Original Article

Comparative Evaluation of Three Electronic Apex Locators in Determining Working Length: An In-Vitro Study

Adil O. Abdullah[1,2*], *Aso M. Abdulkarem*[1], *Zana A. Hamadameen*[1]

Abstract

Objective: The purpose of this in-vitro study was to determine the precision of three electronic apex locators (AppleDent AL, Eighteeth AL, and Coxo AL) in determining the working length (WL) of root canals using extracted human teeth. Although several new apex locator models have recently become commercially available, independent evidence regarding their measurement accuracy remains limited, underscoring the need for objective evaluation.

Methods: A total of 90 freshly extracted human permanent single-rooted teeth with mature apices were standardized. Access cavities were prepared and canal patency was controlled (with a 10 K file) and AWL (with size 15 K file at ×25 magnification) were detected by the stereomicroscope. After embedding them in alginate to recreate the periodontium, teeth were randomly divided into 3 groups (n = 30). The average of 3 repeated measurements was used for the calculation of the EWL in each group. The value of AWL and EWL have been calculated. The accuracy was measured under ±0.5 mm and ±1.0 mm. Data were statistically treated with Shapiro-Wilk test (to assess data normality), Levene´s test, one-way ANOVA and Tukey's post hoc testing (α = 0.05).

Results: In comparison with Eighteeth AL (0.41 ± 0.27 mm), the mean deviations of AppleDent AL and Coxo AL from AWL were by a lower level (by 0.24 ± 0.58 mm and by 0.24 ± 0.33 mm, respectively). Precision within ±0.5 mm was 50.0%, 86.7%, and 73.3% for AppleDent, Coxo, and Eighteeth models, respectively. All devices achieved a 90% or greater accuracy within ±1.0 mm. The ANOVA analysis confirmed that Eighteeth was different from AppleDent and Coxo (p = 0.012), which the Tukey's test also confirmed.

Conclusions: All 3 electronic foramen locators showed clinical accuracy. Coxo AL performed far better, while AppleDent AL showed similar mean scores, but had higher variability, and Eighteeth overestimated the working length.

Keywords: *Endodontics, Dental instruments, Root canal preparation, Dental pulp test, Tooth apex.*

Submitted: October 17, 2025, Accepted: January 12, 2026, Published: April 1, 2026.

Cite this article as: Abdullah AO, Abdulkarem AM, Hamadameen ZA . Comparative Evaluation of Three Electronic Apex Locators in Determining Working Length: An In-Vitro Study. Sulaimani Dent J. 2025;13(1):20-27.

DOI: https://doi.org/10.17656/sdj.10218

1. *Dental Assistant Department, Erbil Technical Medical Institute, Erbil Polytechnic University, Erbil, Iraq.*
2. *Endodontics Department, Faculty of Dentistry, Tishk International University, Erbil, Iraq*

** Corresponding author*: *adil.abdullah@epu.edu.iq.*

Introduction

Effective endodontic treatment depends on complete debridement, shaping, and obturation of the root canal system with minimal disturbance to periapical structures[1]. It is important to establish the working length (WL), defined as the distance from a coronal reference point to the apical constriction beyond which preparation and obturation do not extend[1]. Both under-instrumentation and over-instrumentation may be detrimental to the outcome of treatment: apical trauma leading to impaired healing through over-instrumentation and infected material remaining as a nidus for infection within canal dimensions[2-3].

Working length confirmation was based on tactile sensation and radiographic evidence[13]. Conventional radiographs are useful, but they are two-dimensional, suffer from distortion and superimposition due to overlying structures, and contribute to cumulativeexposure for the patient[4-6]. When canals are curved, when they have apical resorption, or when they diverge[5-6], the reliability of these measurements decreases. Later, in the middle of the 20th century, with an attempt to overcome these shortcomings, electronic apex locators (EALs) were introduced and became indispensable[6-7].

Current devices use multifrequency impedance ratios, allowing for a better localization of the apical constriction even in irrigant-filled conditions[2,7-8]. Clinical tests also show that the root canal length at which new EALs can detect is within 0.5 mm from the apical constriction in more than 95%[9-10] and the measuring accuracy of most vendors′ models is ±0.5 mm. The Root ZX, Raypex, and Apex ID are commercially validated devices that serve as standards[11-12].

