

Evaluation of working length by using Manual tactile sensation, digital radiograph, electronic apex locator and CBCT in comparison with standard histological method under stereomicroscope - An in-vitro study

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Abstract

Aims: To determine the accuracy of working length determination using Tactile Sensation, Digital Radiographic Method (RVG), Electronic Apex Locator (Root ZX mini) & CBCT in lower premolars and compared it with actual working length, measured using Stereomicroscope In-Vitro.

Material and Methods: The study was conducted on 40 human mandibular premolar. access cavity was prepared and canal patency was seen with no. 10 file in each sample. Manually no. 15 K file (Mani k- file) was

inserted from access cavity until the tip was visible at the foramen, a silicone stopper was adjusted corresponding to the buccal cusp tip & root canal length was measured. After that working length were performed using Digital RVG, an Electronic Apex locator (Root ZX mini, J. Morita) and CBCT but actual length was determined only by comparing these methods histologically under stereomicroscope and the data was statistically analyzed with One Way Analysis of variance (ANOVA) followed by Tukey’s Test.

Results: One way ANOVA and Tukey's HSD test showed that there was no significant difference in the measurements by the three procedures ($p>0.05$) when compared to actual length.

Conclusion: Working length measurement with CBCT scan, Electronic Apex locator and other two methods does not show significant difference in measurement.

Keywords: CBCT, Digital Radiograph, Electronic Apex Locator, Manual, Stereomicroscope, Working Length.

Introduction

Working length determination is an important step in endodontic therapy. Success of endodontic treatment depends on perfection in the negotiation of working length. Conventionally, working length of a tooth means "the distance from a coronal reference point to that point at which canal preparation and obturation should terminate." Hence, Cemento Dentinal junction and apical constriction are two most crucial anatomical landmarks of a tooth a clinician must negotiate to achieve success in endodontic treatment.⁽¹⁾

Apical constriction also called minor constriction is considered the ideal end point of the root canal system (Kuttler 1955)

AC lies approximately 0.5-1 mm short of the Apical foramen.⁽²⁾

Various methods are used to determine endodontic working length. Manual method, being the oldest and most common technique in working length determination, requires a learning curve to achieve expertise.⁽³⁾

Digital radiography, an advanced imaging technology, allows image enhancement, lower radiation exposure, and is less time consuming, accuracy of the modalities is still remains controversy⁽⁴⁾. According to the study conducted by Martínez-Lozano *et al.* proved in their study, accuracy of conventional and digital imaging was

50.6% and 61.4%, respectively, in establishing the true working length.⁽⁵⁾

The apical foramen used as landmark in radiographs is not always located at the anatomical apex rather; it often lies on the lingual/buccal or mesial/distal aspect. These factors increase the inaccuracy and discrepancy of radiographic canal length determination. To overcome the drawbacks of radiography, determination of working length by apex locator has also been reported to have met with great success, and it also omits the need of radiation and thereby its hazards.⁽⁴⁾

The electronic apex locator (EAL) was introduced by Custer (1918). Initially these devices had disadvantage of being influenced by the contents of the canals. Over the years newer generations have been developed which can measure root canal length accurately even in highly conductive conditions, such as in the presence of blood, pus and (NaOCl)⁽⁴⁾. Piasecki L et al in 2017, reported that the lateral positioning of the apical foramen or the presence of multiple apical foramen may negatively affect the measurement accuracy of electronic apex locators.⁽⁶⁾

In the field of endodontics, advanced radiological modalities that is CBCT have proved their potential superiority in usefulness in the determination of working length without the need of any surgical modification of the tooth and thereby reducing the patient compliance.⁽³⁾

Dummer, et al.,1984, concluded that it is difficult to detect minor foramen clinically with certainty because of its location and topography.⁽⁷⁾ Grove,1931,has been suggested CDJ as the position for WL where the pulp and periodontal tissue meet is considered as physiological limit for working length, biomechanical preparation and obturation in endodontic treatment.⁽¹⁾

