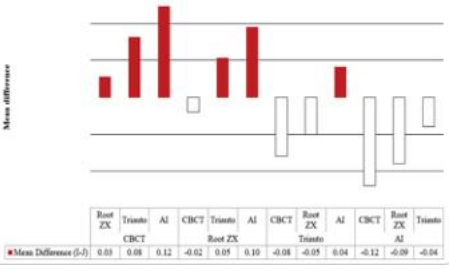
Fig 4: Working Length Measurement by Root ZX 2 Standalone Apex Locator

Fig 5:Working Length Measurement by Tri Auto ZX 2 Plus Integrated Apex Locator

GRAPHS AND TABLES



Graph 1: Mean Working Length of All Groups



Graph 2: Mean Difference Between the Groups Upon Pairwise Comparison

Table 1: Intergroup Comparison of Working Length

Groups	N	Mean	Std. Deviation	Minimum	Maximum	Sig.
CBCT	60	21.49	2.75	16	27	0.995
Root ZX 2	60	21.47	2.73	16.5	26.5	
Triauto ZX 2 plus	60	21.41	2.66	16.5	26.5	
AI motor	60	21.37	2.61	16	26.3	
Total		21.44	2.67	16	27	

Table 2: Pairwise Comparison of Working Length Among the Groups

(I) Groups	(J) Groups	Mean Difference (I-J)	Sig.
CBCT	Root ZX 2	0.03	0.95
	Triauto ZX 2 plus	0.08	0.86
	AI motor	0.12	0.8
Root ZX 2	CBCT	-0.02	0.95
	Triauto ZX 2 plus	0.05	0.96
	AI motor	0.10	0.997
Triauto ZX 2 plus	CBCT	-0.08	0.86
	Root ZX	-0.05	0.96
	AI motor	0.04	0.95
AI motor	CBCT	-0.12	0.8
	Root ZX 2	-0.09	0.997
	Triauto ZX 2 plus	-0.04	0.95

REFERENCES

1. Reddy A, Punathil S, Moyin S, Rathod A, Shah A. Evaluation of the efficacy of different systems in determination of root canal working length: a comparative study. World J Dent. 2021; 12:399-402.
2. Izadi A. Accuracy of working length measurement using cone beam computed tomography at three field of view settings, conventional radiography, and electronic apex locator: an ex-vivo study. Eur Endod J. 2024;266-72.
3. Jha P, Nikhil V, Raj S, Ravinder R, Mishra P. Accuracy of electronic apex locator in the presence of different irrigating solutions. Endodontology. 2021; 33:232-6.
4. Kumari S, Memon S, Arjumand B, et al. Accuracy of working length determination - electronic apex locator versus cone beam computed tomography.2024;24.
5. American Association of Endodontists. (2020). Glossary of Endodontic Terms (10th ed.)
6. Ricucci, D., & Langeland, K. (1998). Apical limit of root canal instrumentation and obturation, part 2. A histological study. International Endodontic Journal, 31(6), 394-409.
7. Sjögren, U., Hägglund, B., Sundqvist, G., & Wing, K. (1990). Factors affecting the long-term results of endodontic treatment. Journal of Endodontics, 16(10), 498-504.
8. Siqueira, J. F., Rôças, I. N., Ricucci, D., & Hülsmann, M. (2014). Causes and management of post-treatment apical periodontitis. British Dental Journal, 216(6), 305-312.
9. Baumgaertel, S., Palomo, J. M., Palomo, L., & Hans, M. G. (2009). Reliability and accuracy of cone-beam computed tomography dental measurements. American Journal of Orthodontics and Dentofacial Orthopedics, 136(1), 19-25.
10. Alamri, H. M., Sadrameli, M., Alshalhoob, M. A., & Alshehri, M. A. (2012). Applications of CBCT in dental practice: a review of the literature. General Dentistry, 60(5), 390-400.
11. Krishnan, I., & Sreedharan, S. (2012). A comparative evaluation of electronic and radiographic determination of root canal length in primary teeth: An in vitro study. Contemporary Clinical Dentistry, 3, 416.
12. Kqiku, L., & Städtler, P. (2011). Radiographic versus electronic root canal working length determination. Indian Journal of Dental Research, 22, 777.
13. Bansal, R., et al. (2024). Comparative Determination of Working Length by Electronic Apex Locator, Digital Radiography, and Cone-beam Computed Tomography: An In vitro Study. Current Trends in Dentistry, 1, 11–16.
14. Cakmak YE, et al. Evaluation of the accuracy of an endomotor-integrated apex locator versus a standalone electronic apex locator in teeth with simulated apical root resorption: an in vitro study. Eur J Ther. 2025.
15. Khattak, O., Raidullah, E., & Francis, M. L. (2014). A comparative assessment of the accuracy of electronic apex locator (Root ZX) in the presence of commonly used irrigating solutions. Journal of Clinical and Experimental Dentistry, e41-6.
16. Karunakar P, Vuppalapati KV, Anumula L, Bolla N, Koppolu P, Lakshmi BS. Comparative evaluation of working length determined using integrated apex locator and Root ZX mini under various irrigating solutions: An in vivo study. J Conserv Dent. 2023;26(3):273-8.