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ACCURACY AND CLINICAL APPLICATIONS OF ELECTRONIC APEX LOCATORS IN PRIMARY TEETH: A SCOPING REVIEW

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ABSTRACT

Background: Accurate working length determination is critical in pediatric endodontics due to anatomical variability and physiological root resorption in primary teeth. Electronic apex locators (EALs) offer a radiation-free and efficient alternative to conventional radiography; however, their accuracy remains under scrutiny. **Objective:** To map and evaluate the diagnostic accuracy, clinical applications, and advancements of various generations of electronic apex locators in primary teeth. **Methods:** A scoping review was conducted according to the Joanna Briggs Institute framework and reported following PRISMA-ScR guidelines. Studies published between January 2014 and May 2025 were identified through electronic searches of PubMed, EBSCO and Google Scholar using keywords such as "*electronic apex locator*", "*working length*", "*tooth apex*", and "*primary teeth*". In vitro and in vivo studies in English assessing EAL use in primary teeth were included. **Results:** A total of[14] studies were included (9 in vitro, 5 clinical). Third-generation apex locators, especially the Root ZX series, showed high accuracy. Fifth and sixth-generation devices demonstrated potential advantages in fluid-filled canals and in cases of apical root resorption. Results varied across devices and canal conditions. Few studies evaluated newer EALs or the effect of irrigants on accuracy. **Conclusions:** EALs are reliable tools for working length determination in primary teeth. Third-generation devices dominate the literature, though newer generations show promise. Further high-quality clinical studies are needed to assess their performance under varied canal conditions.

KEYWORDS: Clinical accuracy; Electronic apex locator; Odontometry; Primary teeth; Tooth apex; Working length.

INTRODUCTION

Working Length (WL) estimation is essential in maintaining the integrity of the periapical area during an endodontic procedure.[1] The success of an endodontic procedure considerably depends on an accurate estimation of the length of the root canal of the primary tooth.[2] It's particularly critical in primary teeth, since over-instrumentation and over-filling of a primary tooth can damage the permanent tooth germ, and under-instrumentation and under-filling are risk factors that account for persistence of apical infection.[3]

The root canal anatomy of deciduous molars is tortuous compared to permanent teeth. Physiological resorption starts soon after the complete formation of the root, even while hard tissue deposition continues to alter the root canal framework. In this way, the shape, dimension, and position of the root apex are constantly modified, posing a challenge for pediatric dentists to determine the exact working length in the primary teeth.[4]

The manual method of working length determination measures the length of a tooth's root canal using physical measurements and tactile feedback. The conventional strategies of determining the working length of primary teeth include looking for moisture/blood at the tip of the paper point and determining the average length of the tooth.[5] Routine radiography or the digital tactile sense approach are common methods utilized to determine the working length. There are a few challenges with both of these. Additionally, since the tooth is three-dimensional (3D) and the image obtained from the radiograph is two-

dimensional (2D), errors in the estimation of working length are inevitable.[4]

One of the advancements that brought electronic science into the traditionally empirical field of endodontics is the Electronic Apex Locator (EAL). When anatomic structures mask the apical portion of the canal, electronic apex locators play a great role. Electronic apex locators are better for pediatric endodontic procedures since they do not cause pain, shorten treatment duration, and help avoid excessive radiation exposure. As a result, they are advised for pediatric endodontic therapy.[6]

The success of EALs has reportedly been shown to be adversely affected by a number of factors, depending on the generation of EAL used, including metallic restorations, excessive electrolytes, blood or exudate in the canal, caries, saliva, endodontic instruments in adjacent canal, debris accumulation in the canal, and calcifications.[7] The various advantages and disadvantages of different generations of apex locators are summarized in Table 1. In spite of widespread use, there remains clinical uncertainty with respect to EAL accuracy in primary teeth, especially in the presence of root resorption and damp canals, making this review timely and relevant.

This scoping review aims to assess the diagnostic accuracy, advantages, limitations, and clinical applications of different generations of electronic apex locators in primary teeth.

