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Comparative Evaluation of Accuracy in Working Length Determination by Apex Locators Working on Different Principles Using Stereo Microscope: An *in Vitro* Study

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ABSTRACT:
Aim: To assess the accuracy of working length determination by different apex locators using stereomicroscope.
Materials: n = 90 extracted teeth access opening was done. working length was determined and kept 0.5 mm short of apex with all apex locators. Flowable composite was flown into the canal and cured.Handle of the file was cut just above the stopper and teeth were then extracted with file at adjusted working length and fixed with flowable composite. Then apical 4 mm of the roots was longitudinally shaved away using a fine diamond disc until the outline of the canal visible under a stereomicroscope at 20Xmagnification, placed over a graph paper. A digital photograph was taken for each tooth. On each digital photograph, the location of the minor diameter and major diameter was determined and measured. Distance from major diameter to minor diameter was calculated in millimeter on each digital image using the calibration of graph paper on which it was placed before taking its digital images.
Results -ROOT ZX, APEX ID , PROPEX PIXI were able to determine the minor diameter within +- 0.5mm with apex VI apex locator presented most accurate results 93.3% followed by root zx (90.0) and propexpixi (86.6%).
Key words: Apical constriction,apex locators,working length.

INTRODUCTION

The apical extent of instrumentation and the final root filling have a role in treatment success.[1] The apical constriction is the recommended end point of instrumentation and obturation since the tooth pulp is narrow at the apical constriction, so the wound is minor, potentially providing optimal healing conditions.[2] The location of the apical constriction is considered to be 0.5-1 mm short of the anatomical apex. Traditionally, the point of termination for endodontic instrumentation and obturation has been determined by taking

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radiographs. The development of the electronic apex locator has helped make the assessment of working length more accurate and predictable.[3]

Working length (WL) has been defined as ‘‘the distance from a coronal reference point to the point at which canal preparation and obturation should terminate’’. Instrumentation and obturation of the root endodontic system should be terminated at the apical constriction. The apical constriction, also defined as a minor diameter, represents the histological point of transition between the pulpal and the periodontal tissue at the cement-dentinal junction (CDJ). It has been suggested that the canal filling should terminate at the CDJ. Anatomical studies have shown the apical constriction to be located 0.5–1.0 mm from the external or major foramen.[4-6]

An electronic apex locator for root length determination was first investigated by Custer (1918). The flow of direct current through the teeth of dogs was revisited by Suzuki in 1942. Electronic apex locators have been used clinically for more than 40 years as an aid to determine the file position in the canal. The apex of the root has a specific resistance to electric current which is measured using a pair of electrodes i.e. endodontic file and lip clip. These devices, when connected to a file, are able to detect the point at which the file leaves the tooth and enters the periodontium.[7, 8]

An electronic method for root length determination was first investigated by Custer. The idea was revisited by Suzuki in 1942 who studied the flow of direct current through the teeth of dogs. He registered consistent values in electrical resistance between an instrument in a root canal and an electrode on the oral mucous membrane and speculated that this would measure the canal length. In a study there was a constructed resistance-based apex locator which used direct current to measure the canal length. This resistance-based apex locators worked on the principle that resistance offered by the periodontal ligament and the oral mucosa is the same 6.5 K Ohms.[9,10]

Analysis of the advantages and disadvantages of apex locators of fourth and fifth generation have led to the invention of the sixth-generation apex locators (Adaptive apex locators) which have come up in the market just recently and its efficacy in the long-term use are still under process. A major advantage of this apex locator is that it eliminates the necessity of drying or moistening of the canal, as well achieving high degree of measurement precision in the presence of blood ,or while manipulating dry canals.[11,12] Hence, the aim of the present study was to compare the accuracy of different apex locators in determination of working length using histological section as a gold standard.

