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Examining Accuracy of New Apex Locators in Working Length Determination in Human Teeth: An In Vivo Study

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ABSTRACT

Background: Proper determination of working length is an essential part of successful endodontic treatment. Despite the proven benefits of electronic apex locators, additional research is essential to assess their accuracy, particularly new models. The aim of this study was to conduct in vivo comparisons of three recent Apex length locators and the established gold standard, Root ZX. **Methods**: The sample comprised forty single-rooted anterior teeth in need of nonsurgical root canal therapy. The teeth were randomly assigned to four groups of ten teeth each: Root ZX, Woodpex V Plus, Bomedent, and Woodpecker AI-pex. The working length of each sample was determined using the assigned electronic method as EAL and digitally as radiographic digital radiographs. Three electronic measurements were taken, and the average length was accepted as the electronic working length for each sample. One-way ANOVA was used to identify statistical significance with the Tukey's post hoc test, with $p \leq 0.05$. **Results**: The working lengths average and standard deviations were with Root ZX 20.51 ± 0.93 mm, with Woodpex V Plus 20.10 ± 0.61 mm, with Bomedent 20.21 ± 0.94 mm, and with Woodpecker Aipex 20.31 ± 0.91 mm. There was no significant deviation between the four methods. Pairwise comparisons among the four devices showed no major variations. **Conclusions**: In vivo results demonstrated good results of the evaluated EALs in determining working length. The tested devices have been shown with a certain level of accuracy, equivalent to the gold standard Root ZX, hence demonstrating acceptable operation in clinical endodontic practice.

KEYWORDS: Apex Locator; Working Length; Endodontics; Root Zx; Woodpex V Plus; Bomedent; Woodpecker Ai-Pex.

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INTRODUCTION

To ensure the accuracy of WL determination, it is essential to follow the aforementioned guidelines. WL determination is used to improve cleaning, shaping, and obturation outcomes. [1,2] WL is defined as the distance between a coronal reference point and the apical constriction, which should be the end of canal preparation and obturation. [3] Over-preparation on the WL can cause over-instrumentation, while underestimation can, on the contrary, will lead to residual infected periapical tissue and periapical reaction. [4,5] On the other hand, over-instrumentation brings a risk of periapical trauma, trauma associated with the extrusion of sodium hypochlorite, post endodontic pain, or delayed healing. [6-9]

The radiographic and tactile methods provide limited assistance in WL determination due to operator variety, envelope distortions, anatomic variations and position variations, and difficulties in image standardization. [10-12] The introduction of electronic apex locators has revolutionized WL determination by enabling operators to identify the apical constriction using electrical impedance principles method. Modern EALs based on multi-frequency impedance measurements, thus improving accuracy even in the presence of moisture, making the WL determination even more accurate. [13-15]

Root ZX (J. Morita, Japan) is considered as the reference standard for apex locators, on the other hand, recent EALs models, e.g., Woodpecker Woodpex V plus, Woodpex AI-Pex, and Bomedent Apex Pro, offer comparable performance based on the newest digital signal processing and artificial learning-assisted calibration. [16-18] However, limited clinical in vivo data is available on the efficiency of these recent devices during clinical procedures. This study aimed to evaluate the accuracy of EALs against Root ZX in clinical conditions, aiming to provide clinicians with equal reliable, cost-effective alternatives.

MATERIALS AND METHODS

Ethical Approval and Study Design

This in vivo clinical study was conducted at the Dental Clinic of National Research Centre (NRC), Dokki, Egypt. This study was approved by the NRC Medical Research Ethics Committee (Approval No.: 0341).

Sample Selection
Forty patients requiring nonsurgical endodontic treatment for single-rooted anterior teeth with completely formed apices were selected. Standardized preoperative periapical radiographs confirmed canal patency and absence of periapical lesions.

Inclusion Criteria

- Vital teeth with a single straight canal.
- Mature apices confirmed radiographically.
- No periapical pathology.

Exclusion Criteria

- Open apices, calcified canals, apical resorption, or previous endodontic treatment.
- Internal or external resorption, root fractures, or necrotic pulp.
- Pregnant patients or those with pacemakers.

