

**Original Research****Evaluation of the Accuracy of Electronic Apex Locator in Determining Working Length using different solvents in Re-treatment: An in vitro study**Naman Keshwani<sup>1</sup>, Anu Narang<sup>2</sup>, Santosh Kumar Singh<sup>3</sup>, Shivani Rawat<sup>4</sup>, Gayatri H. Giramkar<sup>5</sup>, Sadhvi Pateriya<sup>6</sup><sup>1,4,5,6</sup> Post Graduate Student, Department of Conservative Dentistry and Endodontics,, People's College of Dental Sciences, Bhopal, Madhya Pradesh<sup>2</sup> Professor , Department of Conservative Dentistry and Endodontics,, People's College of Dental Sciences, Bhopal, Madhya Pradesh<sup>3</sup> Professor & Head, Department of Conservative Dentistry and Endodontics,, People's College of Dental Sciences, Bhopal, Madhya Pradesh

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## ABSTRACT

**Introduction:** Accurate working length determination is fundamental to endodontic success. While electronic apex locators (EALs) are reliable during primary root canal treatment, their accuracy during retreatment in the presence of different solvents is uncertain.

**Aim:** This study aimed to evaluate the difference in working length measurements obtained using an apex locator during primary treatment and retreatment, and to compare its efficiency in the presence of different solvents.

**Materials and Methods:** Working length was determined using an electronic apex locator in extracted permanent central incisors teeth during primary root canal treatment. After obturation, retreatment was simulated using different solvents, and working length was re-evaluated with the same apex locator. Differences between the two measurements were compared and the efficiency of the apex locator in the presence of various solvents was analysed.

**Result:** There was no statistically significant difference in working length measurements either within or between groups. All three solvents demonstrated comparable performance, with minimal mean differences and negligible effect sizes, suggesting that the type of solvent does not affect the accuracy of the electronic apex locator during retreatment procedures.

**Conclusion:** The type of solvent used during retreatment did not significantly influence the accuracy of electronic apex locator measurements. All three solvents showed comparable working length determination with negligible differences between groups.

**Introduction**

Endodontic retreatment is required when primary treatment fails due to incomplete cleaning or improper obturation. The main goal of retreatment is effective debridement and proper re-obturation of the root canal system. Accurate working length determination is critical for successful endodontic outcomes. The ideal endpoint is the apical constriction, usually 0.5–1 mm short of the apex, but it is difficult to locate clinically. Radiographic methods have limitations due to 2D imaging and anatomical variations. Electronic apex locators (EALs) provide more accurate and reliable working length

measurements. EALs function based on electrical impedance and work even in presence of canal contents. In retreatment, gutta-percha removal is essential and often aided by endodontic solvents. These solvents may alter canal conditions and potentially affect EAL accuracy. Accurate working length determination is critical for successful root canal therapy and retreatment. Electronic apex locators (EALs) are widely used; however, their accuracy may be influenced by the presence of solvents used during removal of gutta-percha in retreatment procedures. This study aimed to evaluate

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the variation in working length readings obtained using an apex locator before and after the application of different gutta-percha solvents.

## **Materials And Methods**

Forty-five permanent single rooted teeth were biomechanically prepared and their working length were recorded using an apex locator. The teeth were then obturated with gutta-percha and a ZOE (Zinc Oxide Eugenol based) sealer and were stored for 10 days to allow complete sealer setting. The samples were then randomly divided into three groups (n = 15) according to the solvent used during re-treatment: (Group I – Acetic Acid), (Group II – Maleic Acid) and (Group III – Citric Acid). Retreatment was performed using standardized rotary instrumentation, and the respective solvent was applied in each sample. Again, the working length was recorded using same apex locator and the difference between the readings were analysed and the efficiency of the apex locator in the presence of various solvents was compared. The detailed steps are as follows:

### **1. Sample Preparation:**

Extracted human permanent single-rooted teeth were selected for the study to ensure standardization of the samples. Only teeth with a single, straight root canal and completely formed mature apices were included, while teeth with root resorption, calcifications, fractures, or curved canals were excluded. After selection, all teeth were thoroughly cleaned to remove debris and soft tissue remnants and were stored in normal saline until the commencement of the study to maintain hydration and preserve the tooth structure. Standard access cavity preparation was performed for each tooth, following which canal patency was established using a #15 K-file. The initial working length was then determined using an electronic apex locator (EAL) according to the

manufacturer's instructions. For working length measurement, the roots were immersed in plastic container containing freshly mixed alginate. The file was placed in the roots and electronic working length was recorded. To achieve uniformity and simulate the clinical apical termination point, 0.5 mm was subtracted from the electronic apex locator reading, and this value was considered as the standardized working length for the study.

### **2. Biomechanical Preparation & Obturation:**

Following working length determination, biomechanical preparation of all root canals was carried out using a standardized rotary instrumentation system to ensure uniform canal shaping and cleaning in all samples. After completion of canal preparation and drying of the canals with absorbent paper points, obturation was performed using gutta-percha cones in combination with zinc oxide eugenol (ZOE) sealer to achieve a hermetic seal of the root canal system. This standardized obturation procedure was carried out in all specimens prior to the retreatment phase of the study.

