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The evaluation of the accuracy of a wireless electronic apex locator in primary molar teeth

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Abstract

Background The working length determination is necessary before root canal shaping, chemical cleaning, disinfection, and obturation in pulpectomy of primary dentition. This study aimed to evaluate the accuracy of Wirele-X and compare it with DentaPort ZX and Woodpex III in primary molar teeth.

Methods The in vitro study was performed by using 30 extracted primary mandibular molar teeth. In distal roots, the actual working length was determined by taking forward a #10 K-type canal file under a dental operating microscope with 10x magnification. Each tooth and lip clip were embedded in alginate before determining the working lengths using electronic apex locators. The average of three electronic working lengths was calculated for each sample, and the actual working length was subtracted from the electronic working length.

Results There were 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 ($P > 0.05$).

Conclusions This study reported that DentaPort ZX, Wirele-X, and Woodpex III can be safely used in the pulpectomy of primary molars. Wirele-X can provide an advantage in working length determination in children because of its wireless feature.

Keywords Working length, Electronic apex locators, Primary teeth

Introduction

Pulpectomy is a treatment approach for maintaining the function of primary teeth in case of irreversible pulpitis or necrosis [1]. The working length determination is necessary before root canal shaping, chemical cleaning, and disinfection, thus obturation in endodontic procedures of primary dentition [2]. However, the anatomical and morphologic variations in primary teeth cause disadvantages in working length determination [1, 3, 4].

These variations include physiologic root resorption, coronal shift of the apical foramen, increased diameter of the apical opening, ramifications, lateral and accessory canals [2, 3, 5]. Otherwise, the prognosis of root canal treatment in primary teeth may become unfavorable, and there is a possibility that irrigation agents and root canal filling materials may be extruded beyond the apex. Accordingly, the periapical tissues and the permanent tooth germ may be negatively affected due to over-instrumentation [2, 4]. In contrast, inadequate instrumentation can result in treatment failure along with the persistence of existing infection. Therefore, the working length determination is critical for the success of treatment prognosis in primary root canals [5, 6].

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The periapical radiographic technique is based on subjective interpretations and operator sensitivity in working length determination [7]. In addition, two-dimensional radiographs can contain image distortions and errors, and the exact location of the apical foramen cannot be determined [8]. To overcome the disadvantage of radiographic techniques in reaching precise results, electronic apex locators (EAL) were introduced to the endodontic field [9].

EALs work on the principle of electrical resistance shown by the apical foramina region rather than visual inspection. Throughout the history of dentistry, EALs have been developed in each generation to address the shortcomings of the previous ones [10]. Root ZX II (J Morita Corp., Tokyo, Japan) was introduced to the dental market as EAL which measured impedance values simultaneously at two different frequencies, calculated them with high precision, and had automatic calibration features [11]. Root ZX II is known as the gold standard for determining canal length in root canal treatment of permanent teeth [12]. The DentaPort ZX (J Morita Corp., Tokyo, Japan) device consists of two modules. Root ZX module is used for root canal measurement and the Tri-Auto OTR module is used for root canal preparation.

Woodpex III (Woodpecker Medical Instrument Co, Guilin, China) has also entered the dental market as a multi-frequency device, recently [13]. The Wirele-X, which has a wireless Bluetooth connection with the file holder tip and the lip clip parts to the EAL screen, is produced by the Forum Tec company (Forum Tec, Ashkelon, Israel). There is no cable connection between the patient and the EAL [14]. Although several studies have evaluated Woodpex III and Wirele-X accuracy in the literature, no study has been conducted on primary teeth. This study aimed to evaluate the accuracy of DentaPort ZX, Wirele-X, and Woodpex III in primary molar teeth.

Methods

Ethics approval statement and guidelines

All stages of the current research were carried out with the approval of Ankara University, Faculty of Dentistry Ethics Committee (decision number: 12/12, date: 06.11.2023). The study protocol was conducted in accordance with the ethical principles for medical research (involving human participants, including research using identifiable human material or data) of World Medical Association (WMA) Declaration of Helsinki. Also, this study was conducted according to the CRIS guidelines (Checklist for Reporting In Vitro Studies) that guide in vitro experimental studies [15]. In this study, before the primary teeth were extracted and collected, parents and children were informed in detail and the parents signed informed consent forms. The reasons for the teeth extraction were regardless of the present study.

Sample size and power analysis

To determine the number of teeth to be used in the study, sample size calculation was made in the G*Power analysis program (Franz Faul, Universität Kiel, Kiel, Germany). It was found that at least 30 samples (per group) were required to detect statistical significance at 90% power and 5% type I error.

