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COMPARISON OF WORKING LENGTH DETERMINATION BY APEX LOCATOR AND CONE BEAM COMPUTED TOMOGRAPHY (AN IN VIVO STUDY)

Shady Ali Hussien*, Sara Hossam Fahmy*
and Ahmed Badr El Din Fouad Abd El Razek*

ABSTRACT

Background: A working length (WL) is defined as the distance from a coronal reference point to the point at which canal preparation and filling should terminate.

Aim: The aim of our study was to compare the accuracy of tooth length measures using: electronic apex locator, CBCT, actual length using image J software (gold standard).

Materials and Methods: A total of 20 anterior upper and lower teeth were selected for the study and were measured using EALs and CBCT scans. EALs measurements were done in in-vivo conditions then the teeth were extracted to compare the results of the EALs and the CBCT scans to the actual tooth length by using image j software acting as a gold standard.

Results: Results were statistically analysed using one way ANOVA test of variance. It was found that there was a statistically significant difference between the measurements obtained from both EALs and the image J measurement. In addition to that, there was a statistically significant difference between the measurements obtained from the CBCT scans and the EALs. CBCT measurements were more accurate than EAL.

Conclusion: CBCT considered a reliable tool for working length determination, new software improve the accuracy of working length determination, APEX locator still considered the gold standard tool for working length determination.

KEYWORDS: Working Length Determination, Apex Locator, Cone Beam Computed Tomography

* Department of Endodontics, Faculty of Dentistry, Ain Shams University

INTRODUCTION

A working length (WL) is the distance between a coronal reference point and the point at which canal preparation and filling should be completed. The radiographic assessment of WL includes constraints such as distortion, shortening, and elongation; interpretation variability; and a lack of three-dimensional representation. Even when a paralleling approach is utilized, pictures are elongated by about 5% (1).

The variation in distance between the radiographic apex and the minor foramen, the root canal termination, can lead to over- or under-instrumentation in a WL that is 1 mm short of the apex. This makes this widely applied "rule" unpredictable and unreliable (2).

One of the innovations introducing electronic science into the customarily empirical endodontic procedure is the electronic apex locator (EAL). When specific anatomic features, like impacted teeth, tori, the zygomatic arch, excessive bone density, overlapping roots, or shallow palatal vaults obscure the apical region of the canal, electronic apex locators are very helpful in avoiding needless radiation (3).

Traditional radiographs have their limitations of being a 2D image of a 3D object and images are affected by the superimposition of the surrounding structures. That's why Cone Beam Computed Tomography was developed, allowing viewing objects in 3D, thus eliminating any chance of superimpositions. With the recent advances in digital radiography, it produces high quality images with minimal dosage of radiation [(4)].

CBCT in endodontics offers a significant advantage by providing a 3D visualization of anatomical elements that cannot be achieved with intraoral, panoramic, and cephalometric imaging. CBCT units utilize projection data to generate inter-relational images in three orthogonal planes: axial, sagittal, and coronal. Furthermore, since the reconstruction of CBCT data is carried out directly on a personal computer, it allows for the reorientation of data in their accurate spatial relationships. CBCT technology allows clinicians to acquire high-resolution three-dimensional volumetric data, which can be displayed as interactive images. This provides an exceptional visualization of the intricate relationships and boundaries between teeth, as well as the associated pathology and anatomical features within the alveolus and jaws, including the maxillary sinus and mandibular canal and foramen (5).

Cone Beam Computed Tomography rose to the scene as a great diagnostic device and its use in endodontics has been proven to be crucial to aid in the visualization of the root canal system especially in difficult cases. CBCT can serve as a substitute for determining the working length of the roots in cases where the apex finder fails to appropriately establish the working length[(6)].

Hence, it was deemed worthwhile to compare the accuracy of Cone Beam Computed Tomography (CBCT) in determining working length to Electronic Apex Locators (EAL). The null hypothesis states that there is no discernible disparity in the precision of apex locators and the measurements obtained from CBCT scans.