There is a need for independent confirmation[12], since gadgetry keeps rolling out. Power generation: owing to pressure from manufacturers, power generators strive for cheapness, convenience of use or technical innovation even when evidence supporting alternative development models is weak[13]. Evaluation should be conducted for new instruments such as AppleDent AL, Eighteeth AL and Coxo AL.

Developments in apex locator technology mirror this idea, with devices designed to address biological conditions within the root canal system 13. Studies on Multi-Frequency Impedance Analysis MFA technology indicate that by analyzing electric signals at multiple frequencies more accurate readings can be achieved, especially in the presence of irrigants and complex canal shapes[12-13]. The importance of accurately recording the presence of a signal and adapting to biological variation, as described with regard to apex locators, underscores the need for dentists to have a precise method for measuring working length (WL) in endodontics[13].

The purpose of this study was to assess the accuracy of three electronic apex locators (AppleDent AL, Eighteeth AL, and Coxo AL) in determining working length for extracted human teeth under controlled in vitro conditions. The null hypothesis was that there would be no differences in precision among the devices.

Materials and methods

Sample selection

The sample selection was performed using 90 freshly extracted human permanent single-rooted teeth (N = 90) with fully developed apices. Teeth that had caries into the root, fractures, resorption, calcifications or previous endodontic treatment were excluded. Following extraction, the attached calculus and soft tissue residues were removed with an ultrasonic scaler, and the teeth were stored in 0.1% thymol at room temperature until use. The teeth were examined under a stereomicroscope (×25 magnification) before the start of the experiment to verify that no fissures, fractures, or open apices existed.

The Ethical Committee at the Erbil Polytechnic University approved the research project with Code No. (25 / 0081 HRE) on February 20, 2025.

Preparation of samples

Standard access preparations were performed in all specimens using a high-speed diamond bur (ISO 014 size, Dentsply, Ballaiges, Switzerland) under constant water irrigation. A size 10 K-file (Dentsply Maillefer, Ballaigues, Swiss) was inserted in the canal for patency test. Actual working length (AWL) through the penetration of a size 15 K-file to be barely visible at the apical foramen determined and observed into a stereomicroscope. The measured length was adjusted by subtracting 0.5 mm to obtain the AWL as the control standard.

The canals were irrigated with 2.5% NaOCl and saline alternately during instrumentation to remove debris. Before EAL measurement, canals were gently dried with paper points to remove excess irrigant while maintaining slight moisture, as completely dry or overly wet canals may compromise electronic length readings. The shape of the coronal third was achieved by flaring with Gates-Glidden drills (numbers 2 and 3) and preparing the canals to a size 25 K-file in all specimens.

Embedding process

Each tooth was embedded in fresh-mixed alginate within a plastic mold to simulate the periodontium and provide an electrically conductive medium for electronic measurements. The upper segment of the root was entirely encapsulated in alginate to ensure conductivity. Alginate was reconstituted prior to each test session to ensure consistent moisture and conductivity.

Research cohorts and digital working length measurements

The 90 teeth were evenly and randomly distributed among 3 experimental groups (n = 30): Group 1–-AppleDent electronic apex locator (AppleDent, Hong Kong, China), Group 2–Eighteeth electronic jusapex locator (Changzhou Sifary Medical Technology Co., Ltd., Jiangsu, China), and Group 3—Coxo electronic apex finder Coxo (Foshan Coxo Medical Instrument Co., Ltd., Guangdong, China) Figure 1. The suffix "AL" used in this study corresponds to the model designation found on the product labels and instruction manuals of the tested devices, although it may not consistently appear in all online listings.

The three electronic apex locators tested in the present study were AppleDent AL (left), Eighteeth AL (middle), and Coxo AL (right) (Figure 1).

A size 15 K-file was attached to the file holder for each EAL in all groups. The instrument was carefully inserted into the canal up to the point where the apical constriction was indicated (0. 0 or an apex mark in the read-out on display). The silicone stopper was placed at the reference point of the coronal (crown), and the file was withdrawn. The length was measured with a digital caliper (Mitutoyo Corporation, Kawasaki, Japan) with 0.01 mm precision, as shown in Figure 2.

All measurements were repeated 3 times for each sample, and the mean value was used as the electronic working length (EWL). A complete overview of the study process is illustrated in Figure 3.