Sample preparation, inclusion, and exclusion criteria

The present in-vitro study was performed by using 30 extracted primary second mandibular molar teeth. The teeth were collected and stored in distilled water containing thymol crystals until the experimental procedure. Before the sample selection, periapical radiographs were taken, and root canals were examined. Also, fractures and cracks on the root surface were examined under a dental operating microscope at x40 magnification. All samples were selected according to limited (not exceeding one-third) or no root resorption based on Kramer and Ireland [16]. Caries cavities (if present) extended below the cementoenamel junction were excluded from the study protocol. Teeth with the root resorption level exceeding 1/3 were also not included to this research. Additionally, after periapical radiographic examination, teeth with internal and external root resorption and intracanal calcification were excluded. Teeth including microcracks and fracture lines on the root surfaces under the operating microscope were also excluded from the study protocol. Teeth with physiological oblique root resorption were included, however, samples with the dimension of the apical foramen not larger than #10 K-file diameter were excluded. In the study procedures, first, the samples were separated from the border of the cementoenamel junction for standardization and to obtain repeatable reference points. Accordingly, the samples were numbered randomly, and the actual working length of the distal root was determined by taking forward a #10 K-type canal file under a dental operating microscope (Carl Zeiss, Germany) with 10x magnification until the file tip was visible through the apical foramen (Fig. 1). The stopper of the instrument was moved to the flat reference point and fixed with cyanoacrylate. To ensure precision in measurements, it was measured using a digital caliper (150 mm Mitutoyo, Kanagawa, Japan) with a precision of 0.01 mm.

Working length determination using EALs

All the EAL measurements were performed by a single operator (A.O.) with at least 5 years of experience in the field of endodontics. Each tooth and lip clip were embedded in alginate (Hydrogum 5, Zhermack, Italy). as previously described by Lipski et al. to determine working lengths using electronic apex locators (EAL) [17]. Subsequently, 5.25% sodium hypochlorite (Cerkamed Medical Company, Stalowa Wola, Poland) was to the root canal

