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RESEARCH ARTICLE

ACCURACY OF APEX LOCATORS VERSUS RADIOGRAPHIC METHOD IN WORKING LENGTH DETERMINATION: A SYSTEMATIC REVIEW AND META-ANALYSIS.

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Key words:-
Electronic apex locator, digital radiography, conventional radiography, working length, Endodontics.

Abstract

Background: Accurate determination of the working length has a great impact on treatment prognosis. Apex locators have evolved to overcome the limitations of conventional radiography and increase the accuracy of working length determination. There is limited evidence about whether apex locators are actually superior to radiographic method.

Aim: This study aims to review different clinical studies on the accuracy of apex locators in comparison to radiographic method for working length determination in permanent teeth.

Methods: Clinical studies that compared apex locators to radiographic method were searched for in 3 databases including PubMed, Cochrane & Lilacs in addition to manual search to identify other potentially relevant articles. Nine articles were included in the study according to the inclusion criteria.

Results: There is no significant difference between radiographic method and electronic apex locators in working length accuracy, obturation adequacy & Postoperative pain, however, there was a statistical significant difference between the two groups regarding the master cone accuracy in the favour of the radiographic method.

Conclusion: Electronic apex locators are comparable in the accuracy of working length determination to radiographic method. However, electronic apex locators and digital radiographic methods were found to be beneficial from the perspective of radiation dose reduction.

Introduction:-

Aim:-

The aim of this systematic review is to review different clinical studies on the accuracy of apex locators in comparison to radiographic method for working length determination in permanent teeth.

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Materials & Methods:-

Pico:-

P: Patients with permanent teeth requiring endodontic treatment.
I: Apex locator.
C: Radiographic method.
O: Primary: To evaluate the accuracy of apex locators versus radiographs in working length determination.
Secondary: Evaluation of master cone accuracy, postoperative pain & Obturation adequacy.

Research Question:-

In patients with permanent teeth requiring endodontic treatment, will apex locators be more accurate than digital radiography in working length determination?

Inclusion criteria:-

1. Randomized controlled trials, Randomized clinical trials & Quasi randomized clinical trials.
2. Studies on patients with permanent teeth requiring endodontic treatment.
3. Studies in English language.

Exclusion criteria:-

1. Studies in language other than English.
2. Clinical studies (in-vivo, ex-vivo), Clinical trials
3. In vitro studies.
4. Studies on primary teeth.
5. Animal studies.
6. Completely off topic or different methodology.
7. Reviews.

Search strategy & Prisma flow diagram:-

The following electronic bibliographic databases; Pubmed, Lilacs & Cochrane Library were searched, in addition to "manual searching" to identify other potentially relevant articles.

Table 1:- search strategy terms and number of articlesfound

Database searched	Keywords used	Number of articles found
PubMed	(apex locator or apex locators or apex-locator or apex finder) AND (digital radiograph or digital radiography or digital radiographs or digital- radiograph or digital xrays or RVG or radiovisiography)	36
Cochrane	(apex locator or apex locators or apex-locator or apex finder) AND (digital radiograph or digital radiography or digital radiographs or digital- radiograph or digital xrays or RVG or radiovisiography)	3
Lilacs	Apex locator and radiograph	5
Manual search	----------	5

