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A Clinical Evaluation of Accuracy of Apex Locator for Determination of Working Length in Primary Teeth when Compared to Conventional Radiography – A Systematic Review

Pradnya Kshirsagar[1], Rahul Deshpande[2], Ujwal Kontham[3], Pranav Dungarwal[4], Charuta Dabholkar[5]

[1]Post Graduate student, Dr. D. Y. Patil Vidyapeeth`s, Dr. D. Y. Patil Dental College, Pimpri, Maharashtra, India

[2]Professor and P G Guide, Dr. D. Y. Patil Vidyapeeth`s, Dr. D. Y. Patil Dental College, Pimpri, Maharashtra, India

[3]Professor, Dr. D. Y. Patil Vidyapeeth, Dr. D. Y.Patil Dental College, Pimpri, Maharashtra, India

[4]MDS Pedodontist, Sangamner, Maharashtra, India

[5]MDS Periodontist and Implantologist, Pune, Maharashtra, India

Abstract: ***This systematic review is to assess the literature regarding the clinical accuracy of apex locator and conventional radiography for determination of working length in primary teeth. Articles published from 1st January 2005 to 30th October 2017 in English with Randomized controlled trials and Original prospective clinical trials were selected.526 articles in total were retrieved, out of which 5 were selected for the systematic review. Summary: Though, there is no significant difference between the use of EAL and RG, the use of EAL might be useful for protecting the children from exposure to recurrent ionizing radiation, over instrumentation, overfilling, damage to the permanent tooth germs.***

Keywords: primary teeth, working length, Apex locator, conventional radiographs

1. Introduction

The practice of paediatric endodontic is being widely practiced and a necessity many a time in the present era with the prevalence of dental caries.[1]In paediatric endodontic procedures the root length should be carefully determined without exceeding the apex and achieve aseptic condition in the root canal, to receive the filling material. It is recommended to obturate canal 2 to 3 mm short of the apex,[2]for this determination of working length (WL) is an important stage in both primary and permanent teeth, but primary teeth have their successors beneath and avoiding any injury to these successors is important.

Many techniques have been proposed for determination of actual root length. It can be done clinically by tactile method, radiography, apex locators, paper points etc.

Radiography (RG) is the most common technique to determine WL that gives information regarding the root canal anatomy and periapical tissues, although it has such limitations as technical disadvantages in children specially in a patients who move frequently or suffer from severe gagging reflex during film placement in the oral cavity is impossible.[3] Also exposure to x-ray, and difficulty in interpretation of images in primary teeth root canal due to superimposition of permanent teeth bud on the tooth root. The other problem associated with IOPA is developing, fixing, drying and storage of the film.

Main advantages of apex locators are that these measure the root canal length to apical foramen, not the radiographic apex. They are easy and fast to operate and have a good accuracy. Artificial perforations can be recognized and radiation to the patient can be reduced. The purpose of the present study is to compare the working length determined by apex locator with that of a conventional radiograph for accuracy.

The first and second generations of EALs were unable to give accurate readings in the presence of irrigants, excessive haemorrhage, pus and pulpal tissue, whereas the newer generations of EAL give reliable results in those situations. They are also painless, easy and fast to operate give accurate results and are able to detect artificial perforations.

According to previous studies, IOPA yields an 82% precision, whereas in a study done by Olson et al, [5] electronic measurements is closer to 95%. Also, literature reveals various studies regarding the techniques of WL determination in permanent teeth but very few sited regarding techniques suitable and as accurate for the primary teeth apart from the IOPA.

Therefore, the aim of this study was to evaluate the accuracy and reliability of electronic and radiographic determination of root canal length in primary molar teeth in vivo.

Eligibility Criteria

Inclusion criteria:

1) Articles in English.
2) Studies published between 1st January 2015 and 30th October 2017.
3) Clinical trials: In vivo studies, where apex locators and conventional radiography have been utilized for determination of working length in the primary dentition
4) Studies involving primary teeth will be included
5) RCT, clinical trials will be included.

Exclusion criteria:

1) Non-availability of the full length articles.
2) Reviews, case reports, letters, abstracts, editorials, historical reviews and in vitro, ex- vivo studies.