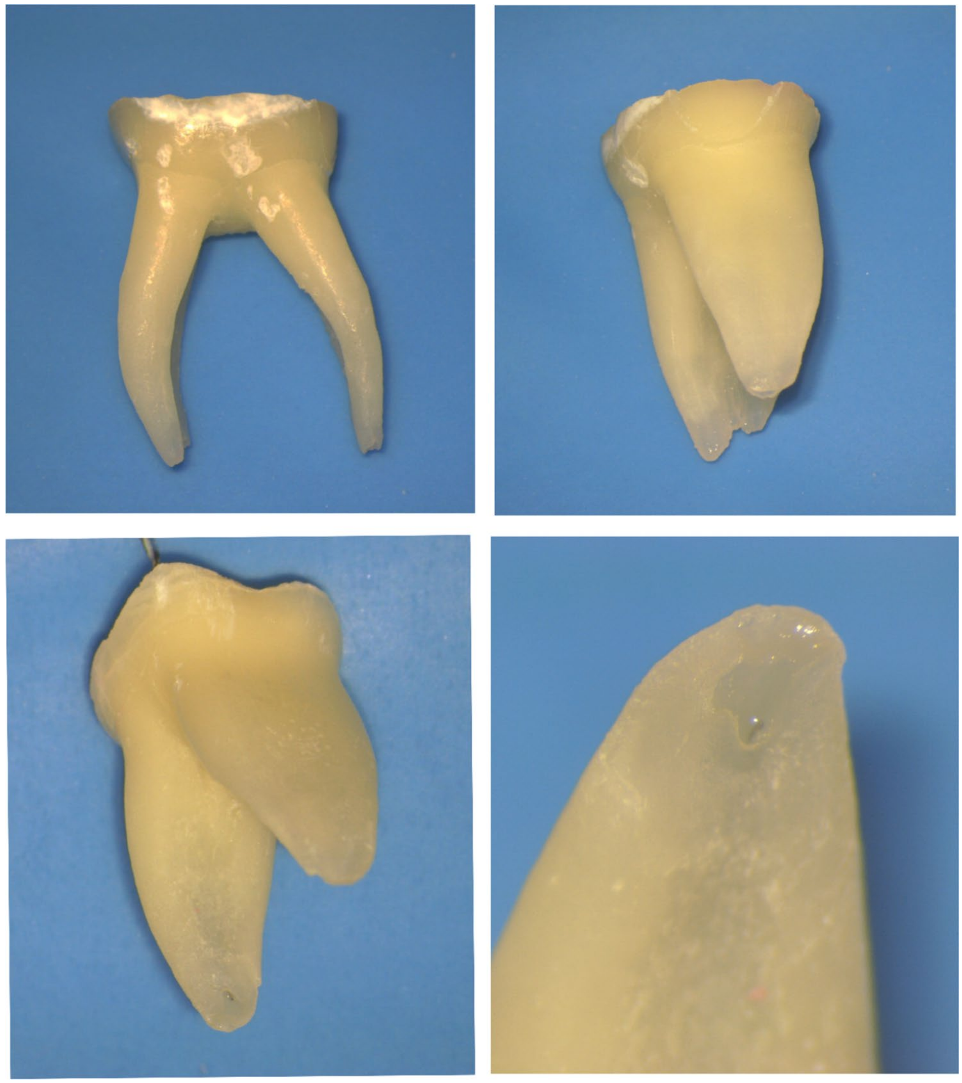

Fig. 1 Primary mandibular molar tooth images under the dental operating microscope

before measurements. A #10 K-type hand file (Micro-Mega, Besancon France) was advanced into the canal until the file tip indicated that it was beyond the apical foramen (red indicator bar), as per the manufacturer's instructions [18]. The file tip was then retracted until the last green indicator bar for DentaPort ZX (J. Morita, Tokyo, Japan) and Woodpex III (Woodpecker Medical Instrument Co, Guilin, China). In addition, the file was retracted until the "APEX, 0" point that first red indicator bar for Wirele-X (Forum Tec, Ashkelon, Israel). The WL determination was completed if the indicator of the device remained at the "APEX, 0" point for continued 5 s (Fig. 2). The stopper was adjusted and fixed at the reference point. The EAL measurements were repeated three times for each sample using the same digital caliper, and the results were recorded. All procedures were completed within 2 h of mixing the alginate.

The average of the electronic working lengths obtained from three separate measurements for each sample was calculated and the actual working length was subtracted from the electronic working length. Positive values indicated measurements that exceeded the actual working length, whereas negative values indicated measurements that were shorter than the actual working length. The results obtained for each sample were categorized into 6 groups as follows (Table 1). The number and percentage of samples in each range were calculated.

Statistical analysis

For each group, the distances to the minor foramen were divided into 6 groups at a level of 0.5 mm, and frequency analysis was performed to determine the accuracy rate of the electronic apex locators. The normality of the data distribution was assessed by means of the Kolmogorov-Smirnov test. One-way analysis of variance (ANOVA)