Prisma flow diagram:-

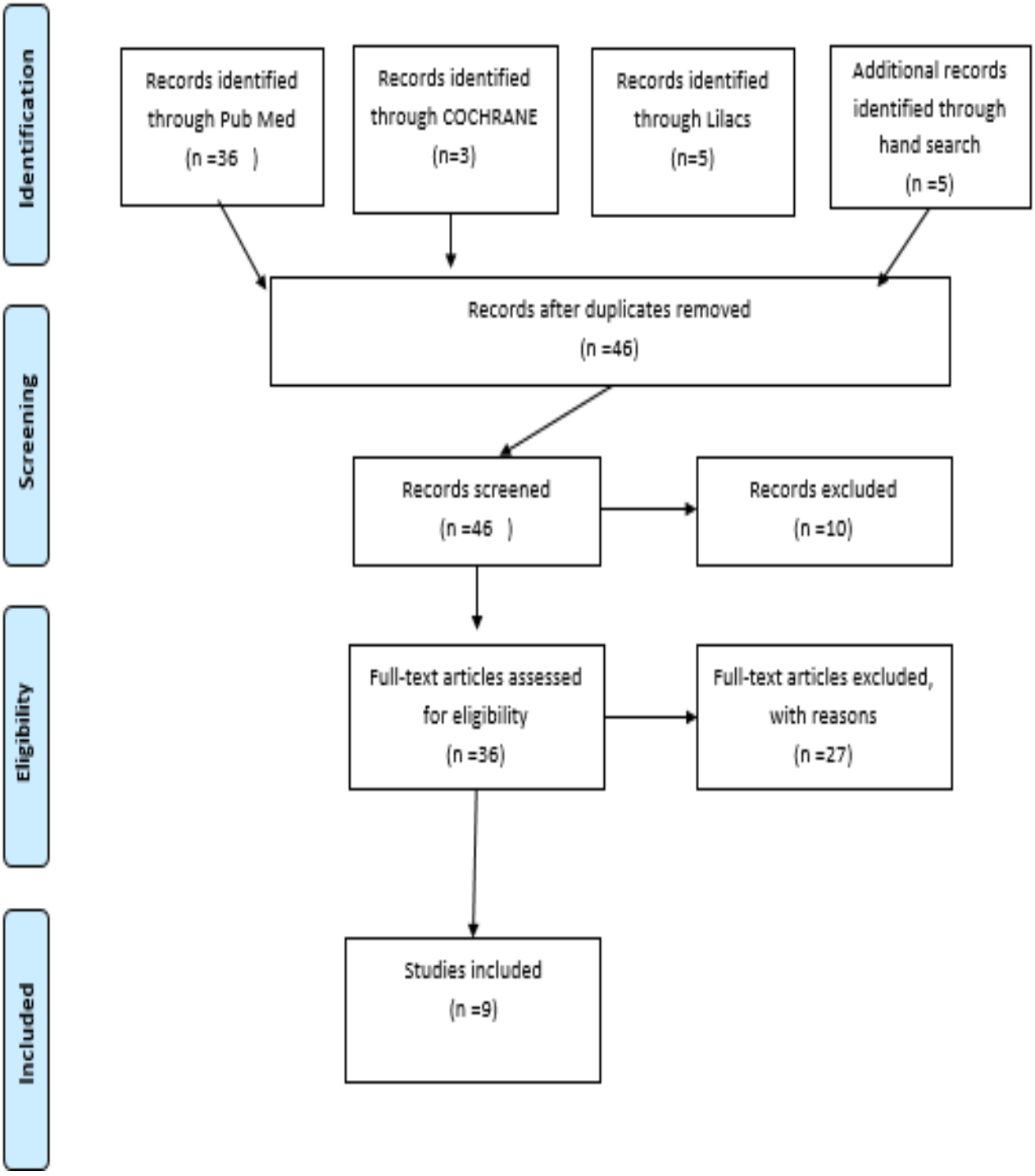

Figure 1: Prisma flow chart

Data collection & analysis:-
A structured electronic search was carried out including only terms related to the intervention. Relevant papers published in English were identified after reviewing their titles, abstracts then full reading of the papers. All the data were extracted and tabulated and risk assessment was performed for each included article.

