

# 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

Anchal Sahni<sup>1</sup>, Rishabh Kapoor<sup>2</sup>, Kapil Gandhi<sup>3</sup>, Dipanshu Kumar<sup>4</sup>, Geetika Datta<sup>5</sup>, Ritika Malhotra<sup>6</sup>

## ABSTRACT

**Aim:** Pulpectomy in the primary tooth has unique challenges due to morphological variations in root pattern and physiological root resorption. The electronic apex locator (EAL) is one of the recent methods to determine the estimation of working length without much radiation exposure to the patient as well as the operator. The present study was undertaken for evaluating and comparing the efficacy of EAL, conventional radiography, digital radiography, and actual visual method for the estimation of in the root canal working length (RCL) in extracted primary teeth.

**Materials and methods:** Ninety extracted, single-rooted primary teeth were selected. Working length estimation was done with an EAL, conventional, and digital radiographic method, and compared it with an actual visual method.

**Results:** Accuracy of EAL was observed to be 99.7% followed by digital radiograph (98.1%) and conventional radiograph (96.1%). Both EAL and digital radiographic methods showed a high correlation as compared to conventional. The comparative efficacy of an EAL with a visual method was found to be statistically non-significant ( $p > 0.005$ ).

**Conclusion:** Root canal working length determined through the electronic method was found to be an accurate and effective tool in single-rooted primary teeth and can be indicated for clinical implementation in endodontic treatment of primary teeth.

**Keywords:** Digital radiograph, Electronic apex locator, Primary tooth, Working length.

*International Journal of Clinical Pediatric Dentistry* (2020): 10.5005/jp-journals-10005-1821

## INTRODUCTION

Preservation of a primary tooth whose pulp has been endangered is a unique challenge to the pediatric dentist.<sup>1</sup> The preservation of tooth is usually done by performing pulpectomy, a pediatric endodontic procedure, which continues to provide unique challenges to the pediatric dentist to date. The success of an endodontic procedure mainly depends on an accurate estimation of the length of the root canal of the primary tooth. Underestimated working length or overestimated working length can cause unsuccessful treatment and dissatisfaction of both the patient and the dentist.<sup>2</sup> In children, it is relatively difficult to capture a diagnostic radiograph because of their limited cooperation and inadequate access in their oral cavity. Moreover, the formation of periapical pathology, ongoing pathological or physiological resorption, presence of a great number of accessory canals, and presence of successor's tooth provide additional challenges, thereby making it all the more difficult to estimate the correct root canal length in deciduous teeth. Clinically, several techniques have been proposed to establish the working length but the ideal technique is yet to be identified. Ingle described a radiographic method for working length determination which continues to be among the most commonly employed methods but it requires the paralleling technique<sup>3</sup> and also lengthens the appointment time and exposes the patients and the dental personnel to ionizing radiations.<sup>4</sup>

With the advancement in technology, digital radiography allowed a significant reduction in the dosage and exposure time to radiations and image processing, thereby making the endodontic

<sup>1-6</sup>Department of Pedodontics and Preventive Dentistry, Inderprastha Dental College and Hospital, Ghaziabad, Uttar Pradesh, India

**Corresponding Author:** Kapil Gandhi, Department of Pedodontics and Preventive Dentistry, Inderprastha Dental College and Hospital, Ghaziabad, Uttar Pradesh, India, Phone: +91 9811311377, e-mail: drkapilgandhi@gmail.com

**How to cite this article:** Sahni A, Kapoor R, Gandhi K, *et al.* 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):523–528.

**Source of support:** Nil

**Conflict of interest:** None

procedures faster which is desirable in pediatric dental practice. Although both the radiographic methods offer advantages, such as, direct observation of the complex root canal anatomy, the canal curvatures, and the existence of a periapical lesion,<sup>5</sup> there still exists a limitation of radiation exposure. So, to overcome the disadvantages of the above techniques, electronic apex locators (EALs) have been employed clinically to locate the file position in the canal through the determination of apical constriction (AC).<sup>6</sup>

Previous studies using EALs on primary teeth concluded that EAL is safe, painless, accurate, and extremely useful without radiation exposure.<sup>7,8</sup>

The present study was designed and carried out for evaluation and comparison of root canal working length (RCL) determination

methods. Currently, available methods of RCL measurements, i.e., EAL, radiographic techniques (conventional and digital) with the actual length of the canal (visually) in primary teeth were compared and assessed statistically to conclude.