AIM OF THE STUDY

The objective of our study was to assess the precision of tooth length measurements by employing an electronic apex locator, cone beam computed tomography (CBCT), and the real length determined through image J software (gold standard).

The null hypothesis

There is no disparity in the precision of both apex locators and the measures obtained from CBCT scans.

MATERIALS AND METHODS

I. Materials

1. Root zx EAL***
2. Sidexis 4 CBCT 3D imaging device**
3. Image J software .

II. Methods

A- Samples selection

The ethical committee of Ain Shams University's Faculty of Dentistry accepted the study protocol. Ten patients from the oral surgery clinic at Ain Shams University's Faculty of Dentistry were among them.

After detailed explanation of our study design had been provided, 3 patients refused to participate and 7 patients agreed. A total of 20 anterior upper and lower teeth were included in this study.

Exclusion criteria:

1. Teeth with apical resorption, calcification, internal and external resorption.
2. Teeth with metallic restoration.

The study was conducted from June 2021to March 2022 including patients referred to the oral surgery clinic as they had more than one anterior teeth indicated for extraction visible within the scope of view. Every one of them had a CBCT scan done outside of the current investigation. The CBCT scans were obtained by SIDEX4 3D imaging device with a 0.01 mm basic voxel size. Specialized software was used to carry out the CBCT image alignment and measurement processes (SIDEX4 3D imaging software). And an experienced resident of the Radiology department at Ain Shams University examined every scan; this resident was not involved in any further phases of the research.

* J.Morita®, Japan

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Preparatory steps before canal length determination

Patients were properly anesthetized with local anesthesia infiltration injection using Lidocaine 2% with 1:100000 Epinephrine. Proper infection control measures were ensured and proper isolation was obtained using rubber dam.

Access cavity preparation was performed using size 2 round bur. Deroofing was completed with a safe end diamond stone. All coronal pulp tissues were removed using an endodontic excavator while the radicular pulp was removed using pulp broaches [(1)]. After that tooth length determination was done before extraction to avoid unnecessary added chair time for our patients.

Group A CBCT –based WL measurments

The data were rebuilt using voxel size 0.01mm after CBCT scans were taken with a Sidexis 4 CBCT 3D imaging system running at 85 kV and 35 mA for 2–6 seconds. Specialized software was used to align and measure the CBCT images (20,23,25). An experienced resident of the radiology department at Ain Shams University assessed each scan; this resident was not involved in any further study phases.

The measurement of CBCT WL was determined by directly connecting the apical foramen and the matching incisal tip using a tracing method. If the foramen and cusp tip were not visible in a single plane, the measurement was conducted in two separate planes. Root canals are then viewed in the multi planar reconstruction (MPR) screen allowing for sagittal and coronal views of the root canals[(6,9,22)].

The length of the canal was determined by using the measure distance tool from software where the measurement lines were traced from the reference point in the occlusal plane following the canal to its coronal part of the canal and the second plane from coronal part of the canal to apex. The WL are measured in sagittal and coronal views and their arithmetic mean is calculated and recorded as the CBCT tooth length[(24,25,18)] as in figure 1 and figure 2.

Fig. (1) Sidexis 4 CBCT 3D imaging device .