Table 2:- Excluded articles with reasons

Excluded study	Reason for exclusion
Saad et al 2000	In Vivo study
Martínez-Lozano et al 2001	In Vitro study
Dotto et al 2005	Article not in English (Portuguese)
Subramaniam et al 2005	Study on primary teeth
Shanmugaraj et al 2007	In Vivo/ex vivo study
Krajczár et al 2008	In Vitro study
Krajczár et al 2008	Article not in English (Hungarian)
Huanca et al 2010	Article not in English (Spanish)
Cianconi et al 2010	In Vitro study
Mello-Moura et al 2010	Study on primary teeth
Real et al 2011	In Vitro study
Orosco et al 2011	In Vivo study
Neena et al 2011	Study on primary teeth
Kqiku et al 2011	In Vitro study
Kishor 2012	In Vitro study
Saritha et al 2012	Study on primary teeth
Dinapadu et al 2013	In Vitro study
Mandlik et al 2013	In Vivo study
Wankhade et al 2013	Study on primary teeth
Diwanji et al 2014	In Vitro study
Khursheed et al 2014	In Vivo/ex vivo study
Mrasori et al 2015	In Vitro study
Reddy et al 2015	Study on primary teeth & In Vitro
Topaloglu-Ak et al 2015	Study on primary teeth
Abdullah et al 2016	Study on primary teeth
Kumar et al 2016	Study on primary teeth
Yılmaz et al 2017	Ex Vivo study.

Table 3:- Study characteristics of selected articles

Study	Sample teeth	Sample size	Age (years)	Sex	EAL used	Method
Fouad et al 2000	Anteriors, premolars, molars	36pts 58 canals	------	------	Root ZX	Evaluation of working length determination by WL radiograph or EAL
Smadi 2006	Premolars, molars	66pts 151 c	12-65	36 f 30 m	Tri Auto ZX	Evaluation of the radiographic extent of the final root canal filling following WL determination with EAL or EAL+ radiograph
Hassanien et al 2008	Mandibular premolars	20 pts	30-45	------	Root ZX	Assessment of WL accuracy after WL determination with EAL or radiograph ad confirmed by stereoscopic analysis after tooth extraction

Ravanshad et al 2010	Single and multicanaled teeth	84 pts 188 c	20-65	------	Raypex5	Evaluation of MC accuracy and obturation accuracy following WL determination using EAL or radiograph
Jarad et al 2011	Single rooted & multirooted	46 pts	------	27 f 19 m	Raypex5	Evaluation of master cone accuracy following WL determination using EAL or radiograph
Kocak et al 2013	------	120 pts 283 roots	20-65	------	Root ZX multifunctional endodontic motor with integrated apex locator (VDW Gold)	Evaluation of master cone accuracyfollowing WL determination using EAL, motor integrated EAL & radiograph
Kara Tuncer et al 2014	Single rooted teeth	220	20-60	99 f 121 m	Root ZX	Evaluation of postoperative pain following WL determination using EAL or DR
Singh et al 2015	Single canal teeth	153	20-45	------	Raypex5	
Abu Naeem et al 2017	Mandibular molars	54 pts	14-47	40 f 14 m	Denta port ZX	Evaluation of post operative pain, analgesic intake following WL determination with EAL or DR

Table 4:- Outcomes of interest and Conclusions

Study	Compared groups	WL accuracy (distance from file tip to AF)	Master cone accuracy	Obturation adequacy	Postoperative pain	Conclusion
Fouad et al 2000	EAL vs Radiographs			✓		EAL better than radiographs
Smadi 2006	EAL vs EAL+ radiographs			✓		No difference between both groups
Hassanien et al 2008	EAL vs Radiographs	✓				EAL better than radiographs
Ravanshad et al 2010	EAL vs Radiographs		✓	✓		EAL comparable if not superior to radiographs regarding the rates of acceptable and short cases. in addition to reducing radiographic exposure, EALs can reduce the rate of overestimation of root canal length.
Jarad et al 2011	EAL+ MC radiograph vs Radiographs		✓			No difference between both groups
Kocak et al	EAL vs		✓			No difference between all

2013	Motor+EAL vs Radiograph					groups
Kara Tuncer et al 2014	EAL vs Digital Radiographs				✓	No difference between both groups
Singh et al 2015	EAL vs Radiographs		✓			No difference between groups EALs can avoid the overestimation of WL
Abu Naeem et al 2017	EAL vs Digital Radiographs				✓	No difference between both groups