Figure 3 is a flowchart of the experimental design, including how samples were selected, prepared, and divided into groups, the measurement method, and data collection/analysis.

Data acquisition and precision evaluation

The difference between the EWL achieved with each device and the AWL (reference standard) was calculated for each sample. A tolerance of Â±0.5 mm from the AWL was considered clinically acceptable, while a larger tolerance (Â±1.0 mm) was also investigated later.

Quantitative analysis

All statistical analyses were performed using SPSS for Windows, Version 25.0 (IBM Corp., Armonk, NY). Normality of the data distribution was tested using the Shapiro–Wilk test. To evaluate homoscedasticity of variance between groups, Levene's test for equality of variances was used. Sample size was estimated in advance using G*Power software (version 3.1.9.7; Heinrich-Heine-Universität Düsseldorf, Germany), considering the effect size of f = 0.25 (medium effect) with $\alpha = 0.05$ and statistical power $(1–\beta)=0.80$, suggesting a minimum of 30 samples for each group to be appropriate.

Parametric testing assumptions were met, and the average difference among the three groups was compared using one-way ANOVA. Post hoc pairwise comparisons were carried out using Tukey's HSD (honestly significant difference) test. Statistical significance was defined as a p-value < 0.05.

Figure 1: The three electronic apex locators assessed in this study are AppleDent AL (left), Eighteeth AL (center), and Coxo AL (right).

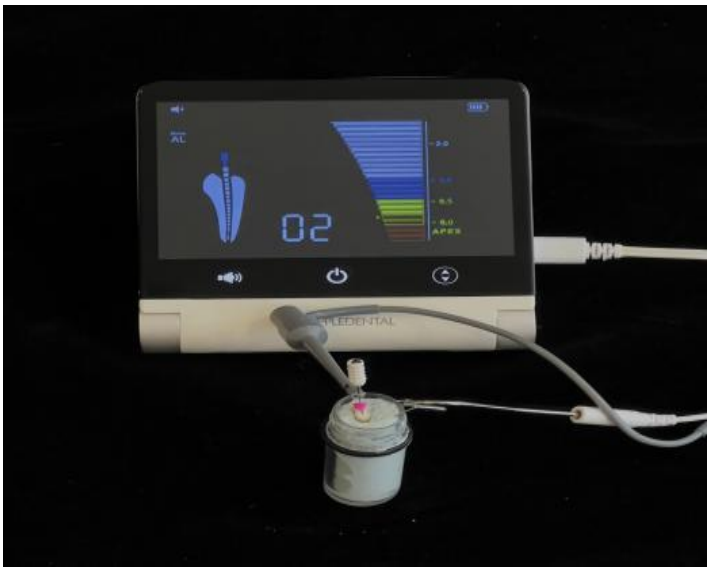

Figure 2: Experimental configuration illustrating the AppleDent electronic apex finder linked to a tooth encased in alginate for the purpose of ascertaining working length.

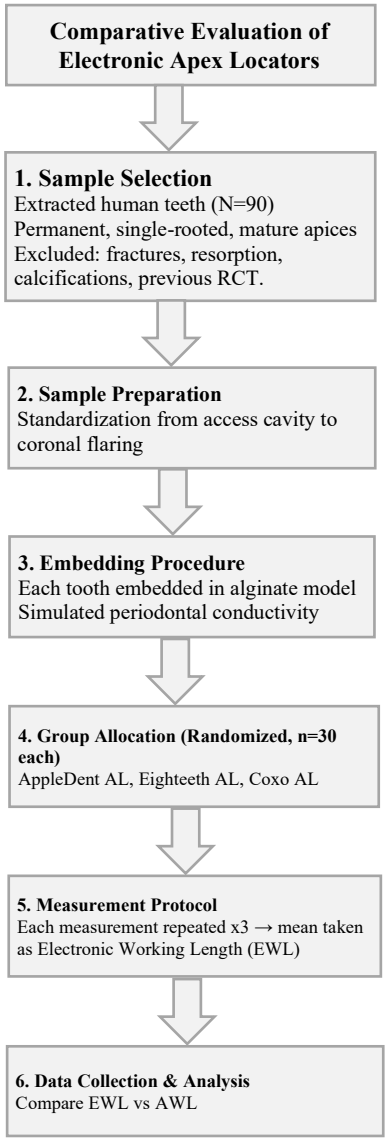

Figure 3: Flow diagram illustrating the study design, encompassing sample selection, preparation, grouping, measurement methodology, and data collection/analysis.