INCLUSION CRITERIA:

- Patients referred to Department of Oral and Maxillofacial Surgery for extraction of anterior teeth.
- Periodontally compromised teeth
- Teeth with fully formed apices
- Single rooted permanent teeth
- Teeth with single and straight root canal without resorption**.**

EXCLUSION CRITERIA:

- Carious Teeth
- Multirooted Teeth
- Teeth with Multiple canals
- Teeth with curved roots
- Teeth with internal or external resorption

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METHODOLOGY

Ninety teeth were selected for extraction of periodontally involved single-rooted permanent teeth, single canal with completely formed apices. The sample was divided into three groups of thirty teeth in each group.

The standardized access cavity preparation was done followed by coronal flaring using Gates Glidden drills sequentially from size 4 to size 2 in a step-down fashion. The canal was irrigated with 5 ml of 2.5% sodium hypochlorite, the pulpal remnants/debris was removed from the canals; and the canal patency was evaluated using size 20/25no K-file. Coronal reference point was marked on the tooth and working length was determined radiographically.

Then the working length was taken with apex locators . Stopper was adjusted at the coronal reference point and length was measured using Endobloc. Then 0.5 mm was subtracted from this working length and file with this working length was again inserted into the canal. Flowable composite was flown into the canal and cured. Then apical 4 mm of the roots was longitudinally shaved away using a fine diamond disc until the outline of the canal visible under a stereomicroscope at 20Xmagnification, placed over a graph paper. A digital photograph was taken for each tooth. On each digital photograph, the location of the minor diameter and major diameter was determined and measured. Distance from major diameter to minor diameter was calculated in millimeter on each digital image using the calibration of graph paper on which it was placed before taking its digital images.

RESULTS

MDL								
GROUPS	**N**	**Mean**	**Std. Deviation**	**Std. Error**	**95% Confidence Interval for Mean**		**Minimum**	**Maximum**
					Lower Bound	**Upper Bound**		
ROOT ZX	30	18.683	1.16325	.2123	18.2490	19.1177	17.00	20.50
APEX ID	30	18.866	.93710	.1710	18.5167	19.2166	17.00	20.50
PROPEX	30	18.783	.96207	.1756	18.4241	19.1426	17.00	20.50
Total	90	18.777	1.01702	.1072	18.5648	18.9908	17.00	20.50

Table 1 shows the mean distance of minor diameter length among the three different groups

ANOVA					
	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	.506	2	.253	0.240	0.787
Within Groups	91.550	87	1.052		
Total	92.056	89			

Table 2 shows the between and within group comparison of minor diameter length among the three different groups

Multiple Comparisons						
Tukey HSD						
(I) Groups	**(J) Groups**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval**	
					Lower Bound	**Upper Bound**
ROOT ZX	ROOT ZX	-.18333	.2648	.769	-.8149	.4482
	PROPEX	-.10000	.2648	.925	-.7316	.5316
APEX ID	ROOT ZX	.18333	.2648	.769	-.4482	.8149
	PROPEX	.08333	.2648	.947	-.5482	.7149

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PROPEX	ROOT ZX	.10000	.2648	.925	-.5316	.7316
	APEX ID	-.08333	.2648	.947	-.7149	.5482

	N	**Mean**	**Std. Deviation**	**Std. Error**	**95% Confidence Interval for Mean**		**Minimum**	**Maximum**
					Lower Bound	**Upper Bound**		
ROOT ZX	**30**	18.6667	1.17688	.2148	18.2272	19.1061	17.00	20.50
APEX ID	**30**	18.8333	.94077	.1717	18.4820	19.1846	17.00	20.50
PROPEX	**30**	18.7333	.93526	.1707	18.3841	19.0826	17.00	20.50
Total	**90**	18.7444	1.01462	.1069	18.5319	18.9570	17.00	20.50

Table 3 shows the post-hoc analysis based on comparison of each group with the other two groups.