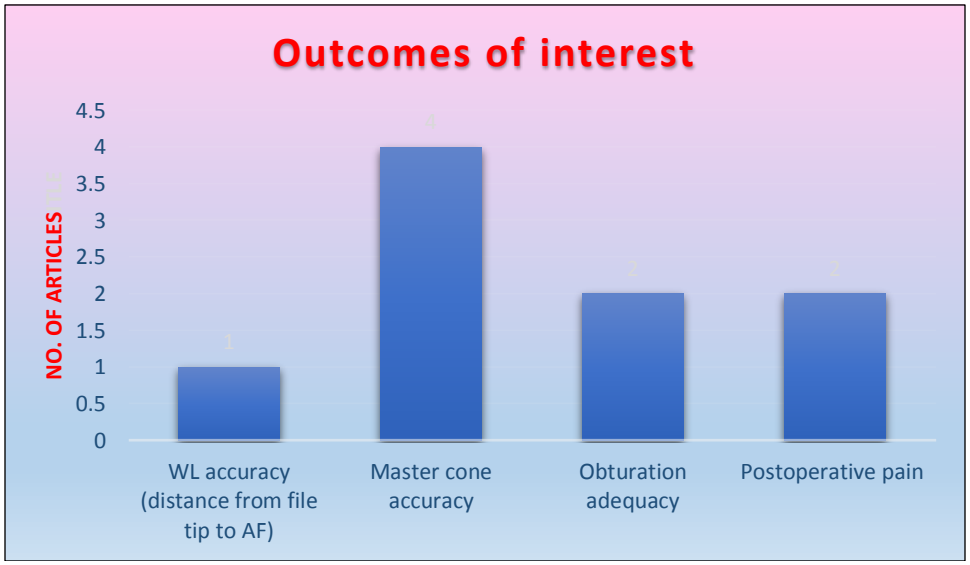

Figure 2:- Chart for overall comparison of outcomes of interest

Table 5:- Evidence methodology

study	Randomization	Allocation concealment	Blinding	Sample size calculation
Fouad et al 2000	Yes Random choice	No	yes	Not mentioned
Smadi 2006	Yes Alternately as they referred for treatment	No	Not mentioned	Not mentioned
Hassanien et al 2008	yes	Not mentioned	Not mentioned	Not mentioned
Ravanshad et al 2010	Yes Flipping coin	Not mentioned	yes	yes
Jarad et al 2011	Yes Computer generated random numbers with random variable block size stratified for the dentist and the degree of difficulty	yes	yes	Not mentioned
Kocak et al 2013	Yes	Not mentioned	yes	Not mentioned
Kara Tuncer et al 2014	yes	Not mentioned	Not mentioned	Not mentioned
Singh et al 2015	Yes	Not mentioned	yes	yes

	Computer generated sequence			
Abu Naeem et al 2017	Yes Computer generated sequence	yes	yes	yes

Results:-

Regarding WL accuracy, only one study was found by Hassanien et al [10] who compared the working length accuracy done by either EALs or radiography and correlated the lengths to the position of the apical constriction and apical foramen. They used a sample size of 20 patients and 30 extracted mandibular premolars and found that there was a statistically significant difference between file-tip position from apical foramen in EAL gp & radiographic method gp. This significant difference was found also between file-tip position in both groups and CDJ and apical constriction.