Results

Analysis was based on 90 measurements (N = 90, n = 30 per group). The AWL, determined under magnification, was used as the final reference standard for comparing with the EW length (EWL) acquired by three EALs: Eighteeth AL (Changzhou Sifary Medical Technology Co., Ltd., Jiangsu, China), Coxo AL (Foshan Coxo Medical Instrument Co., Ltd., Guangdong, China), and AppleDent AL (AppleDent, Hong Kong, China).

Mean differences (EWL – AWL) and standard deviations are summarized in Table 1. Eighteeth AL had a tendency to overestimate canal length, with the highest mean positive deviation (0.41 mm). The absolute mean deviations of Coxo AL and AppleDent AL were lower (0.24 mm). For Coxo AL, variability was lower (SD = 0.33 mm) than in AppleDent AL (SD = 0.58 mm). The accuracy of all 3 EALs tested was clinically acceptable at determining the working length. Coxo AL presented the best compromise between accuracy and precision, AppleDent AL displayed similar mean values but a higher variance; Eighteeth AL made overestimations of working length points that were significantly greater than recorded by the other two devices.

Table 2 summarizes the percentage of measurements within an acceptable clinical tolerance (±0.5 mm and ±1.0 mm) limits. AppleDent AL showed the least proportion at ±0.5 mm (50.0%) but reached 90% at 1.0 mm. Coxo AL presented a higher precision of 0.5 mm (86.7%), and Eighteeth AL showed an intermediate value (73.3%). When the matching tolerance was increased to 1.0 mm, both Coxo AL and Eighteeth AL achieved 100% accuracy.

The One-way ANOVA showed that mean deviations differed significantly between the nine subjects ($p = 0.012$). Post hoc analysis by Tukey's multiple comparisons test disclosed significant difference between Eighteeth AL and Coxo AL ($p < 0.018$), as well as between Eighteeth AL and AppleDent AL ($p < 0.027$), while the difference observed in Coxo AL vs. AppleDent AL was not statistically significant with $p = 0.64$ (Table 3).

Table 1: Mean differences (EWL – AWL) accompanied by standard deviations (mm) for the three electronic apex locators.

Apex locator	Mean difference (mm) ± SD
Eighteeth AL	0.41 ± 0.27
Coxo AL	0.24 ± 0.33
AppleDent AL	0.24 ± 0.58

Table 2: The precision of the three apex locators falls within acceptable tolerance limits.

Apex locator	≤ ±0.5 mm (n/30, %)	≤ ±1.0 mm (n/30, %)
Eighteeth AL	22/30 (73.3%)	30/30 (100%)
Coxo AL	26/30 (86.7%)	30/30 (100%)
AppleDent AL	15/30 (50.0%)	27/30 (90.0%)

Table 3: Results of one-way ANOVA and Tukey's post hoc pairwise comparisons for mean differences (EWL – AWL).

Pairwise comparison	Result
Eighteeth AL vs AppleDent AL	p = 0.027 (significant)
Eighteeth AL vs Coxo AL	p = 0.018 (significant)
Coxo AL vs AppleDent AL	p = 0.640 (NS)

NS = non-significant; AWL = actual working length; EWL = electronic working length.

Discussion

The purpose of this study was to evaluate the precision of 3 EALs: AppleDent AL, Eighteeth AL, and Coxo, in determining the working length of extracted teeth. The findings showed that Coxo AL was the most accurate within ±0.5 mm, AppleDent AL exhibited more dispersion than the other groups, and Eighteeth AL predominantly overestimated WL. All devices achieved clinically acceptable accuracy when in their optimal position (±1.0 mm). The rationale behind this research was the growing uncertainty surrounding the accuracy of newer, commercially available EALs, many of which enter the market without strong independent evaluation. Because clinicians depend on precise WL determination for predictable outcomes, comparing these devices under similar conditions was necessary to clarify their reliability. This study provides missing evidence and helps contextualize how each EAL performs in practice.