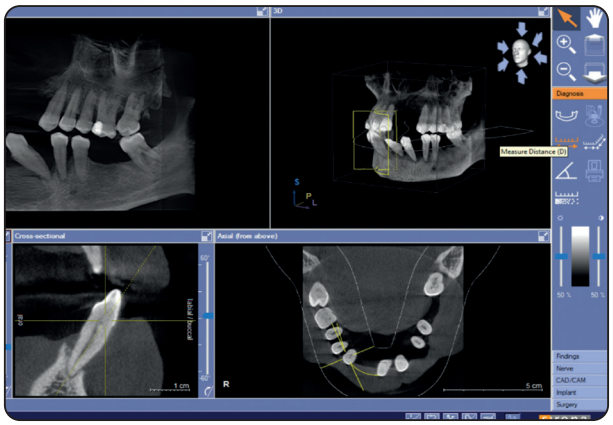

Fig. (2) Measure distance tool

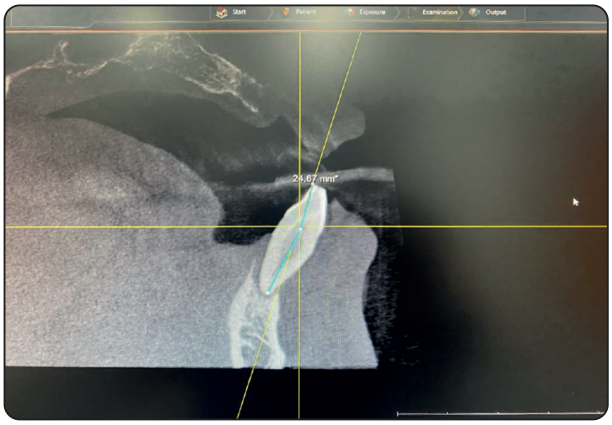

Fig. (3) CBCT coronal cut showing the tracing line used for the distance measurements from reference point to apex

Fig. (4) CBCT coronal cut showing the tracing line used from reference point to coronal part of the canal .

Group B Electronic root canal length measurements

A resident in the endodontics department at the Faculty of Dentistry, Ain Shams University, determined the tooth length. He was blinded to the findings of the CBCT measurements and followed the guidelines provided by the manufacturers of both EALs for all measurements. The root canals were found and then extensively irrigated using a 2.5% NaOCl solution. The #2 and #3 gates-glidden drills were used to prepare the coronal portion of the canal.

For the Root ZX, The probe was attached to a K-file made of stainless steel. The flashing red bar on the EAL's liquid crystal display shows that the file has proceeded to the primary foramen within the root canal [(1)].

The measurements were not recorded until the reading held steady for a minimum of five seconds. After that, the file's silicon stop was adjusted to the reference positions that were defined in agreement with the reference points used in CBCT measurements as the cusp tip[(8)]. The file was then retracted and the distance between the rubber stopper and the file tip is measured using a millimetres endodontic ruler. Measurements for each canal are repeated 3 times and the mean result is recorded [(13,15,16)]. Patients had their teeth extracted atraumatically afterwards.

Group C Actual tooth length measurements using image j

After extraction of the teeth they were cleaned to remove any deposits then teeth were cut longitudinally with disc then scanned by using CCD digital camera mounted on zoom stereomicroscope at magnification 20X in order to allow a complete view of the canals to determine canal length[27], Fig. (6). Digital images were transferred to a computer system and then were analyzed using the image J analysis software.

The National Institutes of Health and the Laboratory for Optical and Computational Instrumentation (LOCI, University of Wisconsin) developed ImageJ, a Java-based image processing program [26]. First the scale was set for image j as measured in pixel so scale was set in its sequale in mm so image was taken for endodontic ruler and measured 10 mm in pixel. So each 10 mm equal 92.0054 pixel determined as in figure 3 and figure 4. Every tooth was cut longitudinally and scanned with image j to measure working length with an endodontic ruler in every scan to ensure the adjusted scale and a line was drawn from the reference point to apex and length is measured as in figure 5.

Statistical Analysis

Data was then subject to statistical analysis using one-way ANOVA test.

Fig. (5) Showing Root ZX apex locator .