Regarding master cone accuracy, 4 studies were found with a sample size of 407 patients. Ravanshad et al [29] assessed the master cone accuracy following WL determination using both methods and they found that regarding master cone adequacy, in radiographic gp, 82.1% were acceptable (69 out of 84), 7.1% were short &10.7% were over while in EAL gp, 90.4% were acceptable (94 out of 1014), 8.7% were short & 1% was over and concluded that EAL results were comparable if not superior to radiographic method. Jarad et al [12] who also compared the MC accuracy among both groups found that in radiography gp, 74% were acceptable (17 out of 23) and mean distance to radiographic apex was 1.23mm +/-0.72 while in EAL gp, 91% were acceptable (21 out of 23) and mean distance to radiographic apex was 1.06 mm+/- 0.67 and concluded that there was no significant difference found between the 2 groups. Kocack et al [16] who also assessed the MC accuracy between radiographic method, EALs and motor integrated EALs found that in radiography gp, 81.9% were acceptable (77 out of 94), 7.4% were short & 10.6% were over, in EAL gp, 87% were acceptable (80 out of 92) , 4.3% were short & 8.7% were over while in motor EAL gp, 83.5% were acceptable, 6.2% were short & 10.3 were over and concluded that there was no significant difference between the 3 groups. Singh et al [36] who studied the MC accuracy was in accordance to the past 3 studies and found that in radiography gp, 83.1% were acceptable (64 out of 77), 3.9% were short & 13.1% were over while in EAL gp, 92.1% were acceptable (70 out of 76), 5.2% were short & 2.6% were over and concluded that EALs results were comparable in their accuracy to radiographic method. Only Jarad et al [12] & singh et al [36] studies resulted in a meta- analysis (RR 1.13, 95% CI 1.02 to 1.27) which yielded a significant difference between the radiographic method and EALs in the favour of the radiographic method. The I_2 value was 0% which represents no heterogenicity between studies (Figure 3). Ravanshad et al [29] and Kocak et al [16] were excluded from the meta-analysis.