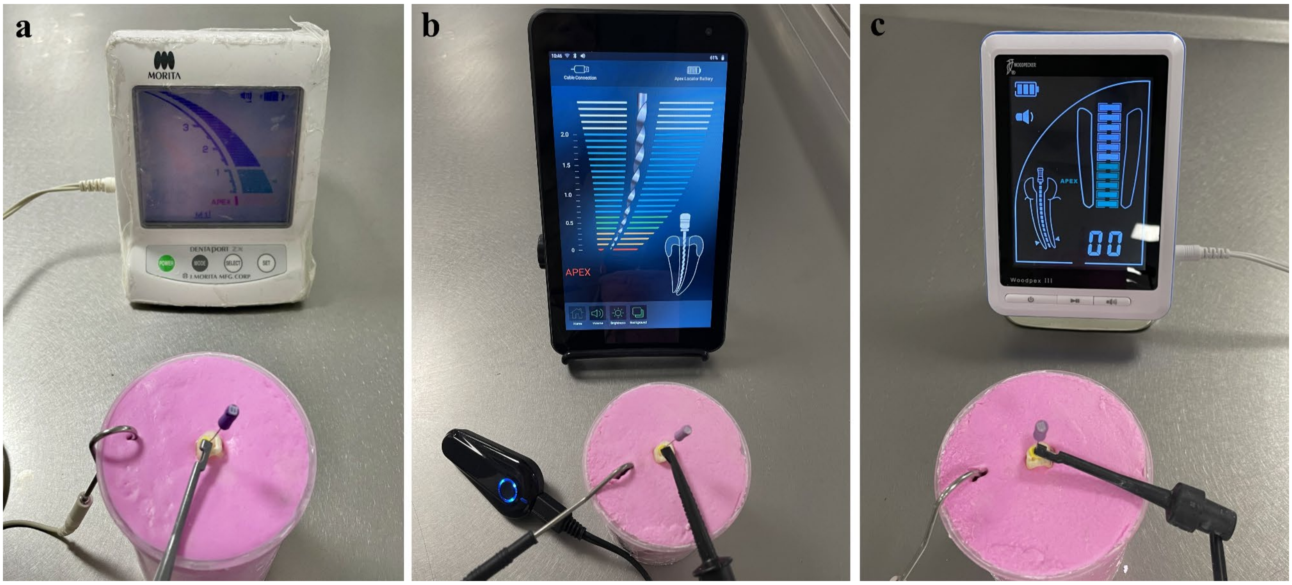

Fig. 2 Experimental models in measurements with each EAL a; Root ZX II, b; Wirele-X, c; Woodpex III

Table 1 The samples were categorized according to the following ranges

≤ -1.1	-1.0 -0.51	-0.5-0.0	0.01–0.5	0.51-1.0	≥ 1.1

was used to evaluate significant differences between tested electronic apex locators at the 95% confidence interval, within values of ±0.5 and ±1, respectively. The significance level was set at $p \leq 0.05$.

Results

There was no significant difference in the accuracy rates of DentaPort ZX, Wirele-X and Woodpex III in determining the working length within the limits of ±0.5 mm and ±1 mm, respectively ($P > 0.05$). According to the measurement results of EALs, the percentage and number of samples in each range were shown in Table 2. In terms of precision measurement percentage, DentaPort ZX showed an accuracy rate of 56.66% range ±0.5 mm and 90% range ±1 mm. In terms of precision measurement percentage, Wirele-X showed an accuracy rate of 56.66% range ±0.5 mm and 93.33% range ±1 mm. In terms of precision measurement percentage, Woodpex III showed an accuracy rate of 56.66% range ±0.5 mm and 90% range ±1 mm. Figure 3 demonstrated the distances from the apical foramen of all samples for each EAL.

Discussion

The accurate working length should be determined in primary teeth to prevent over-instrumentation and ensure optimum chemo-mechanical cleaning of the root canal system [1, 3, 19]. However, determining the working length has become a challenging situation for clinicians in primary molars because of factors such as complex root canal anatomy, continuous change in the shape and dimensions, resorption in the apical third, and hard tissue deposition [20].

Recently, the frequent use of EALs in root canal treatment procedures for primary teeth has been reported in scientific studies [18, 20]. These studies have shown that EALs are highly accurate even in the presence of physiological root resorption, eliminate exposure to ionising radiation, prevent anatomical superposition on

Table 2 The number of samples within ±0.5 ($p = 0.183$) and ±1 mm ($p = 0.876$) range in measurement with EALs

Distance from minor foramen	DENTAPORT ZX	WIRELE-X	WOODPEX III
≤ -1.1	*n* = 0	*n* = 2 (6.66%)	*n* = 3 (%10)
-1 – –0.51	*n* = 4 (13.33%)	*n* = 9 (33.33%)	*n* = 9 (%33.33)
-0.5–0.0	*n* = 9 (30%)	*n* = 13 (43.33%)	*n* = 10 (%33.33)
0.01– 0.5	*n* = 8 (26.66%)	*n* = 4 (13.33%)	*n* = 7 (%23.33)
0.51–1	*n* = 6 (20%)	*n* = 2 (6,66%)	*n* = 1 (%3.33)
≥ 1.1	*n* = 3 (10%)	*n* = 0	*n* = 0
in -0.5 – 0.5 range	*n* = 17 (56.66%)	*n* = 17 (56.66%)	*n* = 17 (56.66%)
in -1 – 1 range	*n* = 27 (90%)	*n* = 28 (93.33%)	*n* = 27 (90%)