PICOS

P - Participants: Primary teeth
I - Intervention: Working length determination with apex locator
C - Comparison: Conventional radiograph
O - Outcome measure: Accuracy
S - Study design: Clinical trials

2. Information Sources

A comprehensive computerized search (since1st January 2015 and 30th October 2017) was conducted in PubMed and Google Scholar and manual search using DPU college library resources. In PubMed the Clinical Queries filter, facilitated finding the controlled clinical trials (RCTs) for comparing apex locator and conventional radiography method for determination of working length in primary teeth. All cross reference lists of the selected studies were screened for additional papers that could meet the eligibility criteria of the study. The databases were searched up using the search strategy.

Search Strategy Used For Pubmed Database

Table 1

Apex locator	Electronic Apex Locator
Conventional radiography	IOPA
Working length determination	
Primary teeth	Deciduous teeth , Milk teeth

Combinations of the following keywords were used to develop search strategies applied for the PubMed database search up to 30th October 2017.

Table 2

Sr. No.	Search strategy	Number of articles	Number of selected articles
LD 1	Apex locator AND conventional radiography AND working length AND primary teeth	5	5
LD 2	Apex locator AND conventional radiography AND working length AND milk tooth	4	4
LD 3	Apex locator AND conventional radiography AND working length AND Deciduous teeth	4	4
LD 4	Apex locator AND IOPA AND working length AND primary teeth	1	1
LD 5	EAL AND conventional radiography AND working length AND primary teeth	2	2
LD 6	Apex locator OR conventional radiography OR working length AND primary teeth	137	27
LD 7	EAL OR IOPA OR working length AND primary teeth	54	24
LD 8	Electronic apex locator OR conventional radiography AND working length OR Deciduous teeth	260	36
LD 9	electronic root length measurement OR conventional radiography AND milk teeth	57	7
Other sources		2	2
Total		526	80
Total after removing duplicates		23	5

3. Study Selection

Selection of studies was done initially by reading the title and abstract of the articles obtained from each database. Only those articles that were relevant to the review were collected and put for further evaluation. Clinical trials and fulfilling the inclusion criteria were assessed further for the review

Full text articles of the selected abstracts were then evaluated independently. The selection process involved two independent investigators and a consensus decision was made with a third evaluator to shortlist the articles that met all the inclusion criteria for the systematic review. Reference lists of the selected articles were also searched for additional data that may have been missed.

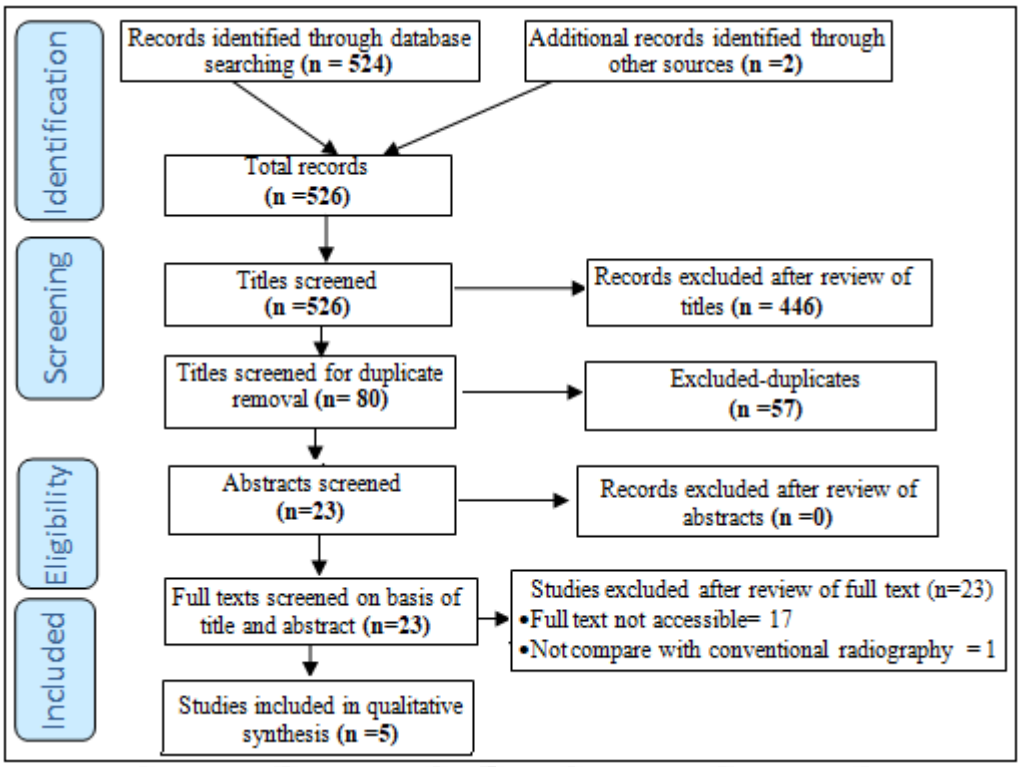
Also hand searching was performed which added one more article data to the digital search results.Out of 526 articles, after removal of duplication 23articles are remained. Out of 23 articles only 5 articles had in vivo studies with both Apex locator and Conventional radiography. Remained 18 articles had either in vitro or ex- vivo studies, so for this systematic review only 5 articles were taken into consideration.