REVIEW METHODOLOGY

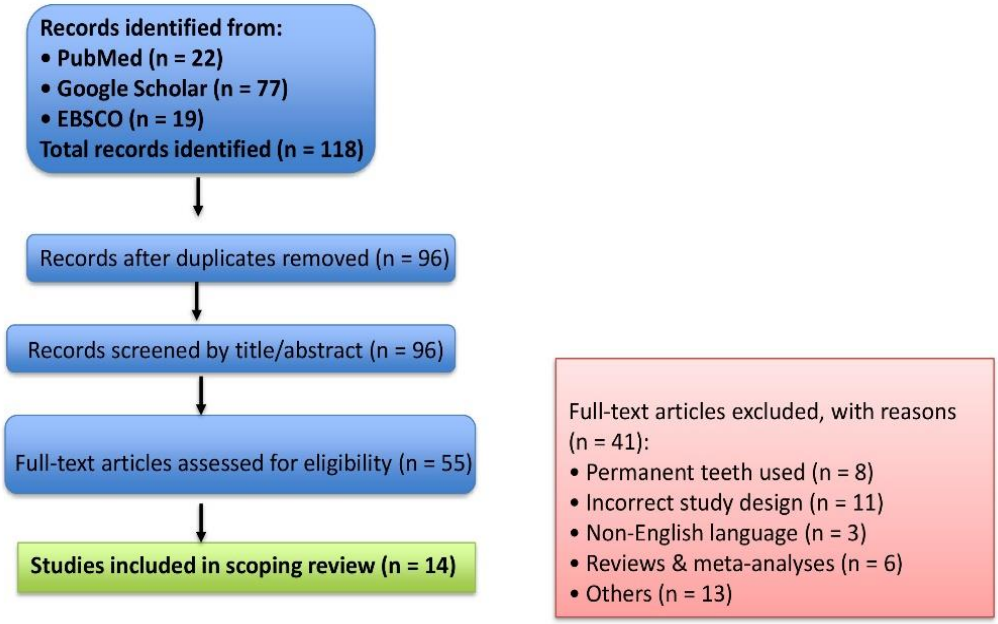
This scoping review was conducted in accordance with the Joanna Briggs Institute (JBI) framework and reported as per the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews) guidelines.

Eligibility Criteria

We included both in vitro studies and clinical trials that used an Electronic Apex Locator (EAL) in primary teeth for working length determination published between January 2014 and May 2025. Studies published only in the English language were considered. Studies including any permanent teeth were excluded.

Search strategy

An electronic literature search was conducted using MEDLINE (*PubMed*), EBSCO, and *Google Scholar* for articles published between January 2014 and May 2025. Search terms included *'electronic apex locator'*, '*working length'*, *'tooth apex',* and '*primary teeth'.* The search yielded 118 results. After removing duplicates, 96 records were found. One reviewer screened these record according to the Title and abstact and 55 full-text articles were assessed for eligibility and finally 14 studies (9 in vitro and 5 clinical) were included in this Scoping Review.



PRISMA Flowchart of Included Studies.

Table 1: Summary of various generations of apex locators.[8,9,10]