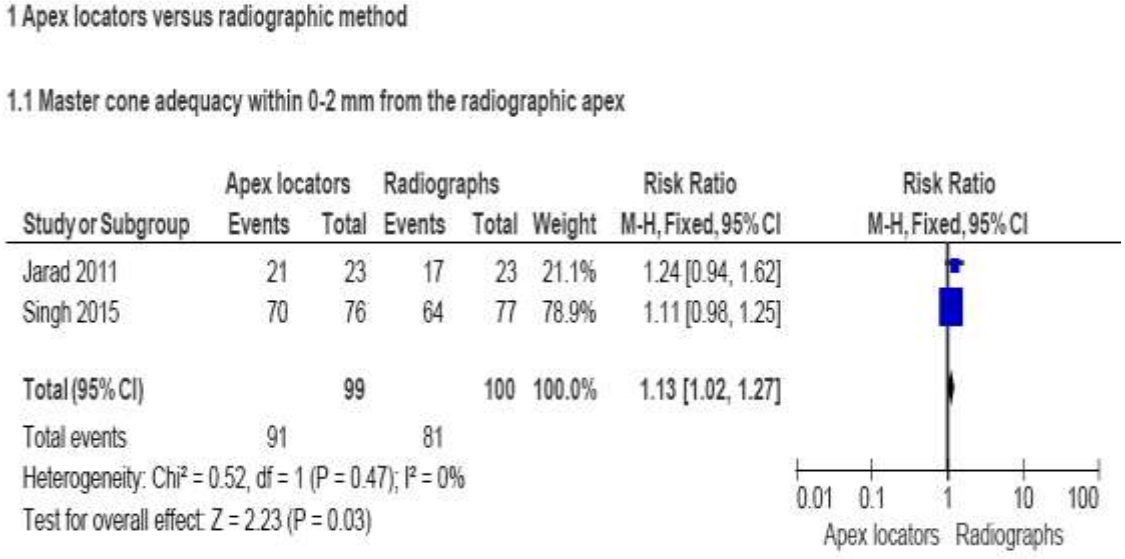

Figure 3:- Results of Meta- analysis for the master cone adequacy outcome

Regarding the obturation adequacy, 3 studies were included with a sample size of 186 patients (397 canals). Fouad et al [7] compared the obturation adequacy after working length determination using EAL or radiographic method. They found that in radiographic gp 62.5% were acceptable (21 out of 28) & 37.5% were unacceptable while in EAL gp, 90% were acceptable (28 out of 30) & 10% were unacceptable and concluded that EAL improved length quality of the final obturation, compared with a radiographic method. On the contrary, Smadi [37] who also compared the obturation adequacy and found that the mean distance from the tip of root canal filling to radiographic apex in EAL gp & radiography gp are -0.5+/-0.5 & -0.4+/-0.5 respectively while and the mean total number of radiographs in EAL gp and radiography gp are 2+/-1 & 3.2+/-0.5 respectively and concluded that there was no statistical significant difference in obturation adequacy when using EAL alone or EAL+ radiograph in determination of WL. Ravanshad et al [29] assessed the obturation adequacy and found that in radiographic gp, 85.7% were acceptable (72 out of 84), 1.2% were short & 13.1% were over while in EAL gp, 90.4% were acceptable (94 out of 104), 1% was short & 8.7% were over and concluded that EAL results were comparable if not superior to radiographic method. Only Fouad et al [7] and Ravanshad et al [29] studies resulted in a meta-analysis (RR 1.10, 95% CI 0.99 to 1.21) which yielded no statistical significant difference between the radiographic gp & EAL gp. The I_2 value was 38% which is considered not important (Figure 4). Samdi [37] study couldn't be included in the meta-analysis because he used apex locator in both groups. In group (1) used apex locator alone and in group (2) used apex locator confirmed with radiograph.

