Systematic Review

Comparative Evaluation of the Accuracy of Electronic Apex Locator and Digital Radiography for Working Length Determination in Primary Teeth: A Systematic Review

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KEY WORDS
Dental Radiovisiography; Digital Dental Radiography; Primary Dentitions; Milk Tooth;

ABSTRACT

Statement of the Problem: It is challenging to perform a pulpectomy procedure in primary tooth because of its physiological root resorption and variation in root morphology. Working length measurement is considered to be one of the critical steps, as it determines the extent of obturation and apical seal.

Purpose: To compare the accuracy of electronic apex locator (EAL) and digital radiography (DR) for working length determination in primary teeth.

Materials and Method: In this systematic review, electronic databases and grey literature were searched from 1st January 2005 to 1st January 2023 for randomized control trial, non-randomized control trial, in vitro studies, ex vivo studies that compared accuracy of EAL and DR in primary teeth. Two reviewers independently identified studies, retrieved data, and assessed risk of bias using the revised and validated MINORS (methodological index for non-randomized studies) criteria.

Results: Ten studies were included in qualitative analysis. Seven out of ten studies showed low risk of bias whereas other three studies showed high risk of bias. In view of methodological heterogeneity of the findings, a meta-analysis was not conducted.

Conclusion: Available evidence suggests a moderate quality of evidence in this systematic review. Analyzing the ten studies included in this systematic review, the majority of studies showed statistically insignificant difference between EAL and DR. However, EAL was closer to actual WL as compared to DR. Based on the evidence that is currently available; EAL can be considered as an alternative for working length measurement in primary teeth.

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Introduction
Pediatric endodontic procedure helps in maintaining teeth in dentition, until their normal exfoliation time [1]. An accurate evaluation of root canal length determines the success of an endodontic procedure.

American Academy of Endodontics (2003) defined working length as ‘the distance from a coronal reference point to the point at which canal preparation and filling should terminate’ [2]. Accurate working length (WL) determination is extremely important, as it has an impact on ideal canal preparation, disinfection, and apical seal of root canal system [3]. The correct root canal length of primary teeth is difficult to predict because of the root resorption pattern, which could be either physiological or pathological. There is continuous alteration in size, shape, and position of root apices of primary teeth.
teeth, [4] that causes difficulty in accurate determination of root canal length [5]. Traditional methods for establishing WL include conventional radiography, tactile sensation, moisture on a paper point, and knowledge of root canal anatomy.

After the introduction of digital radiography (DR), the first commercial integrated digital imaging system in dentistry was radiovisiography (RVG) which comprises an intraoral sensor instead of the conventional X-ray film [6]. DR is based on digital image capture and uses a charge-coupled device [3]. The advantages of a digital radiography above the conventional method are; predominantly a faster image procurement, lower radiation dose and image editing ability [7]. Although both conventional and DR methods offer some advantages, such as direct observation of root canal anatomy, presence of any periapical lesion and canal curvatures, there are limitations associated with them, such as radiation exposure and image distortion, which results in difficulty in identification of resorbed root apices [3]. Electronic apex locators (EAL) have been introduced to overcome the disadvantages of the above techniques. It is used in dentistry to determine where the apical constriction is located in the root canal [8]. It is a more accurate, easy, and painless technique, which is very useful in uncooperative children. Various advantages of EAL include; lesser radiation dosage as well as procedure time, which helps in maintaining patient cooperation. The efficacy of EAL has been proven even in the presence of root resorption, which is frequently encountered in primary teeth [9]. Considering the importance of WL determination for pediatric endodontic treatment and its maintenance until normal exfoliation, the aim of this systematic review was to compare the accuracy of EAL and DR for WL determination in primary teeth.

Materials and Method

Protocol registration and review reporting
The present systematic review was registered with protocol ID CRD42020222326 at the International Prospective Register of Systematic Reviews (PROSPERO). This systematic review was reported according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses checklist (PRISMA 2020) [10].