## MATERIALS AND METHODS

The research was conducted in the Department of Pedodontics and Preventive Dentistry. Institutional ethical committee clearance was obtained before conducting the study (IRB no. 2016/2690L).

### Tooth Selection and Preparation

Ninety already extracted human primary teeth samples were selected for conducting the study. No primary teeth were extracted intentionally for the study. Inclusion criteria included samples with no physiological or pathological root resorption exceeding one-third of total root length, no split or crack present in the root. Tooth resorption exceeding one-third of total root length either physiological or pathological or the presence of cracks or splits in root were excluded from the study.

The teeth were immersed in formalin (10% solution) (Fisher Scientific, Mumbai, India) for 7 days. After 7 days, surface cleaning of all the teeth was done to remove organic and inorganic deposits. Then, the teeth were stored in normal saline until usage as suggested by Lee et al.<sup>9</sup> Decoronation was done at the cement-enamel junction using a disk to create a reproducible reference point. Barbed broaches (Dentsply Maillefer, Ballaigues, Switzerland) were used for the debridement of each root canal which was later disinfected with a 3% NaOCl solution (Fisher Scientific, Mumbai, India). The root canal was dried with a paper point (Meta Biomed Co., Ltd., Korea).

### Method 1: Electronic Determination of Root Canal Length

*In vivo* condition was created by embedding all 90 roots in an alginate impression material (Zelgan-2002, Dentsply, India) in a frame specially designed for this purpose as described by Kaufman et al.<sup>10</sup> The contrary electrode of the EAL (DentaPort — ZX, J Morita Mfg. Corp., Kyoto, Japan) was embedded into the alginate block, while the file holder clip was connected along the shaft of a 21-mm size 15K (ISO) file (Dentsply Maillefer, Ballaigues, Switzerland). File with rubber stopper was introduced into the canal and was gradually moved apically into the canal until the machine produced a fixed beeping sound and the light-emitting diode (LED) flashed at the marked reference point (at triangle) as given in the manual (Fig. 1). Then, the 15K (ISO) file was taken out of the canal, and measurement was recorded using a digital Vernier caliper (Fig. 2).

### Method 2: Digital Radiographic Method

The alginate block containing the tooth was positioned parallel to a digital radiograph sensor (Vatech EZ Sensor, Humanray Co. Ltd., Korea) by placing the block and the sensor placed in a custom-made acrylic jig (consisting of a clear acrylic base plate attached to a long cone paralleling attachment which also contains a slot for placing an intraoral dental film or digital radiograph sensor) (Fig. 3). Preoperative working length through digital radiograph was measured (diagnostic radiograph) and then magnification error was checked by doing calibration through an inbuilt option in the software. A no.15K file with a presumed length, as noted from the diagnostic radiograph, was introduced into the canal, and a radiograph was taken (Fig. 4). The difference between

the endodontic file's end and the apex was measured upon the radiograph. This difference was either added or subtracted from the presumed measured length. Thus, the final working length was obtained using a digital Vernier caliper.

### Method 3: Conventional Radiographic Method

The alginate block containing the tooth was again placed in the jig parallel to an intraoral periapical radiograph (IOPAR) film. A preoperative IOPAR was obtained using conventional radiographic film (E Speed, Carestream Health, Inc., USA). Preoperative working length was measured on the radiograph and working length was readjusted according to Ingles technique.<sup>1</sup> After that, reinsertion of no.15K endodontic file was done into the root canal and IOPAR was taken (Fig. 5). The IOPAR film was developed and the final working length was measured with a digital Vernier caliper.

### Actual Visual Method (Control Method)

A no.15K endodontic file with a sliding rubber stopper was passively introduced into the canal (according to the diameter of the canal), until the tip of the file was just visible at the apex/apical foramen or the apical resorption level. The file was gently retracted and RCL was measured using a digital Vernier caliper.

### Statistical Analysis

The collected data were tabularized and were subjected to SPSS version 20 software. A one-way analysis of variance (ANOVA) test was used to compare the three methods in assessing the working length (WL) with the actual visual method ( $p < 0.05$ ).