Generation	Working principle	Advantages	Disadvantages	Examples
I generation	*Resistance-based apex locators*	• Easy to operate • Digital readout • Detects perforations	• Requires a dry environment • There should be no caries or defective restorations • Requires calibration • Requires a lip clip with good contact	Endodontic Meter S II (Quinki Medical Co), Sono Explorer (Salatec, India), Neosono-D, MC, and Ultima EZ (Amadent), Dentometer (Dahlin Electromedicine, Copenhagen, Denmark), and the Endo Radar (Electronica Liarre, Imola, Italy)
II generation	*Impedance-based apex locators*	• Operates in a fluid environment • No lip clip • Detects bifurcated canals • Detects perforations	• Technique sensitive • Error-prone • Requires coated probes, which are affected by autoclaving • Requires calibration • Electroconductive materials give inaccurate readings	Sono-Explorer(Hayashi Dental Supply, Tokyo, Japan), Endocater (Yamaura Seisokushu, Tokyo, Japan), Formatron IV (Parkell Dental, Farmingdale, NY, USA), and Digipex II
III generation	*Frequency-based apex locators*	• Powerful microprocessors • Simultaneously measures two impedances at two frequencies • Operates most accurately when the canal is filled with electrolyte	• Needs "reset" or "calibrated" for each canal • Sensitive to the canal fluid level	Endex/Apit, The Neosono Ultima EZ (Satelag Inc., Mount Laurel), Justy II (Yoshida Co., Tokyo, Japan), Mark V Plus(Moyco/ Union Broach, Bethpage, USA), Endy 5000(Loser, Leverkusen, Germany)
IV generation	*Frequency ratio-based apex locators*	• Built-in electronic pulp tester.	• They perform better in relatively dry or partially dried canals. • Cannot be used if there are heavy exudates or blood.	Apex Finder, Elements Diagnostics Unit(Sybron), ROOT ZX II, and PROPEX II
V generation	*Multiple-frequency-based- based apex locators*	• Best accuracy in any root canal condition (dry, wet) • Accurate detection in case there are exudates or weeping canals	• Reduced accuracy or malfunction in dry canals. • Some models require frequent recalibration/resetting. • Lack of standard definition for "5th generation" → causes terminology confusion and product comparison issues.	EMF 100DELUX, JOYPEX 5
VI generation	*Adaptive type apex locators*	• Accurate readings even in the presence of electrolytes • Highest consistency for measurements in the case of root perforation or apical root resorption.	• Limited clinical evidence proving superiority over advanced 5th-gen devices. • Possible accuracy dips in extremely dry canals • Higher cost and complexity. • Less user familiarity and limited troubleshooting support.	DTE Dpex (Woodpecker, Guilin, China)

Working principle of EAL

The working length of a root canal is determined by comparing the electrical impedance of the periodontal membrane with that of the oral mucosa. This can be achieved by using an Electronic Apex Locator, which consists of two ends: one end, called a "lip hook," or a “lip clip” which is placed in contact with the patient's oral mucosa, while the other end, known as the "file holder," is connected to an endodontic instrument, such as a K-file or a rotary file. The endodontic file is gradually inserted into the root canal until it reaches the estimated working length. When the file makes contact with the soft tissues of the periodontal membrane, the electrical resistance readings for both the oral mucosa and the periodontal ligament will be similar. (Fig. 1) By measuring the depth of insertion of the endodontic file, the exact working length of the root canal can be determined.[9,10]

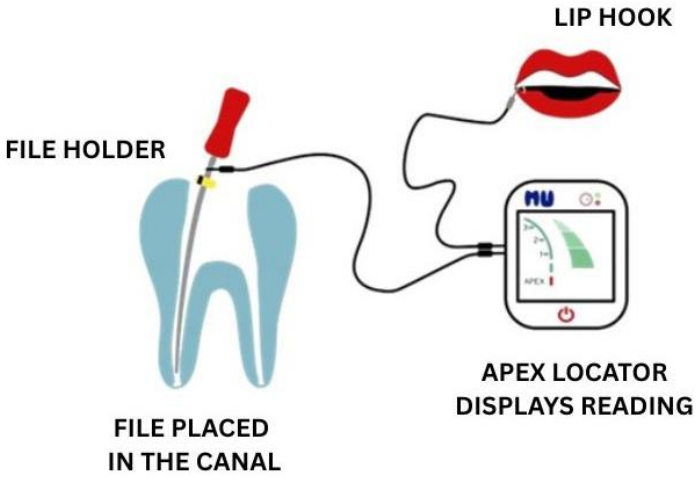


Fig. 1: Working principle of electronic apex locators.

Table 2: IN Vitro Studies Done on Primary Teeth.