4. Data Collection Process

A standard pilot form in excel sheet was initially used and then all those headings not applicable for review were removed. Data extraction was done for one article and this form was reviewed by an expert and finalized. This was followed by data extraction for all the articles

Study Selection (Figure 1)

PRISMA 2009 Flow Diagram



5. Discussion

Root canal length determination is refers to the distance from the coronal reference point to the point at which canal preparation and obturation should terminate. Correct working length determination is one of the main factors for success in root canal treatment. So we summarize below of the studies included in this systematic review.

IE Neena, A Ananthraj, P Praveen, V Karthik, P Rani in 2011 published in-vivo study.conducted in the Department of Paediatric and Preventive Dentistry, D.A. Pandu Memorial Rashtria vidyaniketana Dental College Bangalore. This study was conducted on 30 primary teeth which were indicated for pulpectomy in the patients (5 – 11 yr). Patients were selected according to the inclusion criteria like adequate remaining tooth structure for rubber dam isolation and radiographically visible canals with irreversible pulpitis or pulp necrosis.After administration of block with LA, tooth was isolated with rubber dam. Access cavity preparation was done using a round diamond bur. Pulpal tissue of each tooth was extirpated using a barbed broach, and the root canals were irrigated using sodium hypochlorite solution. The pulp chamber was dried using sterile cotton pellets. Measurements from the preoperative radiographs were made using ISO 15-20 number files with rubber markers, keeping them 0.5 mm short of the root apex. With these measurements, the files were inserted into the canal and an IOPA was taken using conventional method by paralleling technique. The distance between the source and the tooth and distance between tooth and the films, was standardized using X-ray positioning device. Using the same measurement, the files were then again placed in the canals, and an RVG was taken.Then file was attached to the file holder and the lip clip was attached to patients lip. The file was advanced till the device indicated that the apical constriction had been reached. The root lengths estimated from RVG and apex locator were compared with the IOPA measurement for accuracy. Measurements were subjected to statistical analysis .Totally 90 canals (30 teeth) measurements were taken in this study. Mean of apex locator was 11.79, conventional radiograph was 11.76 and digital radiography was 11.98. There was no significant difference in the mean root length measurements from the three techniques ($P > 0.05$) and shown that the distance between apex locator and conventional radiograph is low compared to the distance between intra oral digital radiovisiography and conventional radiography. They concluded that, Apex locator is comparable to conventional radiograph in determining the working length without radiation in the primary teeth. Intraoral digital radiography is the safest method in determining the working length with significant reduction in radiation exposure.[4]

Archana,A Thomas, Shobha Tandon published a vivo study comparing Root ZX, RVG and Conventional Radiography to determine working length in roots of primary molars in 2013. This study was carried out in 50 primary molars out of which 25 were maxillary teeth and 25 were mandibular teeth. Working length was recorded using all the three methods in all the teeth. Only the primary molars with 3 canals and more than 3/4th of root length were included in the study. Recording of working length using Root ZX recorded using no.10 or 20 file depending on the canal size, which is attached to the file holder. After the root ZX was switched on, the contrary electrode was then placed into the corner of the mouth. The file was introduced into the canal until the meter reads 0.5 mm and the rubber stopper was then positioned to the surface of the tooth as a reference mark for determining canal length. The file was advanced

with a slow clockwise turn until "APEX" begins to flash on the display monitor. The file was then withdrawn counter clockwise. At 0.5mm reading, the length of the file is measured and the value was recorded. Working length recording using conventional radiography from the tooth length measured and calculated using the Ingle's method. The files were then placed into the respective canals of the tooth concerned and a working length X-Ray was obtained with an E –speed film. Each film was exposed at 70 kV and 7 mA for 0.6 sec. The films were uniformly exposed and processed by hand. The films were developed for 30 seconds, followed by a 3 second water wash and fixed for 60 seconds. The length of the file was then measured by using a magnifying glass and millimetre metallic scale. This root canal length minus 1 mm was recorded as the working length as by Ellingsen et al, [13] they concluded that weighing the advantages and disadvantages of each technique and based on operator's preference any of the methods can be used for determining the working length in deciduous molars.[1]