## RESULTS

The present study comprised 90 extracted single-rooted teeth (samples) and root canal lengths of all the samples were examined by EAL, digital radiography, conventional radiography, and actual visual method, respectively (Table 1).

The mean working length obtained from the EAL was found to be  $10.10 \pm 1.78$  mm with 5.23 mm minimum working length and the maximum working length was 13.83 mm. Mean working length with a conventional radiograph was found to be  $9.78 \pm 1.81$  mm with a minimum of 5.41 mm and a maximum of 13.70 mm. Mean working length with digital radiograph was recorded  $10.08 \pm 2.10$  mm with minimum 5.62 mm and maximum 14.80 mm, whereas the mean working length with the actual visual method was found to

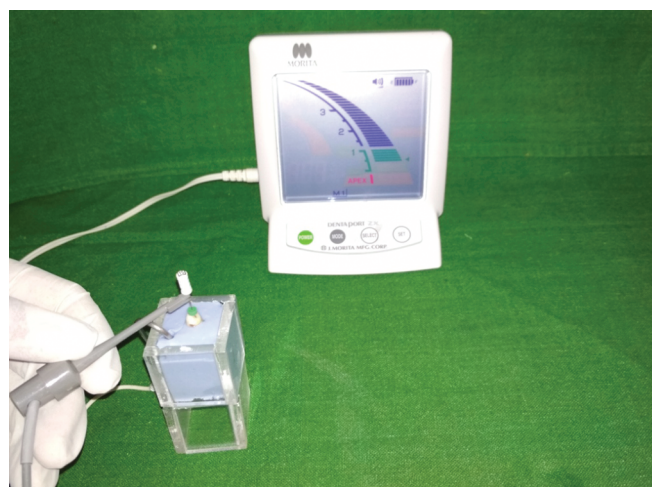


Fig. 1: Working length estimation with electronic apex locator



Fig. 2: File length measurement using a digital Vernier caliper

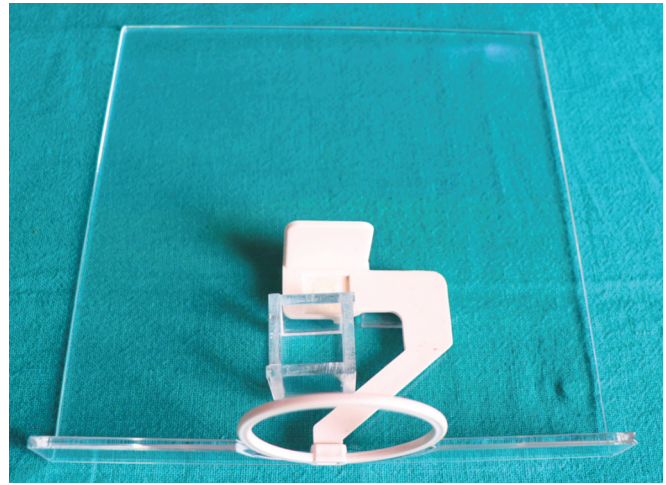


Fig. 3: Jig design

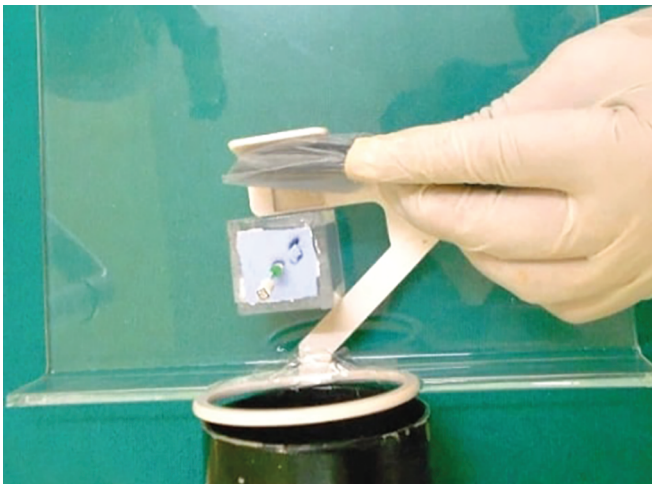


Fig. 4: Working length estimation with digital radiograph

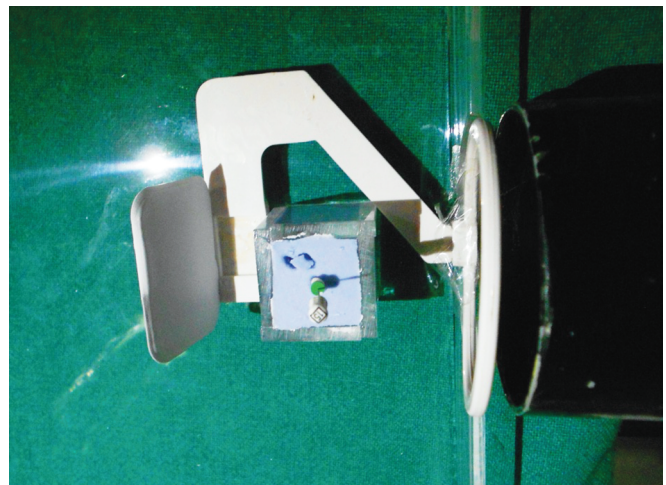