Research question
Research question for this systematic review was struct-

| Table 1: PICOS (Population Intervention Comparison Outcome) Study design, EAL: Electronic apex locator, RVG: Radiovisiography, WL: Working length |
|-----------------|------------------|------------------|
| **Population** | Human Primary Teeth |
| **Intervention** | EAL |
| **Comparison** | RVG |
| **Outcome** | WL |
| **Study design** | Randomized control trial, non-randomized control trial, in vitro studies, ex vivo studies |

ured in PICOS format (participant, intervention, comparison, outcome and study design), depicted in Table 1. Is there a difference in accuracy between an EAL and DR for WL determination in primary teeth?

Eligibility criteria
The eligibility criteria (Table 2) in this study were formulated to find studies based on the PICOS format. All studies were chosen in accordance with the criteria specified in this review.

Information sources and search strategy
Databases used in the search strategy included; Cochrane Library, National Library of Medicine (MEDLINE PubMed), Google scholar, EBSCOhost, Open grey literature, including both electronic and printed literature. The concept table (Table 3) denotes the terms used for search strategy, which included key concepts, as well as free text terms. Boolean operators such as OR/AND were used to combine search terms with other keywords relating to the review’s goal. Additional articles were searched by looking through the references of the chosen publications, as well as previously published reviews on the topic, textbooks and publications, that met the inclusion criteria of the study.

| Table 2: Eligibility criteria for Qualitative assessment of studies (BASED ON PICOS) |
|-----------------|------------------|
| **Inclusion Criteria** | **Exclusion Criteria** |
| Randomized control trial, non-randomized control trial, in vitro studies, ex vivo studies. | Case reports, Case series, Reviews, Book chapters, Expert opinion, Animal studies |
| Studies performed on primary teeth. | Articles reporting medically compromised patients |
| Studies comparing EAL and RVG to evaluate working length | Only Abstracts |
| Well defined information on working length using EAL and RVG | Articles published in English or which can be translated into English |
| Articles published until 31st August 2021. | |
Articles published or studies conducted from January 1, 2005 to January 31, 2023 were included for this systematic review.

**Study selection**

Selection of a study was done in three stages. In stage one, assessment of all the titles of the studies obtained through search strategy were done by two independent reviewers (IA and SP). Stage 2 involved screening of the abstracts, which was followed by screening of the full texts of relevant studies in stage 3. In case of disagreements between the two reviewers, a third reviewer (FK) was called in for a final decision. Only studies with full text reports were examined in this systematic review. Due to differences in the data supplied in abstract and those provided in the final report [11], literature published only as abstracts were excluded from the study. Authors were contacted for a full text of the relevant abstracts wherever possible.

**Data collection and data items extracted**

After defining the inclusion criteria for the selected articles, data extraction was performed independently by two review authors (IA and SP). Any disagreements in data extraction from the selected studies were discussed and resolved by a third (FK) and fourth (DP) reviewer. This information included authors name, year of publication, number of teeth included, demographic details of the patients (age in years), intervention, comparison, outcomes, study design and results.

**Study of risk of bias assessment**

The risk of bias assessment was performed by two independent reviewers (IA & SP); using a modified version of the methodological items for nonrandomized studies (MINORS) scale (Annexure 1) [12]. A third reviewer (FK) validated all modifications to the MINORS scale. Cohen kappa coefficient for overall inter reviewer reliability was 0.725, indicating moderate agreement [13]. Any disagreements regarding risk of bias assessment, between the two reviewers (IA & SP), were resolved by a consensus between third (FK) and fourth (DP) reviewer. The items in MINORS scale were scored 0 (if not reported), 1 (if reported but inadequate) or 2 (if reported but adequate). The ideal score for comparative studies is 24. The checkpoints 6, 7 and 10 were excluded, as it was not applicable for this review. Hence, for the present systematic review 9 check-points were considered. The total score considered for the present review was 18. The score reported between 1 and 11 indicated high risk of bias, whereas score between 12 and 18 indicated low risk of bias.

**Outcomes and data synthesis**

The mean differences and their standard deviations were extracted and used in the presentation of results. The meta-analysis was not performed due to a high degree of heterogeneity seen in data extraction from different studies and methodologies.