ANOVA					
EAL					
	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	.422	2	.211	.201	.818
Within Groups	91.200	87	1.048		
Total	91.622	89			

Table 4 shows the mean working length among the three different apex locators

Comparison of mean WL with mean MDL	**Accuracy within ±0.5mm (%)**	**Accuracy with 0.5mm short of minor diameter**	**WL=MDL(number of times)**	**Accuracy with 0.5mm beyond the minor diameter**
Mean EAL root rootzx<MDL	90	16 times	5 times	6 times
Mean EAL apex id<MDL	93.3	18 times	3 times	7 times
Mean EAL $_{propex}$<MDL	86.66	15 times	6 times	5 times

Table 5 shows the between and within group comparison of mean working length among the three different groups

Multiple Comparisons (EAL)						
Tukey HSD						
(I) Groups	**(J) Groups**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval**	
					Lower Bound	**Upper Bound**
ROOT ZX	**APEX ID**	-.16667	.26436	.804	-.7970	.4637
	PROPEX	-.06667	.26436	.966	-.6970	.5637
APEX ID	**ROOT ZX**	.16667	.26436	.804	-.4637	.7970
	PROPEX	.10000	.26436	.924	-.5304	.7304
PROPEX	**ROOT ZX**	.06667	.26436	.966	-.5637	.6970
	APEX ID	-.10000	.26436	.924	-.7304	.5304

Table 6 shows the post-hoc analysis based on comparison of each group with the other two groups

Paired Samples Statistics					
		Mean	**N**	**Std. Deviation**	**Std. Error Mean**
Pair 1	**EAL_ROOT ZX**	18.6667	30	1.17688	.21487
	MDL_ROOT ZX	18.6833	30	1.16325	.21238

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Pair 2	**EAL_APEX ID**	18.8333	30	.94077	.17176
	MDL_AYPE ID	18.8667	30	.93710	.17109
Pair 3	**EAL_APEX ID**	18.7333	30	.93526	.17075
	MDL_PROPEX	18.7833	30	.96207	.17565

Table 7 shows the pairwise comparison of mean working length (EAL) with minor diameter length (MDL) amongthe three different groups

Paired Samples Correlations				
		N	**Correlation**	**Sig.**
Pair 1	**EAL_ROOT ZX & MDL_ROOT ZX**	30	.991	.000
Pair 2	**EAL_APEX ID & MDL_APEX ID**	30	.991	.000
Pair 3	**EAL_PROPEX & MDL_PROPEX**	30	.978	.000

Table 8 shows the correlation of mean working length (EAL) with minor diameter length (MDL)among the three different groups

Paired Samples Test									
		Paired Differences					**t**	**df**	**Sig. (2-tailed)**
		Mean	**Std. Deviation**	**Std. Error Mean**	**95% Confidence Interval of the Difference**				
					Lower	**Upper**			
Pair 1	**EAL ROOT ZX-MDL ROOT ZX**	-.016	.159	.029	-.076	.043	-.571	29	.573
Pair 2	**EAL APEX ID - MDL_RAYAPEX ID**	-.033	.126	.023	-.080	.014	-1.439	29	.161
Pair 3	**EAL PROPEX – MDL PROPEX**	-.050	.201	.036	-.125	.025	-1.361	29	.184

Table 9 shows the mean and standard deviation of mean working length (EAL) and minor diameter length (MDL) among the three different groups

Mean working length (mm)	**Mean±SD**
MDL	18.777±1.020
EAL (ROOT ZX)	18.666±1.176
EAL (APEX ID)	18.833±0.940
EAL (PROPEX)	18.733±0.935

Table 10 shows the mean working length and minor diameter length measured in various groups

Comparison of mean WL with mean MDL	**Accuracy within ±0.5mm (%)**	**Accuracy with 0.5mm short of minor diameter**	**WL=MDL(number of times)**	**Accuracy with 0.5mm beyond the minor diameter**
Mean EAL ROOT ZX<MDL	90	16 times	5 times	6 times
Mean EAL APEX ID<MDL	93.3	18 times	3 times	7 times
Mean EAL PROPEX<MDL	86.66	15 times	6 times	5 times

