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ORIGINAL ARTICLE

Accuracy of two different apex locators in primary teeth with and without root resorption

Haluk Bodur · Mesut Odabaş · Özlem Tulunoğlu · Ali Cemal Tinaz

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Abstract The objective of this study was to assess the accuracy of two frequency apex locators, Root ZX (Morita, Kyoto, Japan) and Endex (Osada, Tokyo, Japan) in primary teeth with and without root resorption in vitro. For this study, 90 sound extracted primary teeth (60 molars and 30 incisors; 93 roots with visible resorption and 51 roots without) were selected. A total of 144 root canals were included. After access preparation, root canal lengths were measured visually. The teeth were embedded in an alginate model developed specifically for testing apex locators. Electronic length was determined with two different frequency apex locators, Root ZX (Morita, Kyoto, Japan) and Endex (Osada, Tokyo, Japan). Statistical evaluation was performed using Mann–Whitney *U* and Wilcoxon *W* tests ($p<0.05$). Results revealed that both apex locator devices did not show similar values to visual length measurements with statistically significant differences in primary teeth with root resorption ($p<0.05$). For the teeth without root resorption, Endex showed similar values to visual length measurements with no statistically significant differences ($p>0.05$), but Root ZX values were different than visual length and the differences were statistically significant ($p<0.05$). There were no significant differences between the two apex locators considering the presence of root resorption. The two frequency apex locators can be recommended for use in root canal therapy for primary teeth with and without root resorption, only if electrical determination of root canal length is supported with other diagnostic measures.

Keywords Apex locator · Primary teeth · Root ZX · Endex

H. Bodur · M. Odabaş (✉) · Ö. Tulunoğlu
Department of Pediatric Dentistry,
University of Gazi Faculty of Dentistry,
8. Cadde 82. Sokak, Emek,
06510 Ankara, Turkey
e-mail: mesut@gazi.edu.tr

A. C. Tinaz
Faculty of Dentistry,
Department of Operative Dentistry and Endodontics,
University of Gazi,
Ankara, Turkey

Introduction

Root canal treatment helps to maintain the integrity of primary dentition until normal exfoliation when their pulps become infected. Early loss of primary teeth and untreated endodontic pathology can cause a number of problems [1, 6, 29]. For successful endodontic treatment of primary teeth, the root canal length should be determined exactly [16]. Moreover, it is important to determine the root canal length in primary dentition to avoid injury to the succedaneous tooth bud.

For permanent teeth, the traditional method of determining endodontic working length is to place a file approximately 1 mm short of the radiographic apex as determined either from an initial radiograph or from tactile sense [15]. But, in primary dentition, the exact location of the actual apex remains difficult to determine because of hard tissue deposition and root resorption. Root resorption by odontoclasts is a characteristic feature of primary teeth. Most of the resorption is physiological root resorption with eruption of permanent successors. However, there is also pathological root resorption with apical periodontitis due to infection by microorganisms, dental trauma, or excessive orthodontic force. Root resorption is not continuous and has resting periods, which sometimes showed cementum deposition in the resorbed root surface [2, 5, 11, 12, 14]. These processes

change the shape and the position of the root apex. For these reasons, the combinations of tactile sense and radiography have important limitations to estimate the ideal length. Moreover, in children, it is often very difficult to get intraoral radiographs to measure the root canal length because of poor cooperation and limited access to the mouth [22]. The use of apex locators during endodontic therapy might potentially decrease the radiation exposure to children by reducing the number of radiographs required for successful endodontic therapy [3].

Since their introduction, the new generation electronic apex locators have gained in popularity. Most electronic measuring devices are based on the theory of Sunada [27]. Suzuki et al. [28] first reported the use of an apex locator in clinical endodontics. Determination of root canal length with new generation electronic apex locators is well established and is being used to a greater extent in permanent teeth [7–10, 17]. Investigators who carried out in vivo and in vitro studies with apex locators on primary teeth with and without root resorption previously concluded that electronic apex locators are safe, painless, and useful because it avoids unnecessary radiation. Therefore, it is recommended for use in primary teeth [3, 16, 18, 22].

A comparative analysis was made between two frequency electronic apex locators in primary teeth with and without root resorption. One is Endex (Osada, Tokyo, Japan), which uses the relative value of the different electric currents 5 and 1 kHz, operating on the principle that impedance measurements of the different frequencies used differ greatly at the area of the apical constriction [24]. The second locator is Root ZX (Morita, Kyoto, Japan), which uses the impedance ratio instead of the impedance difference. This method simultaneously measures impedance values at two frequencies (8 and 0.4 kHz) and calculates a quotient of the impedances [19, 31].