**Results**

**Study selection**

PRISMA flowchart (2020) describing the process of selecting studies is shown in Figure 1 (Page et al. 2020). Electronic literature search yielded 746 results. In the initial step of the screening process, duplicates were removed (299) using Mendeley software for Windows (Mendeley Ltd, Version 1803 Elsevier, London UK). A total of 447 articles were then evaluated, in accordance to the PRISMA standards [10]. In the next step of the screening process, 409 articles were removed due to irrelevance based on titles and abstracts. Finally, 38 full

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**Table 3: Concept table**

<table>
<thead>
<tr>
<th>Key concept</th>
<th>Population</th>
<th>Intervention</th>
<th>Comparison</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free terms / Text words / TIAB terms</td>
<td>Human Primary teeth</td>
<td>Apex locators Formatron D10 Root Zx DentalPort ZX Propex II Root Zx Mini COXO C Smart-1 PRO iPex Apex ID</td>
<td>Digital radiography Digital radiovisigraphy Radiography Dental digital radiography Digital dental radiography</td>
<td>Working length determination Working length Working length measurement Apex localization Root length determination Root canal length</td>
</tr>
<tr>
<td>MeSH terms</td>
<td>Tooth Deciduous</td>
<td></td>
<td>Radiography Dental Digital</td>
<td></td>
</tr>
</tbody>
</table>
# Table 4: The excluded studies are as follows: (EAL – Electronic apex locator, WL – Working length, SD – Standard deviation, CBCT – Cone beam computed tomography, DR – Digital radiography)

<table>
<thead>
<tr>
<th>Sr. no</th>
<th>Author and Year</th>
<th>Title</th>
<th>Reason for exclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.</td>
<td>Krajczár K, et al. (2008) [16]</td>
<td>Direct comparison of working length determination by ProPex electronic apex locator and radiographic method—an in vitro study</td>
<td>They have included permanent molar teeth. They haven’t specified gold standard method</td>
</tr>
<tr>
<td>4.</td>
<td>Ravanshad S, et al. (2010) [17]</td>
<td>Effect of Working Length Measurement by Electronic Apex Locator or Radiography on the Adequacy of Final Working Length: A Randomized Clinical Trial</td>
<td>They have included 20 to 65 years age group patient who presented for endodontic therapy</td>
</tr>
<tr>
<td>8.</td>
<td>Vieyra JP, et al. (2011) [21]</td>
<td>Comparison of working length determination with radiographs and two electronic apex locators</td>
<td>They have included permanent teeth</td>
</tr>
<tr>
<td>9.</td>
<td>Vieyra JP, et al. (2011) [22]</td>
<td>Comparison of working length determination with radiographs and four electronic apex locators</td>
<td>They have included permanent teeth</td>
</tr>
<tr>
<td>10.</td>
<td>Saritha S, et al. (2012) [23]</td>
<td>Clinical evaluation of Root ZX II electronic apex locator in primary teeth</td>
<td>They haven’t taken any gold standard method for comparison</td>
</tr>
<tr>
<td>13.</td>
<td>Mandlik J, et al. (2013) [26]</td>
<td>An in vivo evaluation of different methods of working length determination</td>
<td>They have included premolar and supernumerary teeth</td>
</tr>
<tr>
<td>14.</td>
<td>Ozrunhar F, et al. (2014) [27]</td>
<td>Clinical evaluation of apex locator and radiography in primary teeth</td>
<td>They haven’t taken any gold standard method for comparison</td>
</tr>
<tr>
<td>15.</td>
<td>Basso MD, Jeremiás F, Cordero RC, Santos-Pinto L (2015) [28]</td>
<td>Digital radiography for determination of primary tooth length: in vivo and ex vivo studies</td>
<td>They compared accuracy of radiographic tooth length obtained from in vivo digital radiograph with that obtained from ex vivo digital radiograph</td>
</tr>
<tr>
<td>16.</td>
<td>Singh D, et al. (2015) [29]</td>
<td>Comparative evaluation of adequacy of final working length after using Raypex5 or radiography: an in vivo study</td>
<td>They included patient aged 20 to 45 years who presented for endodontic therapy</td>
</tr>
<tr>
<td>20.</td>
<td>Adriano LZ, et al. (2018) [33]</td>
<td>In vitro comparison between apex locators, direct and radiographic techniques for determining the root canal length in primary teeth</td>
<td>They compared the accuracy of EAL with the conventional radiographic techniques</td>
</tr>
<tr>
<td>22.</td>
<td>Davaithakta RN, et al. (2021) [35]</td>
<td>Comparative evaluation of root ZX Min® apex locator and digital radiography in determining the working length of primary molars: An In Vivo study</td>
<td>They used tactile method as gold standard method for WL determination</td>
</tr>
<tr>
<td>24.</td>
<td>Moussavi SA, et al. (2021) [37]</td>
<td>Comparative Evaluation of Root Canal Working Length Determination with Three Methods: Conventional Radiography, Digital Radiography and Raypex6 Apex Locator: An Experimental Study</td>
<td>They have included permanent single rooted teeth</td>
</tr>
<tr>
<td>25.</td>
<td>Singh AK, et al. (2021) [38]</td>
<td>Evaluation of the efficacy of different systems in determination of root canal working length: A comparative study.</td>
<td>They have included premolar teeth</td>
</tr>
</tbody>
</table>
text articles were assessed and checked for eligibility criteria. Following full-text screening, 28 articles (Table 4) were eliminated, as they were not in accordance to inclusion criteria [14-41]. Any inconsistency over final inclusion was discussed and resolved amongst two review authors (IA and SP), whereas, a third reviewer (FK) acted as mediator. Thus, ten full text articles that met eligibility criteria and were included in present systematic review. Detailed summary of data selection was presented in the form of PRISMA 2020 flow diagram (Figure 1).