The CDJ is the ideal termination point for RCT. Sealing the root canal system at this point would theoretically,

prevent microbial escape into periapical tissues and block entry of tissue fluids into the canal space. This landmark cannot be precisely determined radiographically. ^(8,9) Estimated working length can be determined with radiography, an electronic method and CBCT but correct working length can be determined only by comparing these methods histologically under microscope. ⁽¹⁾ Therefore, the study was aimed to evaluate working length with Manual, Digital radiography, electronic method using Apex locator and CBCT and comparing methods with the actual length from histological sections under stereomicroscope.

Material and Methodology

Fourty human mandibular premolars extracted for orthodontic purpose will be selected for this study. Teeth was cleaned and stored in sodium chloride (0.9%). Access cavity was prepared, and canal patency was seen with no. 10 K-file (Mani k-files) in each tooth.

Methods of collection of data

Working length of each tooth is measured with four different methods:

Manual method - In this method, no. #15 K-file was inserted from access cavity until the tip was visible at the foramen, a silicon stopper was adjusted to the corresponding buccal cusp tip, and the length was measured (from buccal cusp tip to to 0.5 mm short to apical foramen) (Figure 1)

Digital radiograph method – In this method a #15 K-file with a silicon stop was inserted into the root canal, Digital radiograph (RVG, Acteon X-mind DC –X ray) was taken. Working length was measured from tip of buccal cusp to 0.5 mm short to the apex. (Figure 1)

Electronic Apex locator method

The canal was irrigated using 2.5% NaOCl & then the canal was thoroughly dried with paper points.15 k-file was inserted into the canal, the silicon stop was adjusted

to the level of reference. Alginate was condensed within the molds, and upon setting, the corresponding tooth was embedded within the alginate. During electronic measurement, the circuit was closed *in vitro* environment by inserting the labial clip of the corresponding locator into the alginate and measured. (Figure 1)

CBCT

Wax models (Modelling wax) were fabricated with extracted lower premolars.15 K-file was inserted into the canal to 0.5 mm short to the apex. The silicon stop was adjusted to the level of reference for root canal measurement & CBCT scan was done (Kodak Carestream Dental, CS9300C system in Advanced diagnostic center, Ludhiana) using standard template (0.2mm voxel). The CBCT scans were saved as DICOM file and then analyzed using CS 3D software (Carestream Dental LLC, Atlanta, GA).(Figure 1)

Determination of actual length-The silicon stop was stabilized. Sectioning was done longitudinal direction by selective grinding at apical 4mm of the root was carried out until the canal was visible using a diamond disc, then use stereomicroscope at 45x under magnification. A digital photograph was taken of each tooth with apical constriction, anatomical apex and CDJ. The images were then analyzed with software (Fizi 2.1) and the distance between file tip, CDJ, Apical constriction and anatomical apex was measured. (Figure 2)

Statistical analysis

One-way analysis of variance (ANOVA) was performed to calculate the means with corresponding standard deviations followed by Tukey's test was performed with the help of critical difference or least significant difference at 5% and 1% level of significance to compare the mean values. $P \leq 0.05$ was considered statistically significant.

Results

ANOVA showed the mean length of Manual method (21.768), RVG (21.625), CBCT (21.208) & EAL (21.280) from actual length (with stereomicroscope is 21.395) with p value > 0.05 which means non-significant but when comparing apex locator with CBCT, Root ZX mini apex locator showed closest measurements with actual length (Stereomicroscope) than CBCT in determining root canal working length followed by RVG & Manual method shows least correlation (21.768). (Table 1 & 2). Tukey's HSD test confirms there was no statistically significant difference in the mean values measurements of the four methods ($P > 0.05$). (Table 3)

Discussion

An accurate working length is one of the most important criteria for achieving successful endodontic results and minimizing post-operative discomfort.^(9,10)