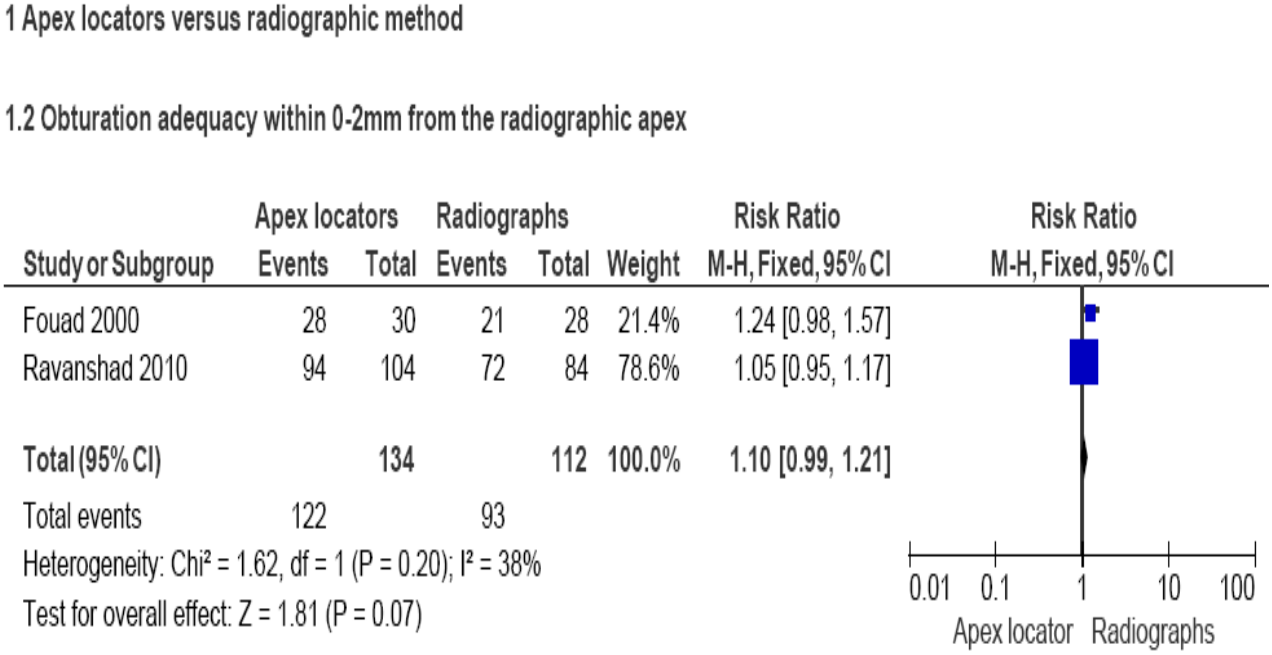

Figure 4:- Results of Meta- analysis for the obturation adequacy outcome

Regarding postoperative pain, 2 studies were found with a sample size of 274 patients. Kara Tuncer et al [13] who studied the effect of working length determination using either EAL or digital radiography on postoperative pain found that the difference between groups was not statistically significant (P > .05) and that the maximum pain level was observed within the 4- to 6-hour period and decreased over time. They also found that postoperative pain during the 4- to 48-hour interval was not significantly different between groups and that the mean times for pain dissipation in the radiographic and electronic apex locator groups were 3.37+/- 2.79 and 3.88+/- 3.34 days, respectively. In agreement to this study Abu Naeem et al [2] who also studied the effect of WL determination on postoperative pain and the analgesic intake found that there was no statistical significant difference between EAL & DR in postoperative pain sores (0.96+/- 1.25 & 0.73+/-1.37), number of days for pain dissipation (1.50+/- 1.48 & 1.35 +/- 1.23) or analgesics intake (0.96+/- 1.24 & 0.73+/- 1.37) respectively (P>0.05). However, these two studies didn't yield a meta-analysis as Kara Tuncer et al [13] represented pain results in a graph so, the appropriate data could not be extracted.

Table 6:- Risk of bias of the selected articles

Study	Selection bias		Performance bias	Detection bias	Attrition bias	Reporting bias	Other sources of bias	AHRQ Standards
	Random sequence generation	Allocation concealment	blinding of participants and personnel	blinding of outcome assessor	incomplete outcome data any drop out of patients	Free of selective reporting?? Incomplete reporting of all outcomes	follow up period or any unclear data	
Fouad et al 2000	High risk of bias	High risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Un clear risk of bias	Poor quality
Smadi 2006	Un clear risk of bias	High risk of bias	Un clear risk of bias	High risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Poor quality
Hassanien et al 2008	Un clear risk of bias	Un clear risk of bias	Un clear risk of bias	High risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Poor quality
Ravanshad et al 2010	Low risk of bias	Un clear risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Good quality
Jarad et al 2011	Low risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Good quality
Kocak et al 2013	Un clear risk of bias	Un clear risk of bias	Un clear risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Poor quality
Kara Tuncer et al 2014	Un clear risk of bias	Un clear risk of bias	Un clear risk of bias	High risk of bias	Low risk of bias	Un clear risk of bias	Low risk of bias	Poor quality
Singh et al 2015	Low risk of bias	Un clear risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Good Quality
Abu Naeem et al 2017	Low risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Low risk of bias	Good quality

Figure 5:- AHRQ standards for the included studies

Discussion:-

A systematic review is a review that attempts to identify, appraise and synthesize all the present evidence that meets pre-specified eligibility criteria to answer a given research question. Researchers conducting systematic reviews use clear and detailed methods aimed at minimizing bias, in order to produce more reliable findings that can be used for decision making in a specific topic. This type of review was chosen for this study to reach a high level evidence conclusion about the accuracy of apex locators versus radiographic method in working length determination.

Accurate working length determination is one of the main factors leading to success in root canal treatment. Radiographic method for working length determination is widely used among dentists, however, with radiographic determination the working length is generally measured either to one or a half-millimeter short of the radiographic apex, a point at which the apical constriction has been generally thought to be located. In reality, however, this point might be well beyond the apical foramen [(10)]. Apex locators have become a valuable clinical tool for assessing root canal length and may have the ability to improve clinical outcomes, decrease radiation dose and decrease clinical time. However, up till now there is no high level evidence to confirm which is more reliable in determining the working length in clinical practice [(12)].

Two systematic reviews were performed earlier related to this topic. Mohan et al [(25)] conducted a systematic review on the accuracy of working length determination in endodontics using 11 studies containing only 2 RCTs and the rest were In vivo, Ex vivo and clinical studies. They concluded that there was no significant difference between conventional methods and electronic apex locators in the accuracy of working length determination. On the contrary Martins et al [(23)] conducted a systematic review on the clinical efficacy of electronic apex locators using 21 studies containing 5 RCTs and 16 In vivo studies. They concluded that the available scientific evidence base is short and at considerable risk of bias, However, EALs reduce the patient radiation exposure and may perform better on the working length determination but at least one radiographic control should be performed to detect possible errors of the electronic devices.