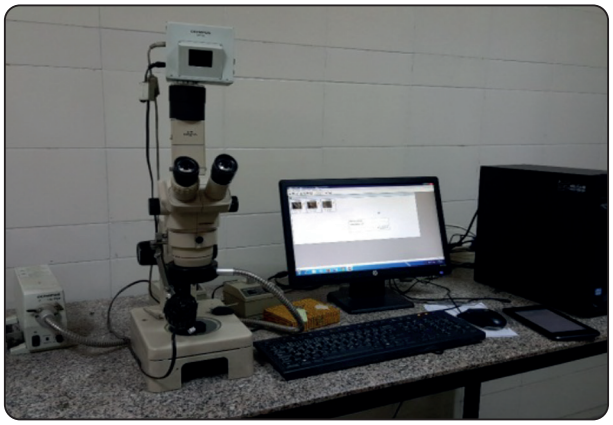

Fig. (6) CCD digital camera mounted on stereomicroscope.

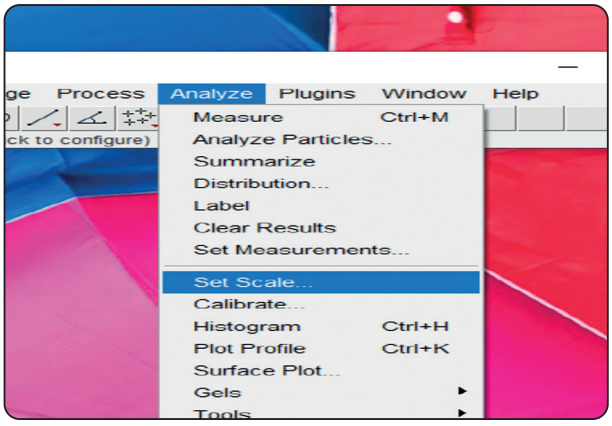

Fig. (7) Scale setting in image j software in mm.

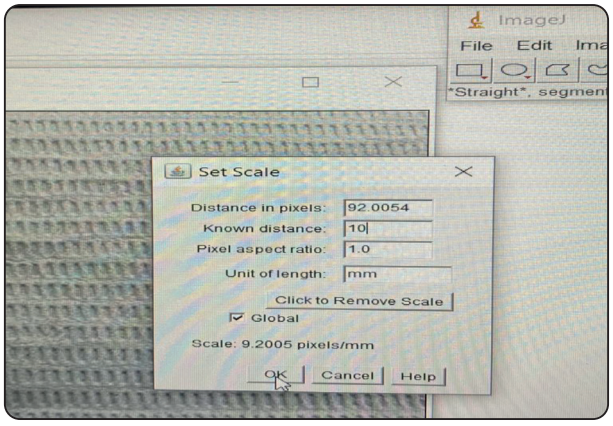

Fig. (8) Image j software scale set for each 10mm equal 92.0054 pixel.

Statistical Analysis

The standard deviation, minimum and maximum values, and the mean with 95% confidence intervals were used to present the numerical data. They were examined for normalcy using the Shapiro-Wilk test and the data distribution. They were analyzed using a repeated measures ANOVA and the Bonferroni post hoc test once it was determined that they were normally distributed. A significant threshold of $p<0.05$ was established.

RESULTS

A- Lower teeth

The highest value was found in apex locator measurements (21.80±2.35), followed by CBCT imaging (21.41±2.13), while the lowest value was found at image J measurements (21.27±2.12). The differences were really notable between values found in different groups ($p=0.009$). Pairwise comparisons done after the fact revealed that apex locator measurements to have significantly greater value than image J measurements ($p<0.001$).

B- Intragroup comparisons

Apex locator

Upper teeth (23.56±1.36) had a higher value than lower teeth (21.80±2.35) yet there is no significant difference ($p=0.190$).

CBCT

Upper teeth (22.75±2.08) had a higher value than lower teeth (21.41±2.13) yet there is no significant difference ($p=0.305$).

Image J

Upper teeth (22.56±2.04) had a higher value than lower teeth (21.27±2.12) yet there is no significant difference ($p=0.321$).