INVESTIGATOR	DEVICE USED	COMPARED WITH	RESULTS
Bahrololoomi Zahra et al[11] (2015)	Root ZX	In-vitro comparison with direct visual measurements, radiography, and EAL n = 50 extracted primary anterior teeth with root resorption	Accuracy of EAL (86%), accuracy of radiographs (76%)
Oznurhan F et al[12] (2015)	EndoMaster	In-vitro comparison of EAL with radiography n = 32 human primary molar teeth (96 roots)	The accuracy of EndoMaster was 80.2%
Ghule KD, Naik S.[4] (2019)	CanalPro™	In vitro comparison of cone-beam computed tomography and electronic apex locator n = 99 primary teeth (207 root canals)	The CBCT method was more accurate, but statistically insignificant
Sahni A et al[2] (2020)	DentaPort ZX	Comparative Evaluation of Efficacy of Electronic Apex Locator, Digital Radiography, and Conventional Radiographic Method n = 90 extracted, single-rooted primary teeth were selected.	The accuracy of EAL was observed to be 99.7% followed by digital radiograph (98.1%) and conventional radiograph (96.1%).
Talukdar A et al[13] (2021)	Apex D.S.P.	In vitro comparison of cone-beam computed tomography and electronic apex locator in the presence of three different irrigating solutions, namely 0.9% saline, 0.2 % chlorhexidine, and 2.5 % sodium hypochlorite n=45 primary molars (canals chosen randomly)	Significant difference in working length determination using apex locator in the presence of saline and chlorhexidine when compared to sodium hypochlorite. Additionally, the working length determination using CBCT did not show any significant difference.
F Katge et al[14] [b](2021)	Propex® II	Comparison of Apex Locator, Digital Radiovisiography and Cone Beam	EAL method performed best for working length determination

		Computed Tomography n = 78 canals, from 30 primary molars (maxillary- 15, mandibular 15)	in primary teeth as compared to RVG, and CBCT techniques.
Shibin J et al[15] (2022)	Woodpex III	In vitro evaluation of the working length determination accuracy by cone-beam computed tomography in primary teeth n = 60 root canals from 34 extracted primary teeth were included.	EAL demonstrated 87% accuracy, compared to 63% for the radiographic method, when CBCT was used as the reference standard.
Topçuoğlu G et al[16] (2023)	Root ZX - mini	In vitro evaluation of the accuracy of an electronic apex locator in the presence of Sodium Hypochlorite (NaOCl) in primary teeth with and without resorption. n = 64 extracted primary lower molar teeth with 32 root resorption and 32 without resorption were selected.	The presence of NaOCl in the root canal affected the accuracy of the Root ZX mini in primary teeth with apical resorption, but not in teeth without resorption.
Oncu A et al[17], (2024)	Wirele-X DentaPort ZX Woodpex III	In vitro study n = 30 extracted primary mandibular molar teeth	No significant differences in the accuracy rate of DentaPort ZX, Wirele-X, and Woodpex III in the determination of the working length set at ± 0.5 mm and ± 1 mm, respectively ($P > 0.05$).

Table 3: Clinical Studies Done on Primary Teeth.

INVESTIGATOR	DEVICE USED	COMPARED WITH	RESULTS
Abdullah A et al[18] (2016)	Dentaport ZX Propex II	In vivo evaluation of two different varieties of electronic apex locators and radiovisiography (RVG) n = 30 primary teeth indicated for pulpectomy in children aged 3 to 8 years	Radiovisiography and apex locators are equally effective in determining working length in primary teeth.
De Alencar et al[19] (2019)	Root ZX	Clinical evaluation of electronic apex locator and conventional radiography in primary molars. n= 64 children (192 canals) between 5 and 9 years of age.	No statistically significant difference between both the methods.
Nellamakkada K et al[19] (2020)	Propex Pixi Formatron D10	Clinical evaluation of two electronic apex locators and conventional radiography n = 115 mandibular primary second molars indicated for pulpectomy in 90 pediatric dental patients.	Both the apex locators were as accurate as conventional radiography with Formatron D10 being more precise than Propex Pixi.
Davalbhakta RN et al[20] (2021)	Root ZX - mini	Comparative evaluation of apex locator and radiovisiography in determining the working length of primary molars n = 30 primary molar teeth	Both Root ZX mini and radiovisiography are seen to be precise in the determination of working length in primary molars.
Suguna et al[21] (2021)	Propex Pixi	Comparative evaluation of apex locator and Digital radiography in determining the working length of primary molars n = 30 primary mandibular molar teeth in children aged 4-10 years	No significant difference between both the methods

DISCUSSION

The main goal of endodontic therapy in the primary dentition is to preserve it as a natural space maintainer until its permanent successor erupts. Pulpectomy becomes the recommended choice of treatment in such conditions, which involves the complete extripation of the coronal and radicular pulp tissue. This procedure has many potential challenges, including accurate estimation of working length.[23]

Multiple factors can affect the determination of working length in primary teeth, such as the presence of complex root canal anatomy, physiological resorption of the roots, developmental status of the successor tooth, age, and the maturity status of the child, which can make this procedure a hassle.[24] The most common method for estimation of WL is Ingle's radiographic method, Although, measurement by this method is generally one or a half-millimeter (mm) short of the radiographic apex,

where the apical constriction is generally thought to be located.