Accordingly, the null hypothesis of no significant differences among the three devices was partially rejected. There was a significant difference between Eighteeth AL and both AppleDent AL and Coxo AL, but no significant difference between AppleDent AL and Coxo AL.

Regarding Eighteenth AL, the overestimation is of clinical importance through causing apical perforation and removal of irrigation or filling materials, followed by periapical tenderness[14-15]. Similar results have been found in previous in-vitro studies highlighting the device-specific differences in impedance algorithms[16-19]. The high accuracy of Coxo AL is in accordance with other laboratory evaluations of next-generation EALs. AppleDent AL was inconsistent in performance, though mean values were similar; a shortfall was identified in other studies involving new devices[19-22].

The results are consistent with the previous studies showing that there is a general reliability of ±1.0 mm for most electronic apex locators[23-26]. Although significant differences were reported in different models by standardized protocols, with most adopting technological improvements, independent validation is still essential before implementing them into clinical settings[27-28].

From the treatment viewpoint, Coxo AL appears to be the most reliable for apical precision. Eighteenth AL is acceptable within ±1.0 mm but should be verified by radiograph to avoid iatrogenic errors of over-instrumentation. AppleDent AL may perform adequately in simple canals; however, its high variability limits its suitability for complex canal anatomies.

The in-vitro design of this study, while controlled, cannot fully replicate the complex biological conditions present in vivo, where periapical tissue resistance, irrigant dynamics, and ongoing structural changes can influence EAL performance. Our sample was limited to single-rooted teeth with fully developed apices, so the findings may not translate seamlessly to multi-rooted teeth or immature root forms. These factors should be considered when extrapolating the results to real-world clinical scenarios.

Further study should include controlled clinical trials, evaluation in difficult conditions (curvatures, resorption), and comparison with standard devices such as root ZX or raypex across different centres.

Conclusion

All three electronic apex locators evaluated in this in-vitro study—AppleDent AL, Eighteeth AL, and Coxo AL—demonstrated clinically acceptable accuracy within ±1.0 mm. Coxo AL exhibited the most reliable overall performance, showing high accuracy and the lowest variability, with 86.7% of measurements falling within ±0.5 mm. AppleDent AL produced mean values comparable to Coxo AL but showed substantially greater variability, indicating less consistent measurement stability. Eighteeth AL achieved 100% accuracy within ±1.0 mm but consistently overestimated the working length and demonstrated significantly higher mean deviation compared with the other two devices. Within the limitations of this in-vitro design, Coxo AL appears to provide the most predictable measurements, whereas readings from AppleDent AL and Eighteeth AL may require greater clinical caution due to variability and overestimation, respectively.

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. Tsesis I, Blazer T, Ben-Izhack G, Taschieri S, Del Fabbro M, Corbella S, et al. The precision of electronic apex locators in working length