There is a statistically significant difference between apex locator and image j and it is the least accurate is apex locator. A statistically significant difference exists between CBCT & image j and it is the most accurate is CBCT.

Fig. (9) Longitudinal cut of anterior teeth showing the tooth length by line drawn from the reference point to the apex on the image J software.

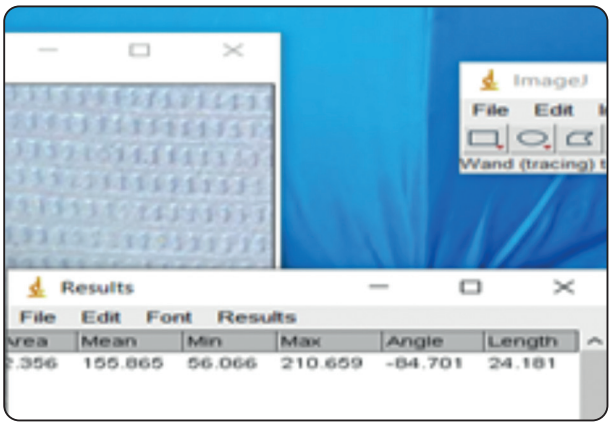

Fig. (10) The WL measurement as displayed on the image J software.

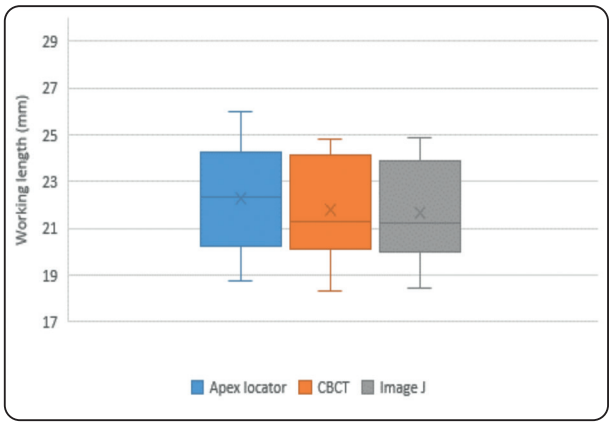

Fig. (11) Box plot showing working length values (mm)

TABLE (1) Intragroup comparison, Mean and Standard deviation values of working length (mm)

Teeth	Working length (mm) (mean±SD)			p-value
	Apex locator	CBCT	Image J	
Upper	23.56±1.36^{A}	22.75±2.08^{AB}	22.56±2.04^{B}	**0.042***
Lower	21.80±2.35^{A}	21.41±2.13^{AB}	21.27±2.12^{B}	**0.009***
p-value	**0.190ns**	**0.305ns**	**0.321ns**	

Superscript letters within the same horizontal row indicate significant differences, denoted by an asterisk (*). Non-significant differences, denoted by "ns", occur when the p-value is greater than 0.05.

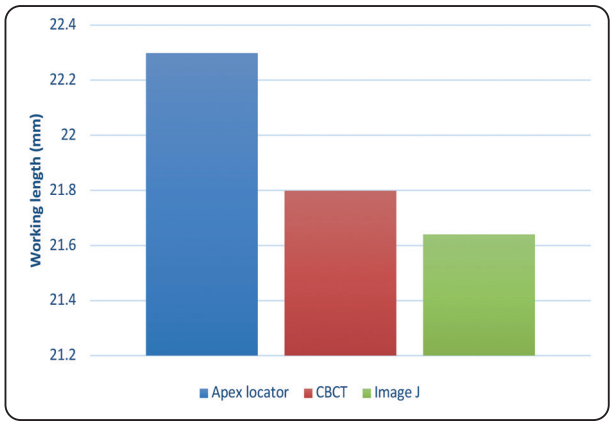

Fig. (12) Bar chart showing average working length (mm) for different groups

II- Working length determination

A) Relation between groups:

1. **Upper central**: The highest mean value was found in Apex-locator (23.70±0.25), followed by CBCT measurement (22.04±0.66), while the lowest mean value was found in Image J (21.58±1-08) .