Since the tooth is a three-dimensional object and the radiographic method can only provide two-dimensional images, it poses a major disadvantage. Advanced radiographic methods, such as Cone Beam Computed Tomography (CBCT), have proven to be effective; however, they have the drawbacks of requiring patient compliance, being costly, and exposing patients to radiation.[4] Also, not every clinical setting might be equipped with the same, and hence it does not come in handy.

Since the development of Electronic Apex Locators (EALs) by Sunada in 1962, they have proven to be an effective and reliable tool for working length measurements in primary teeth pulpectomies as they do not cause any pain, eliminates the radiation exposure, reduces chair side time and is a portable device making it versatile to be used in various clinical settings.[12] In a previous meta-analysis done by Vitali et al,[25] showed a tendency of the electronic measurement to differ by ± 0.5mm from the comparison methods.

The literature is ambiguous about the use of EALs in primary teeth. A study done by Bahrololoomi et al[11] (2015) concluded that the accuracy of EAL was 86% while the radiography method showed 76% accuracy. Sahni and co-authors[2] (2020) compared EAL, conventional radiography and digital radiography and found accuracy of 99.7%, 96.1% and 98.1% respectively. Three in vitro studies (Ghule KD[4], 2019), (Katge F et al[14], 2021), and (Shibin J.[15], 2022) compared EALs with Cone Beam Computed Tomography (CBCT). While the study by Ghule KD[4], 2019 concluded that CBCT is better, Katge F et al[14] stated that EAL method performed the best which was contradictory. Meanwhile, Shibin et al[15] stated that accuracy of EALs and CBCT was 87% and 63% respectively.

Nasiri K et al[24], in their systematic review involving studies conducted in permanent teeth, concluded that all the generations are equally effective. But, as the 5th and 6th generations have an advantage of better accuracy in weeping canals and in presence of apical resorption, they should be considered for use in primary teeth. There are a limited number of studies (Angwaravong O, et al.[3] 2009), (Talukdar et al.[13] 2021) and (Topçuoğlu G, et al.[16] 2023) considering the resorption status and the presence of irrigating solutions within the canals, both of which can impact the accuracy. Talukdar et al.[13] 2021 stated that measurements of the APEX DSP (Septodont, France) were more precise in the presence of 0.9 % saline and 0.2% chlorhexidine gluconate. The presence of NaOCl solution in the canal almost inhibited its working ability, indicating that when the canals were filled with strong electrolytes, the results were negatively affected.[13] While Topçuoğlu G, et al.[16] 2023 concluded that the presence of NaOCl affected the accuracy of the apex locator only in teeth with resorption, which might be due to the absence of a definitive apical constriction and not due to the electroconductivity of the solution.[16]

Limitations and Future Directions

The main limitations in the current research on electronic apex locators (EALs) for primary teeth stem from variability in device brands and generations, with most studies focusing on third-generation models despite more advanced options being available. Study outcomes can be influenced by complex canal anatomy, root resorption, and different irrigating solutions, leading to some conflicting results—particularly when compared with CBCT. Therefore, future research should prioritize comprehensive clinical trials evaluating newer-generation EALs in various canal conditions, standardize protocols to allow meaningful comparison, and further investigate how anatomical and environmental factors affect device accuracy. Addressing practical aspects like user training, troubleshooting, and cost-effectiveness will also be crucial to optimizing the clinical utility of EALs in pediatric dentistry.

CONCLUSION

Electronic Apex Locators (EALs) offer an accurate, non-invasive, and efficient method for determining root canal working length in primary teeth. Third-generation devices, like Root ZX, have shown the best results overall, although conflicting evidence exists when compared with CBCT and among different EAL generations. EALs reduce discomfort and chairside time for pediatric patients, making them a valuable clinical tool.

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