determination: A systematic review and meta-analysis of the literature. J Endod. 2015;41(11):1818-23.
3. Pirani C, Camilleri J. Effectiveness of root canal filling materials and techniques for treatment of apical periodontitis: A systematic review. Int Endod J. 2023;56 Suppl 3:436-54.
4. Broon NJ, Palafox-Sánchez CA, Estrela C, Camarena DCS, Uribe M, Ceja I, et al. Analysis of electronic apex locators in human teeth diagnosed with apical periodontitis. Braz Dent J. 2019;30(6):550-4.
5. Patel S, Durack C, Abella F, Shemesh H, Roig M, Lemberg K. Cone beam computed tomography in endodontics: A review. Int Endod J. 2015;48:3-15.
6. Przesmycka A, Tomczyk J. Differentiation of root canal morphology: A review of the literature. Anthropol Rev. 2016;79(3):221-39.
7. Mourão PS, Fernandes IB, Moreira LV, Machado GF, Falci SG, de Souza GM, et al. Conventional methods and electronic apical locator in determining working length in different primary teeth: Systematic review and meta-analysis of clinical studies. Evid Based Dent. 2025;26(2):116.
8. Golkar S, Khademi A, Saatchi A, Ghorani A, Iranmanesh P. Factors influencing the accuracy of electronic apex locators: A scoping review. Dent Res J. 2025;22:26.
9. Santhosh L, Raiththa P, Aswathanarayana S, Panchajanya S, Reddy JT, Susheela SR. Influence of root canal curvature on the accuracy of an electronic apex locator: An in vitro study. J Conserv Dent Endod. 2014;17(6):583-6.
10. 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(4):232-6.
11. Yolagiden M, Ersahan S, Suyun G, Bilgec E, Aydin C. Comparison of four electronic apex locators in detecting working length: An ex vivo study. J Contemp Dent Pract. 2018;19(12):1427-33.
12. Mahmoud O, Awad Abdelmagied MH, Dandashi AH, Jasim BN, Tawfik Kayali HA, Al Shehadat S. Comparative evaluation of accuracy of different apex locators: Propex IQ, Raypex 6, Root ZX, and Apex ID with CBCT and periapical radiograph-In vitro study. Int J Dent. 2021;2021:5563426.
13. Baruah Q, Sinha N, Singh B, Reddy PN, Baruah K, Augustine V. Comparative evaluation of accuracy of two electronic apex locators in the presence of contemporary irrigants: an in vitro study. J Int Soc Prev Community Dent. 2018;8(4):349-53.
14. Monteiro Czornobay LF, de Oliveira Rocha A, Leite CC, Menezes Dos Anjos L, Ribeiro JS, Pacheco de Castro Henriques BA, et al. A global overview on electronic apex locator use from 1968 to 2023: a bibliometric analysis. J Endod. 2024;50(7):925-33.
15. Abdullah AO. A survey of root canal treatment in Kurdish community: A pilot study. Polytech J. 2024;14(2):8.
16. Mosleh H, Khazaei S, Razavian H, Vali A, Ziaei F. Electronic apex locator: A comprehensive literature review, part I: Different generations, comparison with other techniques and different usages. Dent Hypotheses. 2014;5(3):84-97.
17. Dutlu D, Yilmaz A. Apex locators and apical resorption. Int Dent J. 2024;74:S310.
18. Venturi M, Breschi L. A comparison between two electronic apex locators: an in vivo investigation. Int Endod J. 2005;38(1):36-45.
19. Shirazi ZA, Saleh AR. Electronic apex locators and their implications in contemporary clinical practice: A review. Open Dent J. 2023;17(1):1-10.
20. Mancini M, Palopoli P, Iorio L, Conte G, Cianconi L. Accuracy of an electronic apex locator in the retreatment of teeth obturated with plastic or cross-linked gutta-percha carrier-based materials: an ex vivo study. J Endod. 2014;40(12):2061-5.
21. Chogle S, Zuaitar M, Sarkis R, Saadoun M, Mecham A, Zhao Y. The Recommendation of cone-beam computed tomography and its effect on endodontic diagnosis and treatment planning. J Endod. 2020;46(2):162-8.
22. D'Assunção FL, Silva JR, Arnaud KC, Leite TB, dos Santos JP, de Almeida AC. Evaluation of the effect of irrigants on the accuracy and repeatability of three electronic apex locators: An ex vivo study. Res Soc Dev. 2021;10(3):1-8.
23. de Morais AL, de Alencar AH, Estrela CR, Decurcio DA, Estrela C. Working length determination using cone-beam computed tomography, periapical radiography and electronic apex locator in teeth with apical periodontitis: A clinical study. Iran Endod J. 2016;11(3):164-8.
24. Ahmad IA, Pani SC. Accuracy of electronic apex locators in primary teeth: a meta-analysis. Int Endod J. 2015;48(3):298-307.
25. Khandewal D, Ballal NV, Saraswathi MV. Comparative evaluation of the accuracy of 2 electronic Apex locators with conventional radiography: An ex vivo study. J Endod. 2015;41(2):201-4.
26. ElAyouti A, Dima E, Ohmer J, Sperl K, von Ohle C, Löst C. Consistency of apex locator function: a clinical study. J Endod. 2009;35(2):179-81.
27. Çalışkan MK, Kaval ME, Tekin U. Clinical accuracy of two electronic apex locators in teeth

with large periapical lesions. Int Endod J. 2014;47(10):920-5.

28. D'Assunção FL, Silva JR, Arnaud KC, Leite TB, dos Santos JP, de Almeida AC. Comparative evaluation of the accuracy of electronic apex locator and digital radiography for working length determination in primary teeth: A systematic review. J Dent (Shiraz). 2024;25(13):203-14.