- A statistically significant difference exists between (Apex-locator), (CBCT) & (Image J) where (p=0.026).
- Between (Apex-locator) and each of (CBCT) and (Image J), a statistically significant difference was discovered where (p=0.005) and (p=0.023).
- No meaningful difference was seen with statistical significance between (CBCT) and (Image J) where (p=0.512).

2. **Upper lateral**: The highest mean value was found in Apex-locator (21.95±0.31) , followed by CBCT measurement (20.32±0.48) , while the lowest mean value was found in Image J (19.50±0.64) .

- A statistically significant difference exists between (Apex-locator), (CBCT) and (Image J) where (p=0.004).
- Between (Apex-locator) and each of (CBCT) and (Image J), a statistically significant difference was discovered where (p=0.002) and (p=0.002).
- A statistically significant difference exists between (CBCT) and (Image J) where (p=0.046).

3. **Upper canine:** The highest mean value was found in Apex-locator (24.74±0.50) , followed by CBCT measurement (23.49±0.34) , while the lowest mean value was found in Image J (23.13±0.67).

- A statistically significant difference exists between (Apex-locator), (CBCT) and (Image J) where (p=0.024).
- A statistically significant difference exists between (Apex-locator) and each of (CBCT) and (Image J) where (p=0.012) and (p=0.034).
- No meaningful difference was seen with statistical significance between (CBCT) and (Image J) where (p=0.310).

4. **Lower central:** The highest mean value was found in Apex-locator (19.53±0.80) , followed by Image J (19.82±1.28) , while the lowest mean value was found in CBCT measurement (19.83±0.68).

- No meaningful difference was seen with statistical significance between (Apex-locator), (CBCT) and (Image J) where (p=0.825).

5. **Lower lateral**: The highest mean value was found in Apex-locator (21.13±1.13) , followed by CBCT measurement (21.02±1.10) , while the lowest mean value was found in Image J (20.85±1.74) .

- No meaningful difference was seen with statistical significance between (Apex-locator), (CBCT) and (Image J) where (p=0.601).

6. **Lower canine:** The highest mean value was found in Apex-locator (25.07±1.22) ,followed by CBCT measurement (22.62±0.74), while the lowest mean value was found in Image J (22.13±0.82) .

- A statistically significant difference exists (Apex-locator), (CBCT) and (Image J) where (p=0.014).
- A statistically significant difference exists (Apex-locator) and each of (CBCT) and (Image J) where (p=0.021) and (p=0.021).
- No meaningful difference was seen with statistical significance between (CBCT) and (Image J) where (p=0.235).

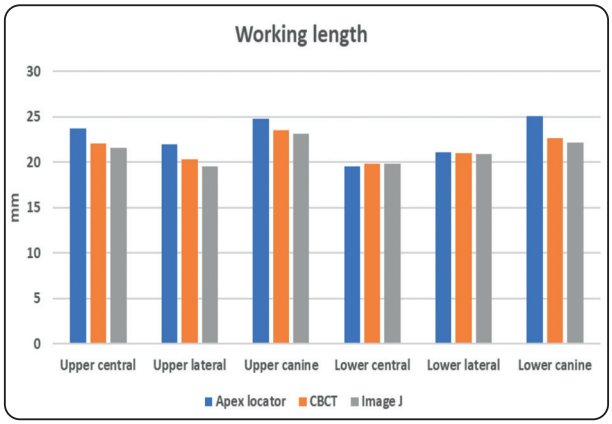

Fig. (13) Bar chart representing working length determination.

TABLE (2) The Mean, standard deviation (SD) values of different groups.