Milad Soruri et al published in-vivo study in 2013 in 60 root canals from 20 children referred to department of paediatric dentistry of Ahvaz Jondishapour University of medical sciences in 2009 to 2010 who were selected by simple sampling. 27 children (5-7 yrs) with mandibular primary molar pulpectomy for treatment of abscesses entered the study. Seven children were excluded from the study because of non-cooperation during therapy. Acccess opening procedure carried out. After irrigating, canals were dried by a paper cone. lip clip of the electrode of EAL was attached to mouth corner and the file holder was attached to a k-file ≠15. File was introduced to the canal until the EAL monitor showed that it has reached to apical constriction. At this time a rubber stop was set on the coronal reference point and file was removed. This process was done for all 3 canals of each tooth. Then the distance between rubbers stop and file apex was measured by a millimetre ruler and recorded as the measured working length by EAL in mm. For determination of canal length by radiographic method, at first a k-file ≠15 was placed in the tooth canal using the initial radiograph. Practically, measurement was done 0.5 mm short of the root apex. 2 mm was subtracted from this measure: 1 mm for magnification and distortion and 1 mm for the difference between the location of apical constriction and radiographic apex. Rubber stop was set on the coronal reference point and radiograph was taken by using an X-ray positioning device.Results of the study were in 56 canals (93.3%) the measured length by EAL was equal to radiographic method. In 3 canals (5%) measured length by EAL was 1 millimetre shorter than radiographic length and in 1 canal (1.7%) it was 1 millimeter longer. Paired samples T test failed to show a significant difference between two methods (p = 0.85).One of the disadvantages of this device is unfamiliarity of dentists with the device and its high price.[6]

Fatih Oznurhan, Murat Unal, Arife Kapdan, Ceren ozturk & Serkan Aksoy in 2013 publishedan in-vivo study in the Department of Paediatric Dentistry, Faculty of Dentistry, Cumhuriyet University and Sivas, Turkey. In this study a total of 32 human primary molar teeth (96 roots) were selected from patients (4–10 years old) who were indicated for root canal treatment. Thenan endodontic access preparation, root canals were irrigated withsaline solution. The roots were dried with paper points. The EAL measurements were taken with EndoMaster device with a ♯ 15 K-file. The file was advanced apically into the root until the device gave the signs of apex. A rubber stopper was adapted to the reference point. Measurements were considered valid if the instrument remained stable for at least 5 sec. The file was carefully withdrawn from the canal and the measurements were recorded with a digital calibre. A radiography holder was used to have standard radiographs. A no.15 K-file was advanced into the canal and a WL radiograph was taken. The primary WL was determined to be 0.5 mm short of radiographic apex. The measurements were recorded with a digital calibre, and the classification was made as correct measurements (EAL = radiographic measurement), 0–0.5 mm (the differences in measurements were in the range 0– 0.5 mm), 0.5–1 mm (the differences in measurements were in the range 0.51– 1 mm) and 1 mm (the differences in measurements were bigger than 1 mm).Results of the study was the mean values of WL measurements for RG were 13.23± 1.92 mm and for EAL were 13.08 ± 1.77 mm and no significant differences were found between RG and EAL (P = 0.585). The use of EAL might be useful for protecting the children from exposure to recurrent ionizing radiation, over instrumentation, overfilling, damage to the permanent tooth germs, and the need of extra radiographs and might be useful in cases where radiographic determination of root lengths has some limitations.[7]