Table 5: Data Extraction Sheet: (ARCL: Actual root canal length, EAL:Electronic apex locator, WL: Working length, SD: Standard deviation, CBCT: Cone beam computed tomography, DR: Digital radiography)

<table>
<thead>
<tr>
<th>Study ID</th>
<th>Author</th>
<th>Sample</th>
<th>Age group</th>
<th>Intervention</th>
<th>Comparison</th>
<th>Actual WL/ reference method</th>
<th>Outcome</th>
<th>Study design</th>
<th>Result</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Subramaniam P et al. (2005) [14]</td>
<td>22, single-rooted primary teeth</td>
<td>-</td>
<td>Formatron D 10 EAL</td>
<td>Digital radiographs with the digital sensor (Cygnus Media, Cygas Technologies, USA)</td>
<td>Actual root canal length (ARCL) of each tooth was measured under stereomicroscopy using direct observation of apical exit of k file</td>
<td>Higher similarity between apex locator measurements and actual canal length, followed by digital radiography and actual canal length. No significant difference was seen.</td>
<td>In vitro</td>
<td>EAL=15.94±2.06 DR=15.91±1.60 ARCL=15.53 ± 2.64</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td>2</td>
<td>Mello-Moura A C et al. (2010) [19]</td>
<td>20 primary incisors</td>
<td>-</td>
<td>Root ZX apex locator</td>
<td>RVG (Ultimate Image, Trophy, France)</td>
<td>ARCL of each tooth was measured at 15x stereomicroscopy magnification</td>
<td>EAL gave low absolute differences compared with digital radiographic method</td>
<td>Ex vivo</td>
<td>Absolute differences among the ARCL, EAL, EAL=0.36 ± 0.30 RVG=1.40 ± 2.16</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td>3</td>
<td>Neema I E et al. (2011) [6]</td>
<td>30 primary teeth, 90 canals</td>
<td>5-11 years</td>
<td>Apex locator</td>
<td>DR</td>
<td>Conventional radiographic method</td>
<td>No significant difference in the mean root length measurements in both techniques</td>
<td>In vivo</td>
<td>Apex locator=11.79±1.70 DR=11.98±1.70 Conventional radiograph=11.76±1.67</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td>4</td>
<td>Tawil S et al. (2012) [15]</td>
<td>30 extracted primary incisors</td>
<td>-</td>
<td>Root ZX, J. Morita Corporation, Tokyo, Japan</td>
<td>Digital x-ray sensor size # 1</td>
<td>ARCL was determined by advancing number 15K file until the tip of the file was showed by the naked eye to be at the level of the apical foramen</td>
<td>No significant difference between apex locator and digital X-Ray</td>
<td>In vivo</td>
<td>Apex locator=12.87±1.84 Digital X-Ray =12.89 ±1.82 ARCL =13.07 ±1.78</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td>5</td>
<td>Wankhade D et al. (2013) [4]</td>
<td>70 extracted single primary teeth</td>
<td>5-8 years</td>
<td>Joypex (Denjoy Dental Co, Chin)</td>
<td>5 Size # 0 Schick CDR intraoral X-ray sensor (Schick Technologies, USA)</td>
<td>Stereomicroscopic examination under 8x magnification to determine ARCL</td>
<td>Group I (without PR) EAL revealed statistically insignificant difference when compared with ARCL</td>
<td>In vitro</td>
<td>EAL=16.43±0.79 DR=16.45±0.78 ARCL=16.44±0.79</td>
<td>&gt;0.98 &lt;0.97</td>
</tr>
<tr>
<td>Group</td>
<td>Methodology</td>
<td>Sample Size</td>