Variables	Working length						p-value
	Apex locator		CBCT		Image J		
	Mean	SD	Mean	SD	Mean	SD	
Upper central	23.70 [a]	0.25	22.04 [b]	0.66	21.58 [b]	1.08	0.026*
Upper lateral	21.95 [a]	0.31	20.32 [b]	0.48	19.50 [c]	0.64	0.004*
Upper canine	24.74 [a]	0.50	23.49 [b]	0.34	23.13 [b]	0.67	0.024*
Lower central	19.53 [a]	0.80	19.83 [a]	0.68	19.82 [a]	1.28	0.825ns
Lower lateral	21.13 [a]	1.13	21.02 [a]	1.10	20.85 [a]	1.74	0.601ns
Lower canine	25.07 [a]	1.22	22.62 [b]	0.74	22.13 [b]	0.82	0.014*

Significant difference is shown by means of distinct lettering in the same row. * ; ns; significant (p<0.005); non-significant (p>0.005)

DISCUSSION

Determining the tooth length is one of the most crucial componentsof root canal treatment, as proper estimation of the working length is a important factor in the triad of success of the root canal treatment that is microbial disinfection, ideal canal preparation and a hermetic seal obturation. Thus failure to determine the proper root canal measurements can affect the success of the root canal treatment as short measurements would leave parts of the canals instrumented and long measurements could cause damage to the periodontal tissues.

Different methods are employed to ascertain the precise measurement of the working length including radiographic method that was the initial method. EALs were developed to allow for more accurate tooth length determination thus improving the success rate of endodontic treatment and decrease the need for ionizing radiation. The use of EALs in Endodontics has been proven to be of great value in tooth length determination and has been proven to be more accurate than the traditional radiograph[7] as the latter had its limit of being a 2D image of a 3D object, and The anatomical apical constriction and the radiographic apex might not line up[3,8].

However EALs may still have their limitations as their accuracy is affected by the electric conditions of the canals, presence of large metallic restorations that can cause a short circuit, open apices[1,4] this brought up that there is another method to allow accurate tooth length determination and CBCT can allow accurate tooth length measurements.

This study aimed to compare the precision of tooth length measurements. Obtained from CBCT scans with those obtained from the electronic apex locators. The null hypothesis was rejected.

CBCT provided 3D images thus eliminating any structures superimposition and has proven to be valuable in pre-endodontic treatment planning as compared to classical 3D imaging such as Computed Tomography (CT), the radiation dose is lower[6]. But when it comes to ionizing radiation, each new image needs to be carefully considered[6].

Previous studies compared the perisician of EALs & CBCT in evaluating the tooth length, but they compared the accuracy of EALs in-vitro or in ex-vivo[6,17,19] So, in our study we decided to test the EALs in an in-vivo environment which is the actual environment in which the EALs normally operate in.Upper and lower anterior teeth where selected for our study.

All the CBCT scans that were used in our study were involved in an interdisciplinary treatment planning for our patients to avoid unnecessary exposure to ionizing radiation. CBCT scans with a 0.01 mm voxel size were obtained which allow for better image quality and improve the ability to trace the root canal [16,23]

The J. Morita Corporation introduced the Root ZX II and Root ZX Mini, two distinct devices, replacing the original Root ZX. They were developed using the same operating principle as the Root ZX, which measures the impedance at two distinct frequencies, but with the benefit of being a smaller version (Root ZX Mini) [4]. Considering the great popularity of the Root ZX models with endodontists, we chose to test the accuracy of the Root ZX mini.

During electronic length determination proper isolation was done using properly applied rubber dam sheet as saliva leakage may alters the canals electric conditions. Sodium hypochlorite was used as an irrigant in endodontic treatment. As it is documented that the canal condition whether wet or dry and the type of used irrigant could affect the measurements of the apex locator [14]. We used it in all canals as an irrigant to equalize its effect on EAL.

After collecting and analysing the data and comparing it with the actual tooth length, A statistically significant difference was observed

between the ability of Root ZX and CBCT in determining the tooth length.