K Vidya Bhat, Prakashchandra Shetty, Latha Anandakrishna in 2017 published in-vivo study in Department of Pedodontics and Preventive Dentistry, Mathrushri Ramabai Ambedkar Dental College and Hospital, Bengaluru Karnataka, India. Samples of 30 primary posterior teeth, which are indicated for pulpectomy,were selected for the study. After LA, access cavities were prepared using a no.10 round bur in a high-speed handpiece. After the initial exploration of the canals with no.10 K-file, pulp was extirpated with a barbed broach followed by irrigation of the canals with 0.9% saline. Finally, the access cavity was dried with cotton pellets before using EAL. AniPex was used according to the manufacturer's instructions. The clip was applied to the patient's lip and no.10 K-file connected to the electrode of the device was apically advanced in the canal, until it reached the previously calibrated 0.5 mm sign on the screen of the device, which is accepted as the apical constriction. At the meter 0.5 reading, the length of the file was measured and the value recorded. Conventional radiographic measurements were made according to Ingle's method by the operator. The file was introduced into the canal till the tentative working length which was obtained from the preoperative radiograph. Paediatric film was used in the study with an exposure of 0.6 second. Paralleling radiographic technique was followed. Results shown radiographicmethods were 12.56 ± 1.93 mm and for EAL were 12.34 ± 1.86 mm. There was no statistically significant difference found when using EAL as compared with that of conventional radiographic method (p = 0.51) for working length determination in primary teeth. They conclude that iPex apex locator can be used as an

alternative in determining the working length of primary teeth.[8]

There are a number of factors that may affect electrical measurement of the root canal length:

1) The apical foramen is often located laterally, rather than apicocentral, because of the presence of physiologic root resorption in case of primary teeth
2) It is difficult to identify the position of the apical foramen on the radiograph when it is located short of the radiographic apex on the facial or lingual aspect of the root
3) There is a probability of getting an electronic working length reading which is longer than radiographic reading, when the root canal curvature is in buccolingual direction. Radiographic assessment of small areas of resorption is difficult particularly in cases where resorption occurs on the buccal or lingual aspects of the root.

This will often not be visible radiographically, resulting in an increased risk of over instrumentation and/or overfilling, [9] in such cases of resorption, working length readings with EALs would be lower than radiographic readings. A study on the accuracy of EAL in primary teeth with root resorption showed that although the apical foramen was resorbed and enlarged, the conical shape of the canal was still maintained. The EAL (Root ZX) was capable of functioning accurately in primary teeth with resorption because the root canal typically had a decreasing taper toward the defect.

Studies included in this systematic review newer generations Apex locators like NSK iPEX (4^{th} generation), Endomaster (is a combined device with fourth generation apex locator, simultaneously calculates the impedance of three different frequencies), Root ZX (3^{rd}generation). The first generation of EALs was resistance, based whereas the second generation was based on impedance. The main shortcoming of both types (which corresponded to poor accuracy with electrolytes) was overcome by the introduction of third-generation apex locators, such as the Root ZX (J Morita Corp, Tokyo, Japan). The Root ZX uses the ‘‘ratio’’ method to measure the root canal length. This method involves the measurement of impedance values at two frequencies (8 KHz and 0.4 KHz) simultaneously and the calculation of a quotient that expresses the position of the file tip in the canal.[11] The Root ZX apex locator is considered to be the gold standard against which newer EALs are evaluated. The iPex (NSK, Tochigi, Japan) is claimed to be a fourth-generation apex locator.[12]

6. Limitations

As with any study, this systematic review also comes with a few limitations due to lack of sufficient in-vivo researches in this issue, more in vivo studies especially on teeth with root resorption is required.

7. Conclusion

This systematic review offers some definitive conclusions. There is no significant difference between the use of EAL and RG for determining the working length in primary teeth. The use of EAL might be useful for protecting the children from exposure to recurrent ionizing radiation, over instrumentation, overfilling, damage to the permanent tooth germs, and the need of extra radiographs and might be useful in cases where radiographic determination of root length has some limitations. However, considering limited studies it will not be appropriate to frankly conclude that the three methods can be used independently in deciduous molars.

8. Future Implication

1) Large number of studies are required to be carried out considering the factors like resorbed or non-resorbed primary teeth.
2) As this systematic review based on two databases namely PubMed & Google Scholar, for new systematic review inclusion of other databases would have given more authentications.

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Author Profile

Pradnya Kshirsagar is Post Graduate Student, Dr. D. Y. Patil Vidyapeeth`s, Dr. D. Y. Patil Dental College, Pimpri.

Rahul Deshpande is Professor and P G Guide, Dr. D. Y. Patil Vidyapeeth`s, Dr. D. Y. Patil Dental College, Pimpri.

Ujwal Kontham is Professor, Dr. D. Y. Patil Vidyapeeth, Dr. D. Y.Patil Dental College, Pimpri

Pranav Dungarwal, MDS Pedodontist, Sangamner

Charuta Dabholkar, MDS Periodontist and Implantologist, Pune