Manual working length determination is an age-old method. Dohaithem had shown in his block randomization trial study that treatment outcome may vary between working length determination by tactile sensation and radiographic method, where tactile sensation turned out to be a more accurate method. Yet, it should also be considered that accuracy in tactile working length determination requires a learning curve and may vary depending on operator tactile perception as well as the morphology of the root canal system.⁽³⁾

In this ex-vivo study working length values by Manual method showed least correlation with the actual working length values measured using Stereomicroscope when compared with other methods in this study.⁽⁹⁾

Through the rapid advances of science and technology, conventional analog radiographies have been replaced with digital images. Regarding the advantages of digital radiography techniques and the convenience of image production by this method, dentists have attempted to

improve the quality of images through supplementary and image processing algorithms.⁽¹²⁾

Other advantages of the digital system are image acquisition, the possibility of enhancing, editing the image and quantifying the distance between two points on a given image.⁽¹³⁾

A question exists as to the ideal apical limit of a root canal filling, since the apical foramen is not always located at the anatomic apex of a tooth. This deviation of the foramen from the anatomic apex cannot be easily detected by radiographic observation, particularly when the opening occurs on the buccal or lingual root surface, because it is superimposed by root structure.⁽⁹⁾ It was demonstrated that the apical foramen is located laterally in 78 to 93% of posterior teeth.⁽¹⁴⁾ Therefore, proper location of the apical foramina could not be made in all the cases from a radiograph which is a 2- dimensional interpretation. CBCT images give volumetric data that provides more diagnostic information and define the location of the major foramen, which is not identifiable with precision in conventional radiographs. Their high reproducibility also aids in multi-planar reformatted reconstructions of the root canal morphology to be viewed by the clinician on a computer display. In the present study, the CBCT scanner settings were in accordance to the as low as reasonably achievable (ALARA) principle despite the fact that the procedure was carried in extracted tooth. In this study we used multiplanar reformatted sections for selecting the best sagittal view for the measurement of working length. Similar technique was suggested by Jeger et al 2012 in their study.⁽⁹⁾ Previous studies by Mohamed I. Elshinawy et al in 2017 compared 4 working length measuring techniques- regular radiographic film, digital radiographic image, CBCT & EAL, found that EAL and CBCT were more accurate techniques to determine the

working length.⁽¹⁶⁾ In our study CBCT group showed more accurate results than the 2D digital radiograph, because 2D digital radiograph can't determine the exact lateral position of apical foramen.

Use of Electronic Apex locator for endodontic working length determination eliminates many disadvantages of radiographic method in terms of accuracy, ease, and patient convenience.⁽⁹⁾ Bernardes concluded that apex locators are able to produce good precision at 1 mm distance from the apical foramen. However, it is also reported that accuracy of apex locator is highly dependent on the establishment of electrical circuit and electrical conduction properties of canal.⁽¹⁷⁾ Some researches proved that electrical conductivity of solution also may affect the accuracy of apex locators. Moreover, apex locators cannot be used in a patient with pacemakers.⁽³⁾ There are several other conditions negatively affect the accuracy of EALs, such as tooth length, enlarged apical foramen, solutions used in the root canal, brand of device, type of tooth & file size.⁽¹⁸⁾

Root ZX mini (J. Morita Corp., Kyoto, Japan) was used in this study, It is a modified version Root ZX EAL. Root ZX mini is a third-generation apex locator was built on the industry standard Root ZX technology and works on the same principle, It can measure in both wet or dry canal conditions.⁽⁹⁾ The alginate model was used in this *in vitro* study to simulate the periodontium. Katz et al., proposed an alginate model. Tinaz, Fuss, and Azabal also used alginate in their studies. The underlying reason for using alginate is its good conductivity for EAL measurements; In addition, it appropriately supplies the equivalent electronic impedance to human periodontium.⁽¹⁹⁾