Fig. 5: Working length estimation with conventional radiograph using the jig

Table 1: Sample distribution

Methods	Working length method	N
Method I	Electronic apex locators (EALs)	90
Method II	Digital radiography (DR)	
Method III	Conventional radiograph (IOPAR)	
Control method	Actual visual method (AVM)	

be  $10.36 \pm 1.80$  mm with minimum working length recorded was 5.31 mm and maximum working length was 14.21 mm ( $F = 0.426$ ,  $p > 0.05$ ) (Table 2 and Fig. 6).

When a comparison was done using a one-way ANOVA test to see the relation between mean working length estimation by an actual visual method with the three experimental methods, it was found that there was no statistically significant difference between the groups ( $p = 0.066, 0.085, 0.07$ ) (Table 3 and Fig. 7).

The linear regression test was used to predict the correlation value with the actual visual method to the value of experimental groups (EAL, DR, IOPAR).

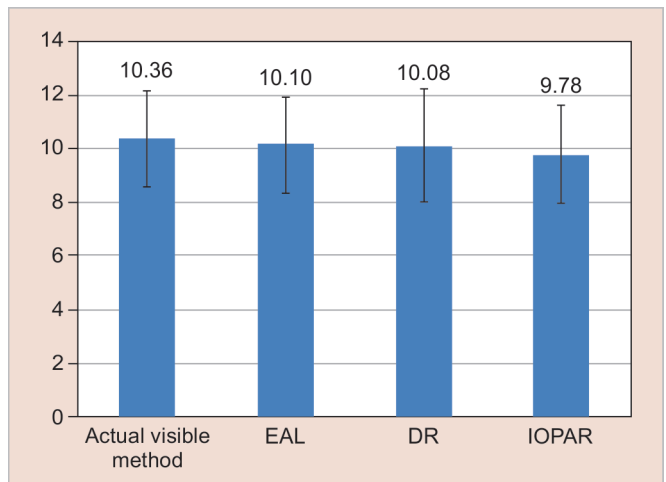


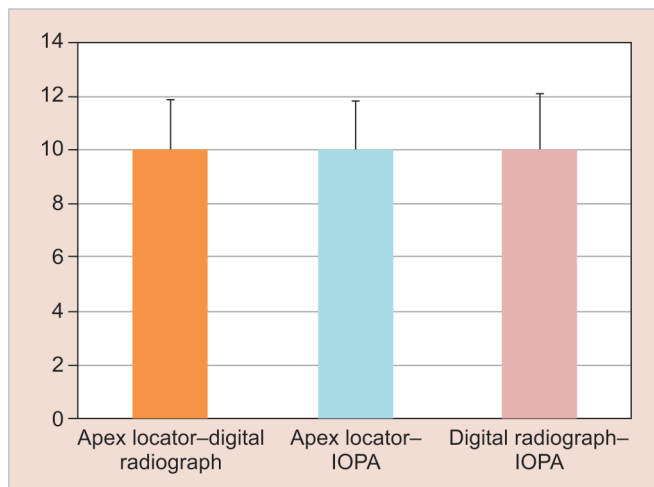
Fig. 6: Comparison of root length measurements among groups