Clinical Procedures
Clinical procedures were done by four experienced Endodontists. Local anesthesia has been administered using 2% lidocaine with 1:100,000 epinephrine, then rubber dam isolation was done. Access cavities were prepared with high-speed diamond burs, and complete deroofing was achieved using safe-ended burs. The pulp tissue was extirpated with barbed broaches.
Canal patency was verified with a #10 K-file (Mani Inc., Japan) extending slightly beyond the apical foramen. Canals were irrigated with 2.5% sodium hypochlorite and then lightly dried with sterile cotton pellets, avoiding over-drying to maintain a conductive environment for EAL measurement.

Group Allocation and Measurement Procedure
The 40 teeth were randomly allocated into four groups (n = 10 each):

- **Group I:** Root ZX (J. Morita Corp., Japan)
- **Group II:** Woodpex V Plus (Guilin Woodpecker, China)
- **Group III:** Bomedent (China)
- **Group IV:** Woodpecker AI-Pex (Guilin Woodpecker, China)

Each EAL was operated according to the manufacturer's guidelines. A size #15 stainless steel K-file was connected to the EAL probe and inserted into the canal until the device indicated the file tip at the apical foramen ("apex" or "0.0" mark). The file was then withdrawn slightly until the display stabilized at the "0.5" mark, which represented the electronic working length (EWL). The reading was accepted after 5 seconds of stability. [19]
Three separate readings were obtained for each canal, and their mean value was recorded as the final EWL. Following this, a digital radiograph with the file at the EWL was taken, and the radiographic working length (RWL) was measured using image analysis software under 3× magnification. The distance between the file tip and the radiographic apex was verified to ensure it was within ±0.5 mm.

RESULTS

Sample size calculation:
Sample size calculation depending on a previous study [20] as reference. According to this study, when mean ± standard deviation in Group I is 14.72 ± 1.85. While the estimated mean difference with Group II is 2 when the (power) is 0.8 and the Type I error probability associated with this test is 0.05. The minimum sample size needed is 14 cases per group. The sample size was calculated using T test which was performed by using P.S Power 3.1.2.

Statistical analysis:
Statistical analysis was performed with SPSS 27®, Graph Pad Prism® and Microsoft Excel 2016. All data were explored for normality by using Shapiro Wilk and Kolmogorov Normality test which revealed that Working length data originated from normal data distribution, accordingly comparison between different groups was performed by using One Way ANOVA test, followed by Tukey's Post Hoc test for multiple comparisons the significant level was set to be at $P \leq 0.05$.

Working length determination:
Table 1 and figure 1 shows descriptive results of working length in all groups and comparison between groups regarding working length determination. For the Root ZX group, the working length ranged from 19.00 mm to 22.00 mm, with a median of 20.50 mm and a mean of 20.51 ± 0.93 mm. The Woodpex V PLUS group recorded values between 19.00 mm and 21.00 mm, with median of 20.00 mm and mean of 20.10 ± 0.61 mm. In the Bomedent group, values ranged from 18.50 mm to 21.50 mm, with median of 20.00 mm and a mean of 20.21 ± 0.94 mm. The Woodpecker AI group showed a range of 19.00 mm to 22.00 mm, a median of 20.00 mm, and a mean of 20.31 ± 0.91 mm. One-way ANOVA analysis revealed no statistically significant difference between the groups (P = 0.63).

Table 2 and figure 2 presents the pairwise comparisons between groups regarding working length. When comparing Root ZX with Woodpex V PLUS, the mean difference was 0.41 mm (95% CI: –0.45 to 1.27, p = 0.59). Between Root ZX and Bomedent, the mean difference was 0.30 mm (95% CI: –0.56 to 1.16, p = 0.79), while the comparison between Root ZX and Woodpecker AI showed a mean difference of 0.20 mm (95% CI: –0.66 to 1.06, p = 0.92). The difference between Woodpex V PLUS and Bomedent was –0.11 mm (95% CI: –0.97 to 0.76, p = 0.98), and between Woodpex V PLUS and Woodpecker AI was –0.21 mm

(95% CI: –1.07 to 0.66, p = 0.91). Lastly, the comparison between Bomedent and Woodpecker AI showed a difference of –0.10 mm (95% CI: –0.96 to 0.76, p = 0.98). All pairwise comparisons revealed no statistically significant differences.