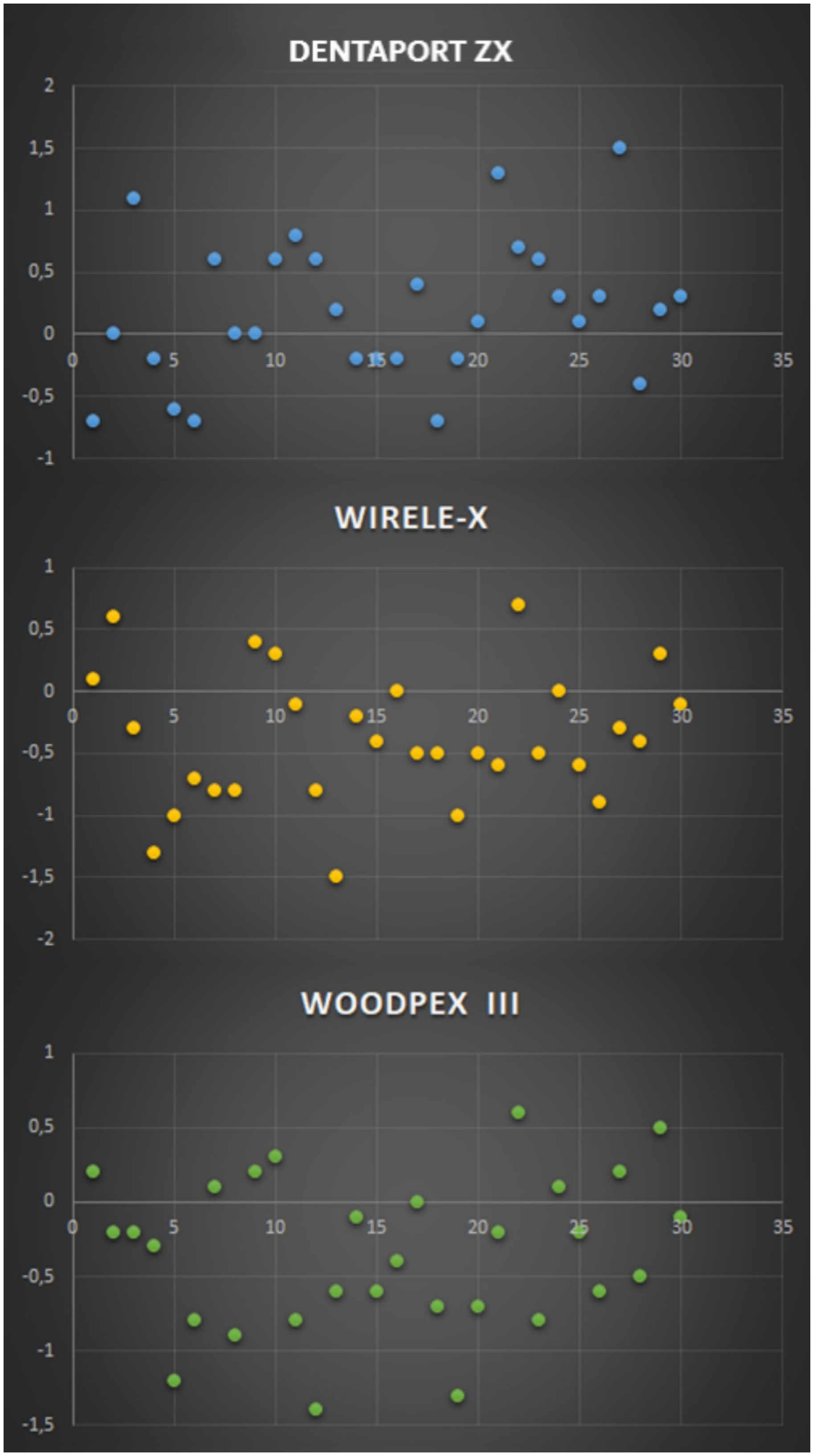

Fig. 3 The graphic represents distances from the apical foramen of all samples for each EAL

radiographs leading to misinterpretation, and avoid subjective interpretation errors [20–22].

The present study evaluated and compared the accuracy of DentaPort ZX, Wirele-X, and Woodpex III in determining the working length in the lower primary molar teeth Dentaport ZX is a third-generation EAL and measures using the ratio method based on 2 different frequencies [23]. Woodpex and Wirele-X are included in the fifth generation of EALs and have a measurement method that uses mathematical processing in addition to frequency-based measurement [24, 25]. This experimental study was conducted in an in vitro environment, and the alginate model method was chosen, which has been successfully applied in previous studies [26, 27]. The actual working lengths were determined by direct observation under a dental operating microscope, and apical patency in the distal roots was verified using #10 K-files.