**Table 2:** Comparison of mean root length measurements among methods

	Mean (mm)	SD	Maximum (mm)	Minimum (mm)	F	p value
Electronic apex locator	10.10	1.78	13.83	5.23	0.426	0.235
Digital radiograph	10.08	2.10	14.80	5.62		
Conventional radiograph	9.78	1.81	13.70	5.41		
Actual visual method	10.36	1.80	14.21	5.31		

**Table 3:** Intergroup comparison of root canal measurement

Variables	Mean $\pm$ SD	F value	p value
Apex locator — digital radiograph	10.104 $\pm$ 1.782	3.099	0.066
Apex locator — IOPAR	10.07 $\pm$ 1.752	10.329	0.085
Digital radiograph — IOPAR	10.08 $\pm$ 2.107	2.458	0.07

**Fig. 7:** Intergroup comparison among different groups

The regression analysis for EAL with actual working indicated that the EAL could predict the actual visual method values with 99.7% accuracy (Table 4), with digital radiography 98.1% (Table 5), and with conventional radiograph 96.1% (Table 6).

## DISCUSSION

In pediatric dentistry, it is important to preserve the deciduous tooth until its normal exfoliation to maintain the integrity of the dental arch. Pediatric endodontics involves the removal of coronal as well as radicular pulp and restoring it with a resorbable medicament. The endodontic anatomy of a deciduous tooth is hard to judge because of the continuously ongoing resorption, shape of a root canal, and shifting the position of the root apex.<sup>11</sup> The RCL should be measured accurately as it is a critical step, underestimation of working length can lead to failure of treatment, whereas overestimation results in periapical injuries and which can lead to damage of the permanent successor.<sup>12,13</sup> Soujanya et al.<sup>14</sup> enumerated various criteria that a method should fulfill to be incorporated in routine endodontic practice, such as, ease of location of the AC; simple measurement (even when the anatomy is complex); prompt and reliable; require no or minimal irradiation of the patient and enables usage on special needs patients or restricted mouth opening patients.

Ingle's radiographic method is among the most commonly used method for RCL estimation. In the radiographic method, the AC

**Table 4:** Correlation of electronic apex locator with actual working length

R	R square	Adjusted R square	Std. error of the estimate
0.999	0.997	0.997	0.53072

**Table 5:** Correlation of digital radiography with actual working length

R	R square	Adjusted R square	Std. error of the estimate
0.991	0.981	0.981	1.44607

**Table 6:** Correlation of conventional radiography with actual working length

R	R square	Adjusted R square	Std. error of the estimate
0.990	0.961	0.961	0.6260

cannot be identified in the image, and also varying angulations and exposure parameters can result in distortion of the image and lead to error.<sup>15</sup> The digital radiography provides a substantial reduction in the treatment time of endodontic procedures as it eliminated the need of time for film processing. But, radiographic evaluation is difficult in primary teeth undergoing root resorption (physiological/pathological) at the facial/buccal or lingual/palatal aspects of the roots, resulting in an increased risk of over-instrumentation.<sup>16</sup>

In the present study, a tooth embedded in an alginate block was placed parallel to the sensor/film, to avoid any radiographic error, but in a clinical situation, this is difficult to perform intraorally because of limited patient cooperation and relatively small oral cavity. When compared to *in vivo* condition, both radiographic methods (DR, IOPAR) offer lower quality because of the surrounding bone and the potential of decreased clarity due to angulation errors.<sup>17</sup>

Therefore, to simulate the conditions present intraorally, in this *in vitro* study, the coronally sectioned teeth were submerged in a medium with electrical resistance properties similar to those of the periodontium, such as, alginate which gives the same environment similar to the oral cavity. This technique is reliable for simulating intraoral conditions in previous studies as well.<sup>10</sup>

In the present study, it was noticed that the working length estimation given by the EAL was close to the actual working length determination. This finding was in accordance with several studies reported in the literature (like Katz et al.,<sup>3</sup> Kielbassa et al.,<sup>17</sup> and Subramaniam et al.<sup>18</sup>) that evaluated the precision of the electronic method in primary teeth, which had demonstrated that electronic measurements were closer to the WL than those obtained radiographically. The anatomy and position of the apex are constantly varying in primary teeth, thus radiographic length determination is a challenge. Although few studies had observed that EAL had readings much shorter than the actual canal working

length in roots with a wide apical foramen.<sup>19</sup> However, most studies focusing on evaluating the use of EAL's in primary dentition recorded accuracy rates of 64 to 96%.<sup>17,20</sup>