Based on these conclusions, the working hypothesis of the presented study is the accuracy of two apex locators operating with different mechanisms utilized in primary teeth with and without root resorption is reliable.

Materials and methods

For this study, 90 sound extracted primary teeth (60 molars and 30 incisors; 93 roots with visible resorption and 51 roots without), which were stored in saline at 4°C were selected. The molar roots, having more than 1/3 apical root resorption, were excluded from the study. A total of 144 roots were included.

Endodontic access cavities were prepared (Tungsten carbide 1157, SS White Burs, NJ, USA). The root canals were not preflared. For determining visual length of primary teeth, magnifying glasses (×2) (Guangdong Baijia Baiter Industry, China) were used to measure by inserting #10 or #15 K-file until it emerged at the apical foramen. The distance from the file tip to the base of the rubber stop was measured with a caliper (Newman Tools, USA) to the nearest 0.5 mm.

After determining the visual length, primary teeth were embedded in an alginate model developed to test apex locators. Alginate (Blueprint, Denstply, England) was poured into a plastic box and teeth were embedded in the alginate. The root canals were irrigated with 2.5% sodium hypochlorite. The electronic length was determined with the Root ZX and Endex electronic apex locators according to the manufacturer's instructions [30]. The root canal lengths were measured visually first and then with Root ZX and Endex by each investigator independently. The measurements were repeated three times and the average of three measurements was taken as the raw length value. Then, 0.5 mm was subtracted from the raw length measurements and the calculated value was considered as the true working length.

For each root canal, the difference was calculated by subtracting the visually determined length from the electronic length. Positive values indicated that the file in the position passed the apical foramen; negative values indicated that the file tip was short of the apical foramen. The mean values of visually determined root canal lengths and electronic lengths were calculated. Statistical evaluation was carried out using Mann–Whitney U and Wilcoxon W tests. Interexaminer reliability was assessed using the Kappa statistics.

Results

Interexaminer reliability was maintained by examinations of the same 30 measurements by 2 examiners and the records were compared with each other to obtain at least 0.95 agreements between the 2 examiners in teeth with or without resorption.

Without root resorption

Table 1 shows the mean scores and SDs of the visually determined lengths and electronic lengths of Root ZX and Endex in primary teeth without resorption. A statistically significant difference was found between canal lengths obtained by Rooth ZX and visually determined root canal lengths ($p<0.05$). No statistically significant differences were found between canal lengths obtained by Endex and visually determined root canal lengths ($p>0.05$). For teeth without root resorption, there were no significant differences between the two devices Root ZX and Endex (Table 2).

We found the accuracy of Root ZX as 54.9% and 70.6% within ±0.5 and ±1 mm, respectively, of the visually

Table 1 The median, Q_1 (25%) and Q_3 (75%) values for visually determined lengths and electronic lengths of Root ZX and Endex in primary teeth without and with resorption

	Primary teeth without resorption				Primary teeth with resorption			
	N	Median	Q_1 (25%)	Q_3 (75%)	*N*	Median	Q_1 (25%)	Q_3 (75%)
Visually determined length	51	16.56	14.18	17.60	93	16.00	14.47	17.95
Root ZX	51	16.16	13.66	17.64	93	15.52	13.44	17.05
Endex	51	16.20	14.10	17.46	93	15.10	13.55	16.95

determined root canal lengths measurements. For Endex, the accuracy was 58.8% and 72.5% within ±0.5 and ±1 mm, respectively, of the visually determined root canal lengths measurements. Of the Root ZX measurements, 72.5% and of the Endex measurements, 64.6% were up to 3 mm short of visually determined root canal lengths.

With root resorption

Table 1 shows the mean scores and SDs of the visually determined lengths and electronic lengths of Root ZX and Endex in primary teeth with resorption. A statistically significant difference was found between canal lengths obtained by the electronic apex locators and actual canal lengths. For teeth with root resorption, there were no significant differences between the two devices Root ZX and Endex (Table 2). We found the accuracy of Root ZX as 25.8% and 63.4% within ±0.5 and ±1 mm, respectively, of the visually determined root canal lengths measurements. For Endex, the accuracy was 21.5% and 48.4% within ±0.5 and ±1 mm, respectively, of the visually determined root canal lengths measurements. Of the Root ZX measurements, 63.4% and of the Endex measurements, 72.0% were up to 3 mm short of visually determined root canal lengths.

With and without root resorption

For actual canal lengths, no differences were found between resorbed and nonresorbed roots. For the two devices, no significant differences were found between resorbed and nonresorbed roots (Table 2).