The minor apical foramen is known as the apical border of the root canal preparation [28]. However, in primary teeth, root canals do not often show a well-defined apical construction because of the physiological root resorption process [29]. Root resorption can occur pathologically or physiologically, which may negate endodontic treatment [30]. Physiological root resorption is intermittent. Sometimes rest periods are observed, characterized by cementum accumulation on the resorbed root surface. All processes result in changes in the shape, size, and position of the root apex in primary teeth [22, 31]. According to Oznurhan et al., measurements may be affected when the apical dimension is wider, and the file does not have contact with the apical walls around the root canal [30]. There is electrical impedance in the dentin wall of the radicular canal and the thickness of the dentin tissue layer decreases as the apical third is approached, which may reduce the electrical insulation capacity [32]. Although there is an opinion that file size does not affect the accuracy of electronic apex locator measurements [33], the EAL reading is more accurate when the file adapts better to the apical canal walls [34]. From a clinical perspective, the apical region in primary teeth changes continuously because of root resorption, and a more coronal endpoint is clinically acceptable according to the comprehensive meta-analysis by Ahmad and Pani [20]. Some studies have reported that a range of up to 1 mm in root canal preparation was considered clinically acceptable in primary teeth [8, 35–37]. Electronic measurements of primary teeth obtained from the root canal tip with an accuracy of up to 0.5 mm are accepted to be quite accurate [29].

This study showed that DentaPort ZX had a high accuracy rate in primary molars, similar to previous studies [37, 38]. Besides, the accuracy rate was observed to be 99.7% in the study of Sahni et al. [39] On the other hand, there has been no study on Woodpex III and Wirele-X in primary teeth in the literature. According to our results, there was no significant difference between DentaPort ZX, Wirele-X, and Woodpex III within the ± 0.5 mm and ± 1 mm limits. In two different previous studies [14, 25] no differences were found in permanent teeth between the accuracy of Root ZX II and Wirele-X.

Mostly, it is extremely difficult to obtain intraoral radiographs to determine working length while the instrument is in the canal because of limited access to the mouth and poor cooperation in children [31]. The use of EALs in the pediatric dentistry clinic offers benefits as a method that is fast, safe, and most importantly does not require radiation [40]. In addition, Wirele-X can provide an advantage for children as there is no cable connection between the patient and the device screen because it is a Bluetooth-enabled device. The fact that the wireless apex locator device included in this study was found to be as effective as the conventional alternatives may also lead to different gains in pediatric dentistry.

Recently, with the increasing importance given to keeping natural primary teeth in the mouth, root canal treatment of primary teeth and the success of these clinical procedures are increasing [1]. In this context, it is thought that wireless equipment will be useful in shortening the chair time in endodontic treatments of pediatric dental patients and in providing more effective treatment modalities. As authors, we recommend that the wireless EAL used in this study be evaluated as an alternative and that the presented findings be supported by further clinical prospective studies to strengthen the behavioral models of pediatric dental patients and increase their cooperation in routine clinical procedures.

This study had some limitations. The periapical tissues and permanent tooth germ could not be reflected and included in the study protocol because it was conducted under in-vitro conditions with extracted primary teeth. On the other hand, due to the in-vitro nature of the present study, the different root canal morphology of each sample included in the methodology, anatomical and morphological variations, and ramifications, especially in primary root canals, the fact that the widening apical opening in primary teeth is not as standardized as in permanent teeth are other limitations of this study. In further studies, the wireless apex locator and different EALs need to be compared with clinical studies in the pediatric population.

Conclusion

Pulpectomy prevents early tooth loss in childhood and is more conservative than the extraction of primary teeth. This experimental study reported that DentaPort ZX, Wirele-X, and Woodpex III can be safely used in the pulpectomy of primary molars. Wirele-X can provide an advantage in working length determination in children because of its wireless feature.

Abbreviations

EAL	Electronic apex locators
WMA	World Medical Association
CRIS	Checklist for reporting in-vitro studies
ANOVA	One-way analysis of variance
p	Probability value
mm	Millimeter
n	Number

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None.

Author contributions
B.C. and A.D. contributed to the study's conception and design. A.O. and E.S. performed material preparation and experimental procedures. A.O. and E.C. performed the data analysis The first draft of the manuscript was written by A.O. and A.D. All authors (A.O., E.C., A.D., and B.C.) commented on previous versions of the manuscript. All authors (A.O., E.C., A.D., and B.C.) reviewed and approved the final manuscript.

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Data availability
The data supporting this study's findings are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
The study protocol was approved by the Local Ethics Committee of Ankara University, Faculty of Dentistry (decision number: 12/12; decision date: 06.11.2023). Also, before the primary teeth were extracted and collected, parents and children were informed in detail and the parents signed informed consent forms. Also, the study protocol was conducted in accordance with the ethical principles for medical research (involving human participants, including research using identifiable human material or data) of World Medical Association (WMA) Declaration of Helsinki.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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References