In the past, several studies had demonstrated that EALs can accurately determine the working length between 75.0 and 96.5% of the root canals with mature apices.<sup>21</sup> In the present study, EAL method for working length estimation was found to be as accurate and efficient as compared to other groups (digital radiograph and conventional radiographic method). The mean working length of EAL was  $10.10 \pm 1.78$  mm which was closer to the actual working length ( $10.36 \pm 1.80$  mm) followed by digital radiograph ( $10.08 \pm 2.10$  mm) and conventional radiograph ( $9.78 \pm 1.81$  mm).

In the present study, a significant correlation was found between the working length of the actual visual method and EAL method which was in accordance to Shabahang et al.<sup>22</sup> who demonstrated in their study that root ZX EAL located the root end accurately even in cases with resorption. Moreover, results from the present study are also in concordance with the observations made by other researchers who reported the high accuracy of EALs in primary teeth.<sup>3,23</sup>

To further support the results of the reported study, linear regression was done between actual visual working length and EAL. Based on the present finding, regression analysis suggested that EAL could predict the 99.7% of the actual value accurately which was in accordance with to study conducted by Krishnan and Sreedharan.<sup>24</sup> In 2013, Neena et al.<sup>25</sup> concluded that digital radiograph was found to be more efficient and correct as compared to conventional radiograph which was also found in the present study.

Although there was not much difference found between working length estimation by different methods, EAL was more efficient as it reduces the procedure time and radiation exposure. Moreover, it can also be useful in children with a gag reflex.

A major limitation of the present study was the fact that the examiner was not blinded for recording the measurements. Also, a larger sample size would have improved the ability to more accurately assess the significance of the outcomes. Because EAL increases the safety and comfort of endodontic treatment in children, their use should be further evaluated and certainly permit more clinical studies.

## CONCLUSION

Root canal working length through electronic measurements indicated they were closer to the actual length than those obtained from conventional radiographic methods followed by the digital radiographic method. Although the use of EAL was found to be convenient with its large and clear digital graphic screen, displaying the relative file advancement through the root canal length, however, working length obtained through all the methods employed in the study was comparable with statistically non-significant differences among them.

Therefore, this study recommended the usage of apex locators in conjunction with high-quality standardized radiographs would provide an accurate and useful adjunct to successful endodontic therapy.

## CLINICAL SIGNIFICANCE

Many methods of estimating RCL in primary teeth have been enumerated in literature; however, the most common and widely

used method is by the use of either digital or conventional radiography. Both of these methods expose the patient to ionizing radiations. Therefore, to evaluate the efficacy of EAL in measuring the RCL in primary teeth, it was observed that EALs work as effectively as other methods and prevent the patient from getting exposed to ionizing radiations.