Actual working length determination with Stereo microscope (Control) to establish the actual length with respect to CDJ, histological method has been

recommended. This study involved the placement of endodontic file inside the canal and the file tip was evaluated using Stereomicroscope at 45x for its location in the CDJ. Martínez-Lozano *et al.* and Muthu et al., stated that histological method is the best approach to establish actual working length, i.e., by removing cementum and dentin. Apical foramen was considered to be standardized.⁽²⁰⁾ In this study the actual working length measurement being the gold standard, had strong positive correlation with EAL > CBCT > RVG > Manual methods of working length determination with p value > 0.05 which means non-significant. The mean discrepancy between the Apex locator & CBCT was found to be 0.073 which is non-significant. In accordance with our stud, Lucena et al also concluded that the EAL was more accurate than the measurements obtained from CBCT scans. These differences can be attributed to differences between study designs, observer performance, selection of landmarks, the CBCT system used, and the CBCT setting and software capabilities.⁽²¹⁾

Conclusion

Within the limitation of this study, it was concluded that Root ZX mini showed closest measurement with actual length followed by CBCT, RVG & Manual although results are not significant. The result of this study are to be considered specific to the one CBCT system evaluated in the absence of streak and beam hardening artifacts, motion artifacts. Further studies are required

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Table 1: Mean±standard deviation, Variance, Mean deviation, and range of measurements by the four methods.

Values of descriptive statistics	Manual method	RVG method	CBCT method	Apex Locator method	Actual length seen on histological section by stereomicroscope
Mean	21.768	21.625	21.208	21.280	21.395
Standard Deviation	3.990	3.946	3.890	3.946	3.962
Variance	1.998	1.986	1.972	1.986	1.991
Mean Deviation	1.6090	1.6130	1.6230	1.6580	1.6420
Range	17.2-26.0	17.0-25.5	17.0-25.5	17.0-25.5	17.10-25.8

Table 2: Analysis of variance between Four methods and within the method (ANOVA)

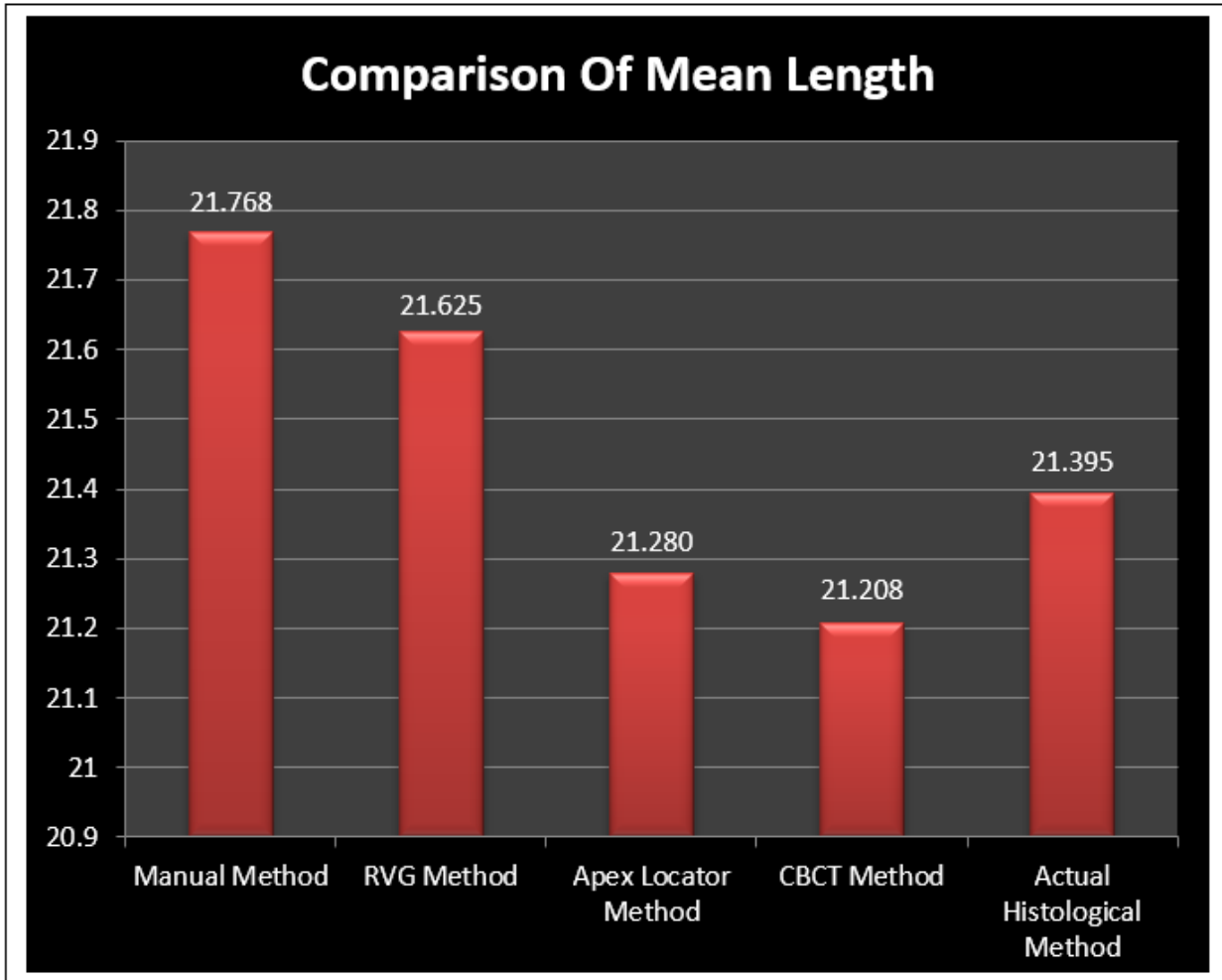
Source of Variation	d. f.	SS	MS	F	p-value
Between Groups	4	8.882	2.221	0.563	0.690
Within Groups	195	769.638	3.947		
Total	199	778.520			