<td>Results</td>
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</table>
| 2     | Group 2 (with 1/4th PRR) | EAL revealed statistically insignificant difference when compared with ARCL. | EAL= 13.44±0.79  
DR= 13.44±0.69  
ARCL= 13.40±0.72 |
|       |              |             | <0.96   | <0.99   |
| 3     | Group 3 (with 1/4th to 3/4th PRR) | DR showed a significant difference when compared with ARCL. | EAL= 9.47±3.38  
DR= 14.77±1.33  
ARCL= 9.47±3.43 |
|       |              |             | >0.99   | <0.01   |
Root ZX mini apex locator  
RVG (Suni Medical Imaging Inc., California, USA) | Actual WL of each canal was measured (the apical exit of the file at the apical foramen or resorption bevel of the root is observed).  
No significant difference between EAL and DR.  
Lowest mean difference was observed in the EWL group indicating that the use of EAL consistently brought the file tip closer to the apex. | EAL=12.659±1.71  
DR=13.037±1.50  
Actual WL=12.67±1.70 |
|       |              |             | p=0.609 |
| 7     | Sahni A et al. (2020) [16] | 90 extracted single-rooted primary teeth  
DentaPort ZX (J Morita Corp., Kyoto, Japan)  
Digital radiograph sensor (Vatech EZ Sensor, Huamray Co. Ltd., Korea) | Actual WL was measured until the tip of the file was just visible at the apex/apical foramen or the apical resorption level.  
No significant difference between EAL and DR, Electronic measurement was closer to actual WL as compared to digital radiography. | EAL=12.659±1.71  
DR=13.037±1.50  
Actual WL=12.67±1.70 |
|       |              |             | p=0.066 |
| 8     | Kayabasi M et al. (2020) [17] | 20 extracted primary molars with resorption and 20 primary molars without resorption  
COXO C Smart-1 Pro, iPex and Apex ID  
RVG with a Size#1 sensor (CASTELLINI X-VS CMOS Radiography, Italy) | Actual WL was measured by inserting a size 15 K-file in the canal until the file tip became visible at the apical foramen under 6x magnification using a microscope.  
No statistically significant difference between the groups with and without root resorption. In the teeth with resorption the nearest measurements to actual WL were Apex ID > COXO C Smart-1 Pro > iPex respectively. In the teeth without resorption the nearest measurements to actual WL were Apex ID > DR > COXO C Smart-1 Pro > iPex respectively. | Teeth without root resorption  
Actual WL = WL= 11.49±1.63  
COXO= 10.92±1.40  
iPex= 10.92±1.56  
Apex ID= 11.18±1.57  
DR= 11.03±1.64 |
|       |              |             | Teeth with root resorption  
Actual WL = WL= 14.14±1.44  
COXO= 13.92±1.38  
iPex= 13.92±1.38  
Apex ID= 13.94±1.32  
DR= 13.78±1.25 |
|       |              |             | p=0.931 | p=0.926 |
| 9     | Pol D S et al. (2021) [18] | 78 canals (30 extracted primary molar)  
Propex II apex locator  
DR (Schick, Germany)  
Actual WL of each tooth was measured at 15X magnification under stereomicroscope  
EAL shows highest closer value to actual WL in vitro thus provided better perfor- | Absolute difference of actual WL  
EAL= 0.007250±0.2612  
DR= 1.9570±1.553 |
|       |              |             | p<0.05  |
Study characteristics