1. Moskovitz M, Tickotsky N. Pulpectomy and root canal treatment (RCT) in primary teeth: techniques and materials. Pediatric endodontics: current concepts in pulp therapy for primary and young permanent teeth. 2016:71–101.
2. Shibin J, Prathima G, Suganya M, Nandhakumar S, Adimoulame S, Kavitha M. Evaluation of the working length determination accuracy by cone-beam computed tomography in primary teeth. Int J Clin Pediatr Dent. 2022;15(Suppl 1):S92.
3. Ahmed H. Anatomical challenges, electronic working length determination and current developments in root canal preparation of primary molar teeth. Int Endod J. 2013;46(11):1011–22.
4. Paradiso D, Tullio A, Bensi C. Working length determination in primary teeth pulpectomy: a systematic review and meta-analysis. Aust Endod J. 2023;49(2):444–54.
5. Tabassum S, Khan FR. Failure of endodontic treatment: the usual suspects. Eur J Dent. 2016;10(01):144–7.
6. Alencar NAd, Vitali FC, Santos PS, Bolan M, Cardoso M. Influence of the method for determining working length on the obturation level of primary molars. Braz Oral Res. 2022;36:e086.
7. Tittle M, Dunlap CA, Scott R, Arias A, Davis S, Peters O. Accuracy of the KontrolFlex AccuFile when used with the Root ZX electronic apex locator in vitro. Aust Endod J. 2022.
8. Mello-Moura ACV, Moura-Netto Cd, Araki A, Guedes-Pinto AC, Mendes FM. Ex vivo performance of five methods for root canal length determination in primary anterior teeth. Int Endod J. 2010;43(2):142–7.
9. Suguro H, Nishihara A, Tamura T, Nakamura T, Toyama Y, Takeichi O. The use of micro-computed tomography to determine the accuracy of electronic working length with two apex locators. J Oral Sci. 2021;63(2):167–9.
10. Leonardo MR, Silva LABd, Nelson-Filho P, Silva RABd, Lucisano MP. Ex vivo accuracy of an apex locator using digital signal processing in primary teeth. Pediatr Dent. 2009;31(4):320–2.
11. Cury MTS, Vasques AMV, Bueno CRE, Machado T, Trizzi JQ, Santana VS et al. Accuracy of Root ZXII, E-PEX and FIND apex locators in teeth with vital pulp: an in vivo study. Braz Oral Res. 2021;35.
12. Aguiar BA, Reinaldo RS, Frota LMA, do Vale MS, Vasconcelos, BCd. Root ZX electronic foramen locator: an ex vivo study of its three models' precision and reproducibility. Int J Dent. 2017;2017.
13. De-Deus G, Cozer V, Souza EM, Silva EJNL, Belladonna FG, Simões-Carvalho M, et al. Clinical Accuracy and Precision of 3 Multifrequency Electronic Apex Locators assessed through Micro–Computed Tomographic Imaging. J Endod. 2023;49(5):487–95.
14. Brand L, Dunlap CA, Scott R, Arias A, Peters O. An in vitro evaluation of the WIRELE-x electronic apex locator. Aust Endod J. 2023;49:41–5.
15. Krithikadatta J, Gopikrishna V, Datta M. CRIS guidelines (Checklist for reporting In-vitro studies): a concept note on the need for standardized guidelines for improving quality and transparency in reporting in-vitro studies in experimental dental research. J Conserv Dent. 2014;17(4):301.
16. Kramer W, Ireland R. Measurements of the primary teeth. J Dent Child. 1959;26:252–61.
17. Lipski M, Trąbska-Świstelnicka M, Woźniak K, Dembowska E, Droździk A. Evaluation of alginate as a substitute for root-surrounding tissues in electronic root canal measurements. Aust Endod J. 2013;39(3):155–8.
18. Bhat KV, Shetty P, Anandakrishna L. A comparative evaluation of accuracy of new-generation electronic apex locator with conventional radiography to determine working length in primary teeth: an in vivo study. Int J Clin Pediatr. 2017;10(1):34.
19. Wankhade AD, Kumar R, Singh RK, Chandra A. Root canal length determination by different methods in primary teeth: an in vivo study. Pediatr Dent. 2013;35(2):E38–42.
20. Ahmad I, Pani S. Accuracy of electronic apex locators in primary teeth: a meta-analysis. Int Endod J. 2015;48(3):298–307.
21. Krishnan IS, Sreedharan S. A comparative evaluation of electronic and radiographic determination of root canal length in primary teeth: an in vitro study. Contemp Clin Dent. 2012;3(4):416.
22. Nellamakkada K, Patil SS, Kakanur M, Kumar RS, Thakur R. A clinical evaluation of two electronic apex locators and conventional radiography in working length determination in primary molar and its influence on children's behavioral responses. J Indian Soc Pedod Prev Dent. 2020;38(2):158–63.
23. Nasiri K, Wrbas KT. Accuracy of different generations of apex locators in determining working length; a systematic review and meta-analysis. Saudi Dent J. 2022;34(1):11–20.
24. Monisha R, Sivakumar A, Chittrarasu M, Sampath SJ, Soundappan SP, Benny R. Comparative evaluation of accuracy of working length determination with fifth-generation apex locator using two different techniques: an *in vitro* study. J Conservative Dentistry Endodontics. 2024;27(3):240–5.
25. De-Deus G, Cozer V, Souza EM, Silva EJNL, Wigler R, Belladonna FG, et al. Micro-CT study of the in vivo accuracy of a wireless electronic apex locator. J Endod. 2022;48(9):1152–60.
26. Mohan M, Verma MR, Jain AK, Rao RD, Yadav P, Agrawal S. Comparison of accuracy of Dentaport ZX, Rootor and E-Pex pro electronic apex locators in two simulated clinical conditions: an in vitro study. J Conserv Dent. 2022;25(1):58.
27. Oliveira TN, Vivacqua-Gomes N, Bernardes RA, Vivan RR, Duarte MAH, Vasconcelos BC. Determination of the accuracy of 5 electronic apex locators in the function of different employment protocols. J Endod. 2017;43(10):1663–7.
28. Saatchi M, Rahimi I, Khademi A, Farhad AR, Nekoofar MH, Dummer PM. Influence of tooth length on the accuracy of the Root ZX electronic apical foramen locator: an ex vivo study. Acta Odontol Scand. 2015;73(2):101–6.