## REFERENCES

- Ingle J, Backland LK. Pediatric Endodontics. Endodontics. 5th ed., Philadelphia: Lea and Febiger; 2002. p. 861.
- Ozsezer E, Inan U, Aydin U. In vivo evaluation of ProPex electronic apex locator. *J Endod* 2007;33(8):974–977. DOI: 10.1016/j.joen.2007.04.003.
- Katz A, Mass E, Kaufman AY. Electronic apex locator: a useful tool for root canal treatment in the primary dentition. *ASDC J Dent Child* 1996;63:414–417.
- Shanmugaraj M, Nivedha R, Mathan R, et al. Evaluation of working length determination methods: an in vivo/ex vivo study. *Indian J Dent Res* 2007;18(2):60–62. DOI: 10.4103/0970-9290.32421.
- Kçkiku L, Stadler P. Radiographic versus electronic root canal working length determination. *Indian J Dent Res* 2011;22(6):777–780. DOI: 10.4103/0970-9290.94666.
- Ghaemmaghamis S, Eberie J, Duperon D. Evaluation of root ZX apex locator in primary teeth. *Pediatr Dent* 2008;30:496–498.
- Bodur H, Odabaş M, Tulunoğlu O, et al. Accuracy of two different apex locators in primary teeth with and without root resorption. *Clin Oral Investig* 2008;12(2):137–141. DOI: 10.1007/s00784-007-0157-5.
- Brunton PA, Abdeen D, MacFarlane TV. The effect of an apex locator on exposure to radiation during endodontic therapy. *J Endod* 2002;28(7):524–526. DOI: 10.1097/00004770-200207000-00009.
- Lee JJ, Nettey-Marbell A, Cook AJr, et al. Using extracted teeth for research: the effect of storage medium and sterilization on dentin bond strengths. *J Am Dent Assoc* 2007;138(12):1599–1603. DOI: 10.14219/jada.archive.2007.0110.
- Kaufman AY, Keila S, Yoshpe M. Accuracy of a new apex locator: an in vitro study. *Int Endod J* 2002;35(2):186–192. DOI: 10.1046/j.1365-2591.2002.00468.x.
- American Academy of Pediatric Dentistry. Guideline on pulp therapy for primary and immature permanent teeth. Reference manual 2009-2010. *Pediatr Dent* 2009;33:212–219.
- Salama FS, Anderson RW, McKnight-Hanes C, et al. Anatomy of primary incisor and molar root canals. *Pediatr Dent* 1992;14:117–118.
- Rimondini L, Baroni C. Morphologic criteria for root canal treatment of primary molars undergoing resorption. *Endod Dent Traumatol* 1995;11(3):136–141. DOI: 10.1111/j.1600-9657.1995.tb00475.x.
- Soujanya A, Muthu MS, Sivakumar N. Accuracy of electronic apex locator in length determination in the presence of different irrigants: An in vitro study. *J Indian Soc Pedod Prev Dent* 2006;24(4):182–185. DOI: 10.4103/0970-4388.28074.
- Lozano A, Forner L, Liens C. In vitro comparison of root canal measurements with conventional and digital radiology. *Int Endod J* 2002;35(6):542–550. DOI: 10.1046/j.1365-2591.2002.00535.x.
- Mente J, Seidel J, Buchalla W, et al. Electronic determination of root canal length in primary teeth with and without root resorption. *Int Endod J* 2002;35(5):447–452. DOI: 10.1046/j.1365-2591.2002.00500.x.
- Kielbassa AM, Muller U, Munz I, et al. Clinical evaluation of the measuring accuracy of ROOT ZX in primary teeth. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2003;95(1):94–100. DOI: 10.1067/moe.2003.99.
- Subramaniam P, Konde S, Mandanna DK. An in vitro comparison of root canal measurement in primary teeth. *J Indian Soc Pedod Prev Dent* 2005;23(3):124–125. DOI: 10.4103/0970-4388.16883.
- Berman LH, Fleischman SB. Evaluation of the accuracy of the Neosono-D electronic apex locator. *J Endod* 1984;10(4):164–167. DOI: 10.1016/S0099-2399(84)80121-1.
- Goerig A, Camp JH. Root canal treatment in primary teeth: a review. *Pediatr Dent* 1983;5:33–37.

21. Felipe MCS, Soares IJ. In vitro evaluation of an audiometric device in locating the apical foramen of teeth. *Endod Dent Traumatol* 1994;10(5):220–222. DOI: 10.1111/j.1600-9657.1994.tb00073.x.
22. Shabahang S, Goon WWY, Gluskin AH. An in vivo evaluation of root ZX electronic apex locator. *J Endod* 1996;22(11):616–618. DOI: 10.1016/S0099-2399(96)80033-1.
23. Goldberg F, De Silvio AC, Manfré S, et al. In vitro measurement accuracy of an electronic apex locator in teeth with simulated apical root resorption. *J Endod* 2002;28(6):461–463. DOI: 10.1097/00004770-200206000-00011.
24. 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):416–420. DOI: 10.4103/0976-237X.107430.
25. Neena IE, Ananthraj A, Praveen P, et al. Comparison of digital radiography and apex locator with the conventional method in root length determination of primary teeth. *J Ind Soc Pedod Prev Dent* 2011;29(4):300–304. DOI: 10.4103/0970-4388.86371.