Discussion

Root length determination is one of the most important factors in root canal treatment in both permanent and primary teeth [18]. There are no strict rules for the exact measurement of the root canal length in primary teeth. The ideal method used to determine the length is controversial [1, 6].

The traditional radiographic method has some shortcomings, including its inaccuracy [26]. Moreover, in primary teeth, it is difficult to predict the radiographic root canal length because of resorption and hard tissue deposition. Electronic root length determination may be helpful in overcoming the shortcomings of the radiographic method, especially in teeth with root resorption. There are several reports on the superiority of electronic vs radiographic length evaluation methods [19, 20, 25]. Since the main focus of the present study was to evaluate the efficiency and accuracy of two different devices and to compare their results to visually determined root canal length measurements, radiographic evaluations were not included in this study. For determining the visual or actual length of the tooth, a similar method reported in previous studies on apex locators was used [8, 13, 16–18, 21, 30].

There are a few studies on the use of electronic apex locator in primary dentition [16, 18, 22]. One of the most important goals in pediatric endodontics is to prevent damage in the periapical tissues. For this reason, the root canal should extend as far as possible: at least 2/3 of the root canal length or 2 to 3 mm short of the apex because of resorption and hard tissue deposition [4, 23]. Fouad et al. [9] and Wu et al. [32] showed that, with the exception of

Table 2 Results of the statistical analysis

	Visually determined length	Root ZX	Endex	
Visually determined length	$p>0.05$	$p<0.05$	$p<0.05$	Primary teeth with resorption
Root ZX	$p<0.05$	$p>0.05$	$p>0.05$	
Endex	$p>0.05$	$p>0.05$	$p>0.05$	
	Primary teeth without resorption			Primary teeth with and without resorption

p values of tests of measurement types (visually determined length, Root ZX, and Endex) for primary teeth with resorption and primary teeth without resorption, and *p* values for tests of root types vs each other

the smallest areas of foramina, electronic root canal length measurements were shorter than the actual lengths.

According to this approach, Kielbassa et al. [18] found that in 85% of the primary teeth, root canal length determined with the electronic device (Root ZX) were up to 3 mm short of working length. The findings of the present study showed that 72.5% of Root ZX measurements and 64.6% of Endex measurements in primary teeth without root resorption were up to 3 mm short of visually determined root canal lengths. These rates were 63.4% with Root ZX measurements and 72.0% with Endex in the primary teeth with root resorption.

Shabahang et al. [25] suggested that electronic apex locator determination of the length of permanent teeth within ±1 mm should be clinically acceptable. In this study, applying the criteria used by Shabahang et al., Root ZX and Endex showed accuracy of the root canal without resorption within ±1 mm of the visually determined root canal lengths at rates of 70.6% and 72.5%, respectively. In resorbed canals, these rates were 63.4% with Root ZX and 48.4% with Endex. These results pointed out that Root ZX and Endex electronic apex locators have demonstrated similar results for determining the length of primary teeth within ±1 mm in nonresorbed root canals. In nonresorbed root canal groups, Endex showed similar results to visually determined root canal length values, and the difference was not statistically significant ($p>0.05$). In resorbed root groups, the values obtained with Root ZX and Endex were different than visually determined root canal length values ($p<0.05$), although Root ZX values were slightly closer to visually determined root canal length values.

Katz et al. [16] first reported the use of electronic methods in primary dentition; measurements obtained by Root ZX were similar to the actual length (−0.5 mm) and the radiographic measurements were longer (0.4 mm–0.7 mm) than Root ZX measurements. The results of the present study were not in accordance with the findings of Katz et al., as the differences between the actual lengths and Root ZX measurements were significant in primary teeth with and without root resorption.

Mente et al. [22] tested an electronic apex locator to determine root canal length in primary teeth with and without visible root resorption and compared the results with the radiographic length measurement. They suggested that in the presence of root resorption, electrical determination of root canal length might be supported with other diagnostic measures to increase the safety of endodontic treatment.

Kielbassa et al. [18] used Root ZX for measuring root canal length in vivo and found no differences between roots with and without resorption. In this study, considering actual canal lengths and also considering two devices, no differences were found between resorbed and nonresorbed roots. Similar to the findings of Kielbassa et al., it can be concluded that Root ZX was more accurate in nonresorbed roots than resorbed roots.

Conclusion

In this in vitro study, the apex locators did not provide reliable data in primary teeth with and without root resorption. The apex locators that were tested in this study may be recommended for use in primary root canal therapy supported with other diagnostic measures. Further in vivo evaluations of these devices in primary teeth should be carried out.

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