In this review, 7 RCTS & 2 Quasi RCTs were included in the study to ensure best evidence away from bias. Only one study by Hassanien et al [(10)] compared the working length accuracy done by either EALs or radiography and correlated the lengths to the position of the apical constriction and apical foramen and found that there was a statistically significant difference between file-tip position from apical foramen in EAL gp & radiographic method gp. This significant difference was found also between file-tip position in both groups and CDJ and apical constriction. This study was regarded to have a poor quality during risk of bias assessment.

Three studies assessed the obturation adequacy. Fouad et al [(7)] compared the obturation adequacy after working length determination using EAL or radiographic method & concluded that EAL improved length quality of the final obturation, compared with a radiographic method. On the contrary, Smadi [(37)] who also compared the obturation

adequacy concluded that there was no statistical significant difference in obturation adequacy when using EAL alone or EAL+ radiograph in determination of WL. Ravanshad et al [29] assessed the obturation adequacy and master cone accuracy following WL determination using both methods and concluded that EAL results were comparable if not superior to radiographic method. Two out of these three studies (Fouad et al [7] & Smadi [37]) were regarded as having poor quality during risk of bias assessment and only one study (Ravanshad et al [29]) was regarded as having good quality.

Four studies assessed the MC accuracy. Ravanshad et al [29] assessed the master cone accuracy following WL determination using both methods and concluded that EAL results were comparable if not superior to radiographic method. Jarad et al [12] compared the MC accuracy among both groups and concluded that there was no significant difference found between the 2 groups. Kocak et al [16] assessed the MC accuracy between radiographic method, EALs and motor integrated EALs and concluded that there was no significant difference between the 3 groups. Singh et al [36] who studied the MC accuracy was in accordance to the past 3 studies and concluded that EALs results were comparable in their accuracy to radiographic method. Three out of these four studies(Ravanshad et al [29] , Jarad et al [12] & Singh et al [36]) were regarded as having a good quality during risk of bias assessment while one study (Kocak et al [16]) was regarded as having a poor quality.

Two studies assessed the postoperative pain. Kara Tuncer et al [13] who studied the effect of working length determination using either EAL or digital radiography on postoperative pain found that the difference between groups was not statistically significant. In agreement to this study Abu Naeem et al [2] who also studied the effect of WL determination on postoperative pain and the analgesic intake found that there was no statistical significant difference between EAL & DR in postoperative pain sores, number of days for pain dissipation or analgesics intake. One study (Abu Naeem et al [2]) was regarded as having a good quality during risk of bias assessment while the other was regarded having a poor quality.

The result of this review was in agreement with Mohan et al [25] & Martins et al [23] regarding working length accuracy and In contrast with Mohan et al[25] regarding and obturation adequacy & master cone accuracy.

Several variables were analyzed in the selected RCTs that served as parameters of evaluation for the comparison between the 2 methods of determining working length such as gender, age, tooth type, & the vitality of the tooth. These variables didn't show any effect on the final results.

Most of the outcomes contained few number of studies with small sample size and a poor quality of evidence. For better results and a better clinical decision more RCTS are needed in this research point to reach the best evidence about the best method for WL determination.

Summary:-

Within the limitation of this review, it is suggested that electronic apex locators are comparable in the accuracy of working length determination to the radiographic method. However, electronic apex locators and digital radiographic methods were found to be beneficial from the perspective of radiation dose reduction.

Implication for clinical practice:-

Working length determination using EALs that are aided by MC radiographic image would provide the benefit of the recommended accuracy minimizing the errors of electronic measurements and radiation dose reduction to the patient achieving the ALARA principle.

Implication for future research:-

More large sized systematic reviews & randomized clinical trials evaluating the success of endodontic treatment and working length accuracy comparing EALs and radiographic methods are needed to reach the best evidence on the best method for working length determination in endodontics.

RCTs that compare the accuracy of these methods to a 3 dimensional assessment tool such as cone beam radiography are needed for obtaining accurate, realistic & reliable information about the best method for working length determination.

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