The study characteristics of 10 included studies were listed in Table 5. The included studies were published from January 1, 2005 to January 31, 2023. Five of the studies were in vitro study [42-46], four were ex vivo [3,4,47,48] and one was in vivo study [6]. No randomized and non-randomized clinical trials were found. The sample size of included studies ranged from 20-90 extracted human primary teeth. Age of the participants in the in vivo and vivo studies varied from five to fifteen years. EAL used in the intervention group were Formatron D 10, Root ZX, Joypex 5, Root ZX mini, DentaPort ZX, COXO C Smart-1 Pro, iPex, Apex ID and Propex II, whereas DR used were size #0 and size #1. Accuracy was evaluated under stereomicroscopy using direct observation of apical exit of advancing K file, until tip of the file was visible at apical foramen or apical resorption level. Outcomes were assessed by comparing the difference among the actual length, DR and apex locator working length measurement. A statistically insignificant difference between EAL and DR was seen in seven out of 10 articles, whereas, other three studies showed statistically significant difference, indicating that EAL was more closely related to actual working length than DR.

Risk of bias assessment

The methodological quality assessment of the selected studies using modified version of MINORS criteria was depicted in Figure 2. It demonstrates the reviewer’s assessment, regarding each risk of bias, which has been presented as percentages across all the included studies. This scale was modified because no clinical trials were found during the search study. Thus, only in vivo, in vitro and ex vivo studies were included. The scores were categorized as low, unclear, and high risk of bias. Low risk of bias indicates plausible bias that was not likely to change the results seriously, unclear risk of bias indicates bias that raised doubts about the results, and high risk of bias indicates bias that does not inspire confidence in the results.

The summary of risk of bias presented in Table 6 and Figure 3 show, seven studies by Mello Moura AC et al. [47], Wankhade AD et al. [4], Kumar LV et al. [3], Sahni A et al. [44], Kayabasi M et al. [45], Pol D S et al. [46] and Khan SA et al. [48], that presented low risk of bias which indicates high quality of evidence.

### Table 6: Summary of risk of bias (MINORS: Methodological Index for Non-Randomized Studies, EAL: Electronic apex locator, DR: Digital Radiography)

<table>
<thead>
<tr>
<th>S. no.</th>
<th>Minors criteria</th>
<th>Study ID 1</th>
<th>Study ID 2</th>
<th>Study ID 3</th>
<th>Study ID 4</th>
<th>Study ID 5</th>
<th>Study ID 6</th>
<th>Study ID 7</th>
<th>Study ID 8</th>
<th>Study ID 9</th>
<th>Study ID 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A clearly stated aim</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
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</tr>
<tr>
<td>2</td>
<td>Extracted Human primary teeth</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Details of methodology-EAL and DR</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Endpoints appropriate to the aim of the study</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Unbiased assessment of the study endpoint</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>Prospective calculation of study size</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
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<td>7</td>
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</table>

*The items are scored 0 (not reported), 1 (reported but inadequate) or 2 (reported and adequate).

#GRADING: Low risk: score equal to 12 or greater than 12; High risk: score less than 12.
The remaining three studies by Subramaniam P et al. [42], Neena IE et al. [6], and Sherif B et al. [43], showed high risk of bias, which indicates low quality of evidence. The summarized findings show that the included studies are of moderate quality overall, with a high risk of bias evident only at definite points.

**Discussion**

Early loss of primary teeth can cause space closure resulting in malocclusion of permanent dentition. Pulpectomy procedure involves complete removal of both coronal and radicular pulp. WL determination is an essential step in pulpectomy procedure, as it decides the position of apical foramen and thus the extent of obturation.

It is hard to judge the root canal anatomy of primary teeth because of continuous ongoing resorption and root canal shape. [49] The position of canal terminus and measurement of WL can be done by various techniques.
One of the widely used methods is the radiographic method for WL determination. However, 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 [50]. To eliminate the many problems associated with the radiographic methods, apex locator is now being used clinically and has become an essential part of the armamentarium of root canal procedure. Several studies have compared WL determination done by EAL and DR in primary teeth; only nine studies have been considered for inclusion in this systematic review.