P value >0.05 means non-significant results.

Table 3: Tukey HSD between Four methods and within the method

Groups	Difference	Test Statistic	p-value	Significant
Actual WL (Stereomicroscopic) vs Apex locator	0.115	0.365	1.000	No
Actual WL (Stereomicroscopic) vs CBCT	0.187	0.596	0.998	No
Actual WL (Stereomicroscopic) vs Manual	-0.373	1.186	0.979	No
Actual WL (Stereomicroscopic) vs RVG	-0.230	0.733	0.996	No
Apex locator vs CBCT	0.073	0.231	1.000	No
Apex locator vs Manual	-0.487	1.552	0.951	No
Apex locator vs RVG	-0.345	1.098	0.984	No
CBCT vs Manual	-0.560	1.783	0.928	No
CBCT vs RVG	-0.418	1.329	0.970	No
Manual vs RVG	0.143	0.454	0.999	No

Graph 1: Comparison of mean values of working length assessed by different methods.



a.



b.



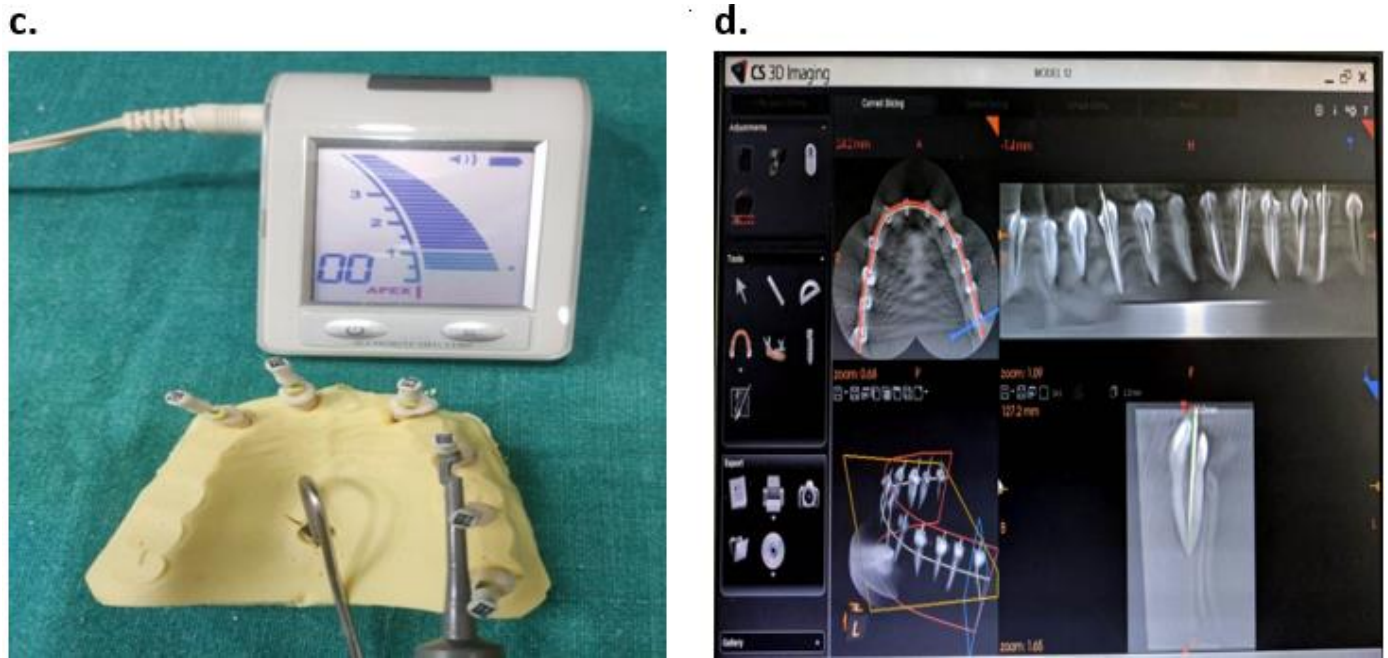


Fig 1 . a. Manual method ,b. Using RVG (Sopro imaging 2.38 software) for WL ,c. Working length measurement using Root ZX mini Electronic Apex locator d. CBCT working length using CS 3D software

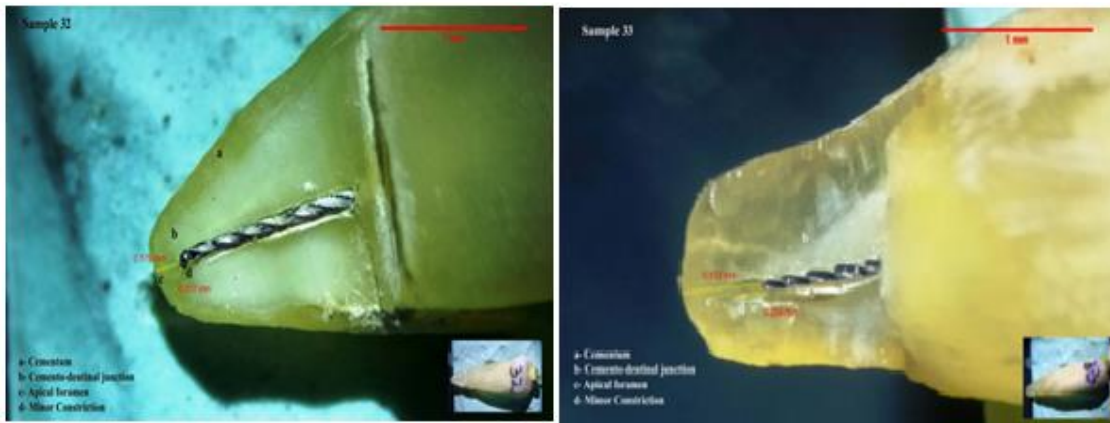


Fig 2: Stereomicroscopic images at 45x