Table 1: Comparison between groups regarding working length determination:

	Minimum	Maximum	Median	Mean	Standard Deviation	P value One Way ANOVA test
Root ZX	19.00	22.00	20.50	20.51	0.93	0.63
Woodpex V PLUS	19.00	21.00	20.00	20.10	0.61	
Bomedent	18.50	21.50	20.00	20.21	0.94	
Woodpecker AI	19.00	22.00	20.00	20.31	0.91	

Table 2: Pairwise comparison between groups regarding working length

Pairwise comparison		Mean 1	Mean 2	Mean Diff.	95.00% CI of diff.	Adjusted P Value
Root ZX	**Woodpex V PLUS**	20.51	20.1	0.41	-0.45 to 1.27	0.59
Root ZX	**Bomedent**	20.51	20.21	0.3	-0.56 to 1.16	0.79
Root ZX	**Woodpecker AI**	20.51	20.31	0.2	-0.66 to 1.06	0.92
Woodpex V PLUS	**Bomedent**	20.1	20.21	-0.11	-0.97 to 0.76	0.98
Woodpex V PLUS	**Woodpecker AI**	20.1	20.31	-0.21	-1.07 to 0.66	0.91
Bomedent	**Woodpecker AI**	20.21	20.31	-0.1	-0.96 to 0.76	0.98

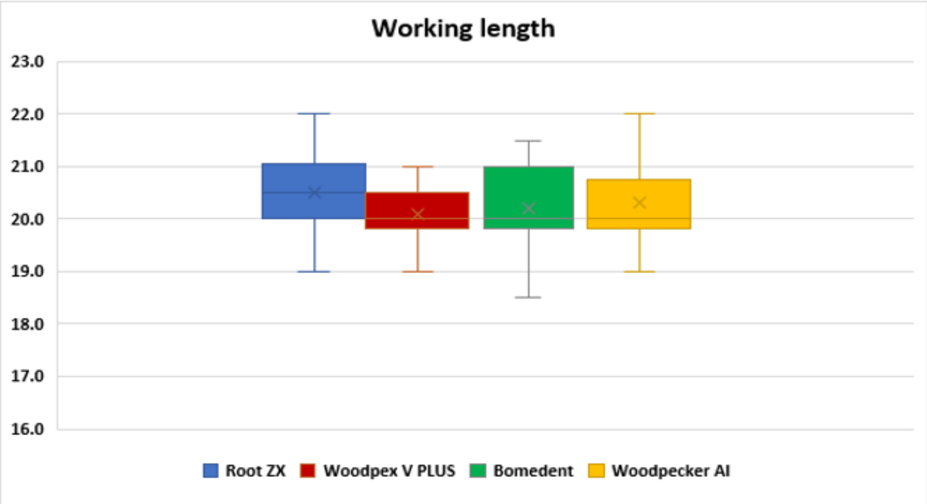

Figure 1: Boxplot represents working length in all groups.