The sample size is important to make any inferences about a population from a sample. Sample size was 20 to 90 primary teeth for the included studies. None of the studies revealed any details about the sample size calculation. This could lead to an increased chance of risk of bias of individual studies. The amount of physiologic root resorption can affect the determination of WL in an endodontic procedure. Amount of root resorption was reported in majority of the studies, however, three studies, Subramaniam P et al. [42], Neena IE et al. [6] and Sherif B et al. [43], inadequately reported the amount of root resorption. The threshold file size for working length measurements should be size # 15 K, as the tip diameter of the No # 10K files is less than 120 micrometers, which is not identifiable [6]. This finding was in accordance with studies by Kumar L V et al. [3], Sherif B et al. [43] and Sahni A et al. [44], Kayabasi M et al. [45]. Density profile plot analysis for digital images found that size #20 files were employed for radiographic length computation, because size #15 and size #10 files have decreasing perceptibility of file length [51].

Because of anatomical variances, anatomical structure interference, and projection problems, determining the precise radiographic root canal length is difficult [52]. Kumar L V et al. [3], Mello Moura et al. [47], Neena IE et al. [6], Sherif B et al. [43] and Kayabasi M et al. [45] employed the paralleling technique which is difficult to perform on paediatric patients. However, in the remaining four studies, they have not reported about the projection technique. These variables may result in over-instrumentation and over-filling of canals, causing permanent tooth bud injury [1,53].

As calibrated digital measurements are more accurate than un-calibrated ones [54], digital image calibration was performed, prior to WL determination, using an on-screen calibration tool. Kim et al. [55] demonstrated in their study that radiographic measurement of WL using an onscreen straight-line measurement was effective.

Apex locators are classified based on their generations. The first and second generations of EALs are obsolete, and are no longer manufactured or utilized in the modern era of dentistry. Nasiri et al. [56] performed a systematic review and meta-analysis and found that all generations are equally beneficial and accurate in WL evaluation.

The real WL was calculated by subtracting 0.5mm from the distance between the apical foramen and the apical constriction, which is roughly 0.5-1.0 mm [57]. A 0.5 mm margin was employed in numerous researches evaluating the accuracy of WL. Amongst the included studies, five studies, by Kumar L V et al. [3], Sahni et al. [44], Kayabasi M et al. [45], Pol D S et al. [46] and Khan SA et al. [48], determined WL by subtracting 0.5mm from apical foramen, while five studies by Wankhade AD et al. [4], Neena IE et al. [6], Subramaniam P et al. [42], Sherif B et al. [43] and Mello Moura et al. [47] did not report about the same. When compared to DR, it was found that the WL measurement provided by the EAL was near to the real WL determination in all of the included studies. This was in line with a number of research studies [42,58] that measured the precision of the apex locator in primary teeth. The radiographic length determination is difficult in primary teeth because of constant change in apex position due to continuous ongoing root resorption. However, only a few studies have found that in roots with wider apical foramen, EAL measurements are much shorter than the true WL [59]. In primary dentition, however, most studies found EAL accuracy rates of 64 to 96 percent [58,60]. In a study by Sahni et al. [44], a substantial correlation was discovered between the WL of the reference technique and EAL, and this was in agreement with Shabahang et al. [61], who concluded that EAL reliably determines the root end even in cases when root resorption is present. Furthermore, this is consistent with the findings of other researchers who reported the great accuracy of EALs in primary teeth.

The disparity in accuracy of WL may be due to variation in study designs, sample sizes, rate of resorption,
file size, reference point, radiographic technique, and different generations of EAL used in the included studies.

This review has some limitations, one of which was usage of limited databases for search strategy. Another limitation was use of English literature only, as articles published in other languages were excluded. Finally, caution should be exercised before applying the results of this review in a clinical scenario, as all the included studies were of in vitro design.

Conclusion
Within the limitation of present systematic review, we found moderate quality of evidence to suggest accuracy of EAL and DR for WL determination. Majority of studies showed statistically insignificant difference between EAL and DR. However, in few studies, electronic measurement was close to actual WL as compared to DR. Based on the evidence that is currently available, EAL can be considered as an alternative for working length measurement in primary teeth. However, future research should include information about the study populations, blinding and sufficient documentation.

Conflict of Interest
The authors declare that there are no conflicts of interest with people or organizations that could inappropriately influence (bias) the work.

References
2008; 101: 107-111.


[38] Singh AK, Rathod A, Reddy A, Moyin S, Punathil S, Shah A. Evaluation of the efficacy of different systems in determination of root canal working length: A comparati-
Accuracy of working length of electronic apex locator and radiovisiography

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