Regarding the accuracy of CBCT measurements there was a statistically significant difference in the ability of CBCT scans and EALs in determining the tooth length and CBCT was the most accurate method, thus rejecting our null hypothesis. This is in agreement with the results of **Jeger FB et al.,** [9] where they analysed Measurements of tooth length were conducted on existing CBCT scans and subsequently compared with measurements received from electronic apex locators and they concluded that CBCT was superior for tooth length determination.

CBCT scans were determined to possess high accuracy and reliability in detecting the tooth length in multiple studies as **Connert et al.**[11] found that CBCT image of 0.2mm voxel size could accurately determine WL. Likewise, **Aktan et al**. [18] found that CBCT that Utilizing the lowest voxel size and greatest resolution resulted in increased accuracyWL determination.

Similarly, **Liang et al**., [10] found that CBCT-based root canal lengths are accurate when compared to measuring the working length with file 10 after extraction of the tooth. However, Merely undergoing normal root canal therapy should not be a sufficient reason to request something a CBCT scan and EALs should be relied upon tooth length determination as for the American association of Endodontics regarding the use of CBCT.

Conversely, the results of our study are in disagreement with **Lucena et al.,** [12] who Evaluated the precision of determining the working length by comparing the use of an electronic apex locator with CBCT and they concluded that the electronic apex locator yielded more precise results than measurements acquired from CBCT images with scans. This was probably related to the author using the CBCT scans at a 0.5 mm voxel size which could have produced less reliable images.

However, the dentist should utilize this trustworthy and precise approach of determining tooth length if the patient had a prior CBCT scan [6,11,18] especially in cases where EALs readings are inconsistent; e.g. large metallic restorations, open apices, large periapical pathosis. In the same context, **Kang & Kim** [4] found that all apex locators were less precise when the apical foramen was bigger.

Hachem et al., [21] found that Root ZX accuracy was adversely affected in the palatal root of maxillary molars in sinus. The reading of apex locator was affected and deceased in accuracy, and they recommended the combine use of apex locator and periapical x-ray. Similarly, **Srivastava et al.,** [24] assessed the effect of open apex on Root ZX mini , iRoot apex locators and CBCT WL in comparison to visual WL and found that Root ZX was superior to iRoot and that CBCT WL was as accurate as visual WL so they recommended the usage of preexisting CBCT.

After measuring difference in working length in intragroup comparisons there was no statistically significant difference within the same tool.

While measuring the working length in relation between groups , all teeth were compatible with the overall result except for lower central and lower lateral incisors due to the small size apical diameter as **Herrera et al.,** [1] found after assessment of using files of varying diameter on teeth with three different degrees of apical widening, the influence of apical constriction diameter on the precision of Root ZX accuracy was examined. No significant difference was observed between the apical constriction widths of 0.37 and 0.62 mm ,A significant different exists in teeth with apical width increased to 1.02 mm which correspond with the result found upper central ,upper lateral ,upper canine and lower canine.

Also **Herrera et al,** [8] found that Root ZX accuracy was lost gradually as the foramen widens above size 0.9 mm , while it was accurate at apical size 0.6 mm , 0.7 mm .

However **Akisue et al,** [15] found that formen diamter did not affect the precision of Root ZX this was may be due to the teeth used were with apical diameter 0.27 mm, 0.47 mm, 0.72 mm and they did not increase apical diameter above 0.9 mm.

CONCLUSION

Within the limitations of this study we concluded that CBCT considered a reliable tool for working length determination, new software improve the accuracy of working length determination, APEX locator still considered the gold standard tool for working length determination.

RECOMMENDATIONS

Future research is recommended to determine whether the voxel size can affect the accuracy of tooth length measurements in the CBCT scans, future research is recommended on different software to compare the accuracy versus standard viewing software, future research is recommended on the effect of metal restoration on the working length determination be the CBCT.

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