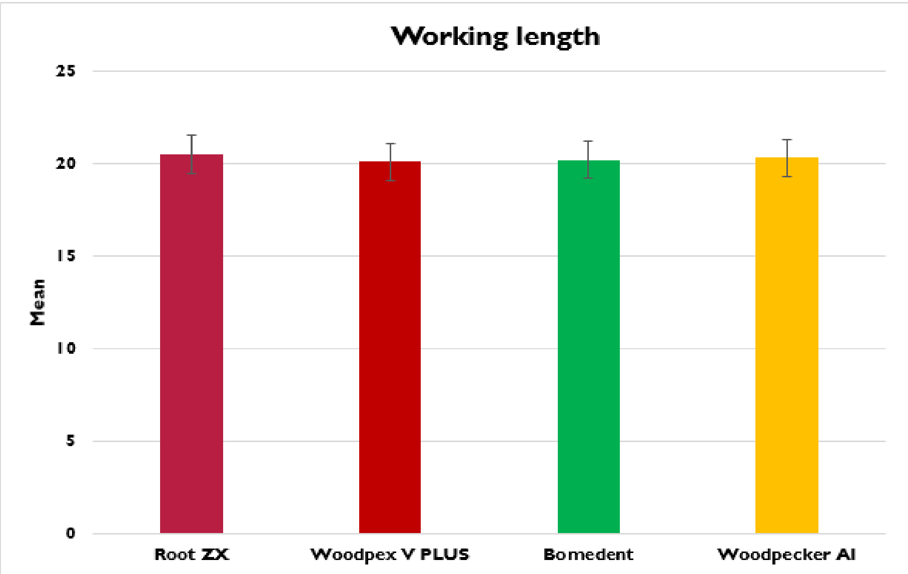

Figure 2: Bar chart represents comparison between groups regarding working length.

DISCUSSION

This study demonstrated that all evaluated EALs provided highly comparable accuracy in determining working length in vivo. The absence of statistically significant differences among devices suggests that newer-generation models perform equivalently to the Root ZX, a third-generation apex locator, has consistently shown high accuracy across multiple studies. [21-23]

Newer models such as Woodpex V Plus and Bomdent employ fifth-generation multifrequency impedance technology, while the AI-Pex uses a seventh-generation system integrated with an artificial intelligence–based calibration algorithm and built-in pulp tester.

These advancements in manufacturing EALs aim to ensure their accuracy even under challenging canal conditions, such as the presence of electrolytes, blood, or exudate. [24,25] In the present study, all tested EALs showed readings comparable to Root ZX, which reinforces the findings from previous literature. [15,26] The absence of significant differences between them suggests that modern EALs can be used as valid alternatives to older models, providing additional features like user-friendly interfaces and dual-function systems. The findings align with prior studies This finding is consistent with prior studies reporting that modern EALs can achieve accuracy within ±0.5 mm of the apical foramen, even under variable clinical conditions. Aguiar et al. [10] confirmed the reproducibility of Root ZX models across different generations, while others found that newer EALs showed comparable performance in simulated canal environments. The Woodpecker AI-Pex incorporates artificial intelligence algorithms to adjust impedance readings in real time, minimizing the effect of canal fluid variations. Similarly, the Woodpex V Plus and Bomedent devices use multiple-frequency impedance ratios to enhance precision even in moist environments. These factors were likely responsible for the consistent performance observed among the devices in this study.

The in vivo design of this study enhances the clinical relevance of these results compared with in other in vitro studies, as actual periapical tissue conductivity, canal moisture, and patient variability were considered. Limited variability was confirmed due to the standardized conditions, such as uniform tooth type, controlled irrigation protocol, patency, file size, and repeated measurements—minimized bias and improved reliability.

The use of a #15 K-file was appropriate in terms of controlling the variables in the experiment as Orosco et al. [27] reported that changes in file size may influence measurement accuracy. Furthermore, the designs incorporated artificial intelligence and multiple-frequency impedance, which contributed to the quality of the results due to their enhanced accuracy settings. [28-30]

While the present study supports the comparable accuracy of all devices, it is limited by its inclusion of only anterior teeth. Future research should evaluate these devices in posterior teeth with complex canal morphologies, different irrigants, and varying apical diameters to generalize findings more broadly.

Clinical Implications

Recent EALs can be adopted confidently in daily practice due to their accuracy in WL measurements, as well as they offer additional ergonomic advantages, such as digital displays, AI calibration, and improved the efficiency of the battery, while being more cost-effective than traditional models.

Limitations and Future Research

This study was limited to single-rooted anterior teeth with straight canals. Further research is recommended on multi-rooted or curved canals, necrotic pulps, and retreatment cases. Evaluating the impact of various irrigants and intracanal medications on EAL accuracy could also enhance clinical understanding.

CONCLUSION

All tested EALs Root ZX, Woodpex V Plus, Bomedent, and Woodpecker AI-Pex demonstrated equivalent accuracy in determining working length in vivo. New-generation devices can thus be considered reliable alternatives to the conventional Root ZX in endodontic practice.

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