29. Vitali FC, Santos PS, Cardoso M, Massignan C, Garcia LFR, Bortoluzzi EA, et al. Are electronic apex locators accurate in determining working length in primary teeth pulpectomies? A systematic review and meta-analysis of clinical studies. Int Endod J. 2022;55(10):989–1009.
30. Oznurhan F, Ünal M, Kapdan A, Ozturk C, Aksoy S. Clinical evaluation of apex locator and radiography in primary teeth. Int J Paediatr Dent. 2015;25(3):199–203.
31. Bodur H, Odabaş M, Tulunoğlu Ö, Tinaz AC. Accuracy of two different apex locators in primary teeth with and without root resorption. Clin Oral Investig. 2008;12:137–41.
32. Pinheiro SL, Bincelli IN, Faria T, da Silveira Bueno CE, Cunha RS. Comparison between electronic and radiographic method for the determination of root canal length in primary teeth. RSBO. 2012;9:11–6.
33. Odabaş ME, Bodur H, Tulunoğlu O, Alaçam A. Accuracy of an electronic apex locator: a clinical evaluation in primary molars with and without resorption. J Clin Pediatr Dent. 2011;35(3):255–8.
34. Garg N. Amit Garg. *Working Length Determination*. Textbook of Endodontics. 4th edition. Jaypee Brothers Medical Publishers. 2019.
35. Tosun G, Erdemir A, Eldeniz A, Sermet U, Sener Y. Accuracy of two electronic apex locators in primary teeth with and without apical resorption: a laboratory study. Int Endod J. 2008;41(5):436–41.
36. Beltrame A, Triches T, Sartori N, Bolan M. Electronic determination of root canal working length in primary molar teeth: an in vivo and ex vivo study. Int Endod J. 2011;44(5):402–6.
37. Saritha S, Uloopi K, Vinay C, Chandra Sekhar R, Rao V. Clinical evaluation of Root ZX II electronic apex locator in primary teeth. Eur Arch Paediatr Dent. 2012;13:32–5.
38. Adriano L, Barasuol J, Cardoso M, Bolan M. In vitro comparison between apex locators, direct and radiographic techniques for determining the root canal length in primary teeth. Eur Arch Paediatr Dent. 2019;20:403–8.
39. Sahni A, Kapoor R, Gandhi K, Kumar D, Datta G, Malhotra R. A comparative evaluation of efficacy of electronic apex locator, Digital Radiography, and Conventional Radiographic Method for Root Canal Working length determination in primary teeth: an *in Vitro* Study. Int J Clin Pediatr Dent. 2020;13(5):523–8.
40. Kayabasi M, Oznurhan F. Evaluation of the accuracy of electronic apex locators, cone-beam computed tomography, and radiovisiography in primary teeth: an in vitro study. Microsc Res Tech. 2020;83(11):1330–5.

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