Table 11 shows the comparison of mean working length with mean minor diameter length, accuracy of individual device within±0.5mm range, accuracy with 0.5mm short of minor diameter, number of times working length coinciding minor diameter length and accuracy with 0.5mm beyond the minor diameter

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DISCUSSION

In the present study, the exact distance between the minor diameter and the major foramen has been determined using histological sections which were viewed under a stereomicroscope at 25X magnification to obtain better viewing clarity and details.

Single-rooted teeth with straight and wide canals were used in this study to minimize problems presented by a more complicated canal anatomy. The presence of electrolytes, differences in canal diameter, technical differences between microscopes, and variation among EALs are important factors which may influence the results of the study. In a study conducted by Herrera et al found that the EAL measurements were more accurate when the foramen diameter was 0.25 mm than when it was between 0.45 and 0.70 mm. Hence, it was considered that the teeth with a small diameter in which 10/15 files could pass through the foramen were selected for standardization. [13 , 14]

Irrigation was performed using a 2.5% sodium hypochlorite solution, which is in agreement to literature stating that irrigating solutions have little influence on the accuracy of modern EALs. In a previous study, Wrbas et al found that the raypex 5 predictably determined the working length to apical constriction with (±0.5mm) 80% accuracy compared with the root ZX's (±0.5mm) 75% accuracy. [15 ,16]

No significant difference was found between the results of root ZX and raypex 5 in determination of apical constriction whereas on the contrary percentage of measurement within ±0.5mm was 100% and 90% for the root ZX and raypex5 in a study done by Vieyra and Acosta and SaxenaDivya et al.[17 , 18] In the present study, Root ZX showed maximum accuracy as compared to the apex id and propex group but there is no statistically significant difference found and hence these results are in consistent with the above studies done. As per our knowledge and research very limited studies have evaluated the accuracy of these three different apex locators together.

In the present study, the accuracy of determination of the MDL was 93.3% within ±0.5 mm of the minor diameter in contrast to root zx and Propexpixi which reached 90% and 86.6% level of accuracy, respectively. It has been observed from previously conducted studies that measurements within the ±0.5 mm limit are acceptable in clinical practice. It was found from the results of a previous study conducted by Oliveira TN et al where the author compared 5 different apex locators and found that the Propex II offered significantly lower results than the other devices, highlighting some difficulty of understanding the electronic parameters in this circumstance and these findings are consistent with the findings of the present study.[19 -22]

The current results were inconsistent with Guise et al reporting the accuracy of apex id to be 53.58% within ±0.5 mm; discrepancies could be due to the different methodology because the apical foramen (apex) was the measuring point rather than the apical constriction (0.5).

The results of the present study confirmed that EALs can accurately determine the canal length within ±0.5 mm from the apical constriction as shown previously. The measurements obtained revealed that the EALs were able to measure the canal length with a high level of precision compared with the AL. [24 , 25]

Within the limits of this study, all three electronic apex locators -the Root zx, apex id and Propex were able to determine the minor diameter within ±0.5 mm with at least 93.3% accuracy. All three EALs are therefore likely to provide clinically acceptable measurements. Our accuracy data (93.3% at ±0.5 mm) presented new information and suggested that it is a valuable clinical device which clearly showed the reliability of these apex locators in determining the working length accurately in clinical situation. Further studies, however, need to be conducted to corroborate the findings of the present study.

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CONCLUSION

It can be concluded from the findings of the present study that all the three EALs (root zx, apex Id, and PropexPixi) were able to determine the minor diameter within ±0.5 mm with apex Id apex locator presenting most accurate results (93.3%) followed by root zx. (90.0%) and PropexPixi (86.6%). This clearly revealed the reliability of these apex locators in determining the working length accurately in clinical situation.

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