### **3. Grouping of Samples:**

A total of 45 samples were included in the study and were randomly allocated into three experimental groups, with 15 samples in each group, to ensure equal distribution and minimize bias. Based on the solvent used during the retreatment procedure, the samples were categorized as (Group I – Acetic Acid), (Group II – Maleic Acid) and (Group III – Citric Acid). This grouping was done to evaluate and compare the effect of different solvents on the working length readings obtained using the electronic apex locator.

#### 4. Retreatment Procedure:

During the retreatment procedure, the coronal portion of the gutta-percha was initially removed to create a reservoir for the placement of the respective solvent. The assigned solvent was then introduced into each canal to



Access cavity prepared



Initial Working length measured



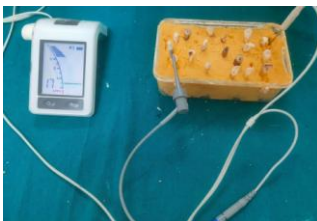
Obturation done



Retreatment was done



Using these 3 solvents



Working length Re-evaluation done

soften the obturating material and facilitate its removal. Following solvent application, retreatment was carried out using rotary instrumentation to remove the gutta-percha and sealer effectively from the root canal system.

#### 5. Working Length Re-evaluation:

After completion of the retreatment procedure, the working length was measured again in all samples to evaluate any variation in the readings following the use of different solvents. The same electronic apex locator that was used for the initial measurements was utilized throughout the study to maintain consistency and standardization. For working length measurement, the roots were again immersed in plastic container containing freshly mixed alginate. All measurements were performed under identical experimental conditions to minimize errors and ensure reliability of the results. Standardized procedures were followed for each sample so that any changes in working length readings could be attributed to the effect of the solvents used during retreatment.

#### 6. Outcome Assessment:

The difference between the pre-retreatment and post-retreatment working length readings was recorded for all samples to assess any variation following the use of different solvents. Based on these measurements, the accuracy of the electronic apex locator was evaluated after retreatment procedures. A comparative analysis was carried out among the three groups to determine the influence of different solvents on working length determination. The obtained data were then subjected to appropriate statistical analysis to compare the groups and identify any significant differences in the working length readings.

#### Result and Observations

The intragroup comparison of pre- and post-retreatment working length measurements is presented in **Table 1**. In

the acetic acid group, the mean working length decreased slightly from  $20.253 \pm 0.522$  mm to  $20.227 \pm 0.473$  mm, with a mean difference of 0.0267 mm. This difference was not statistically significant ( $t = 0.718$ ,  $p = 0.484$ ), and the 95% confidence interval ranged from -0.0529 to

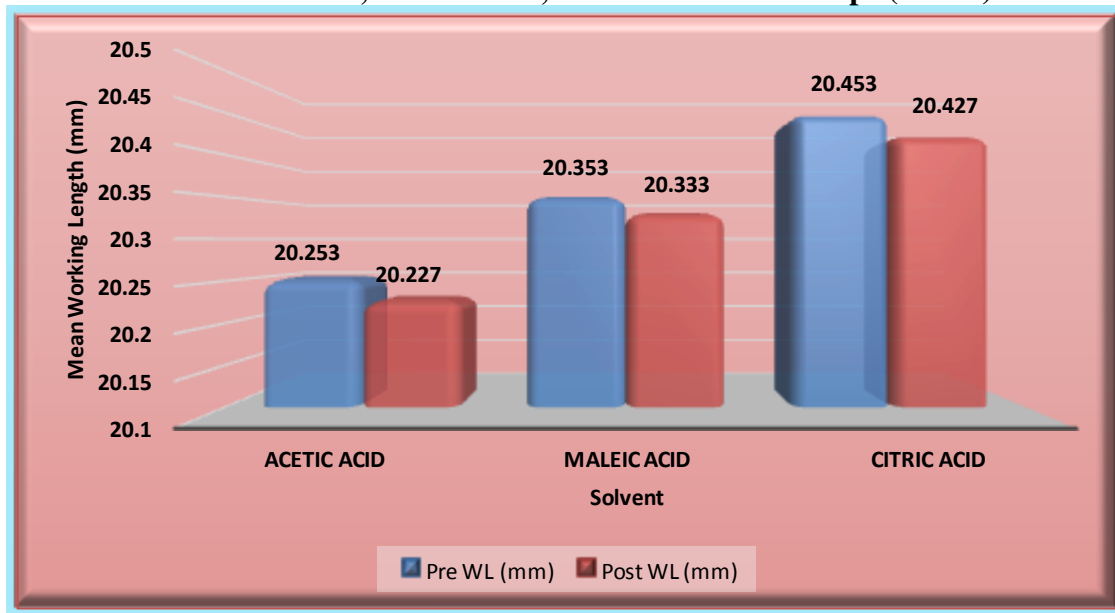
0.1063, indicating that the variation was not clinically meaningful. Similarly, in the maleic acid group, the mean working length changed marginally from  $20.353 \pm$

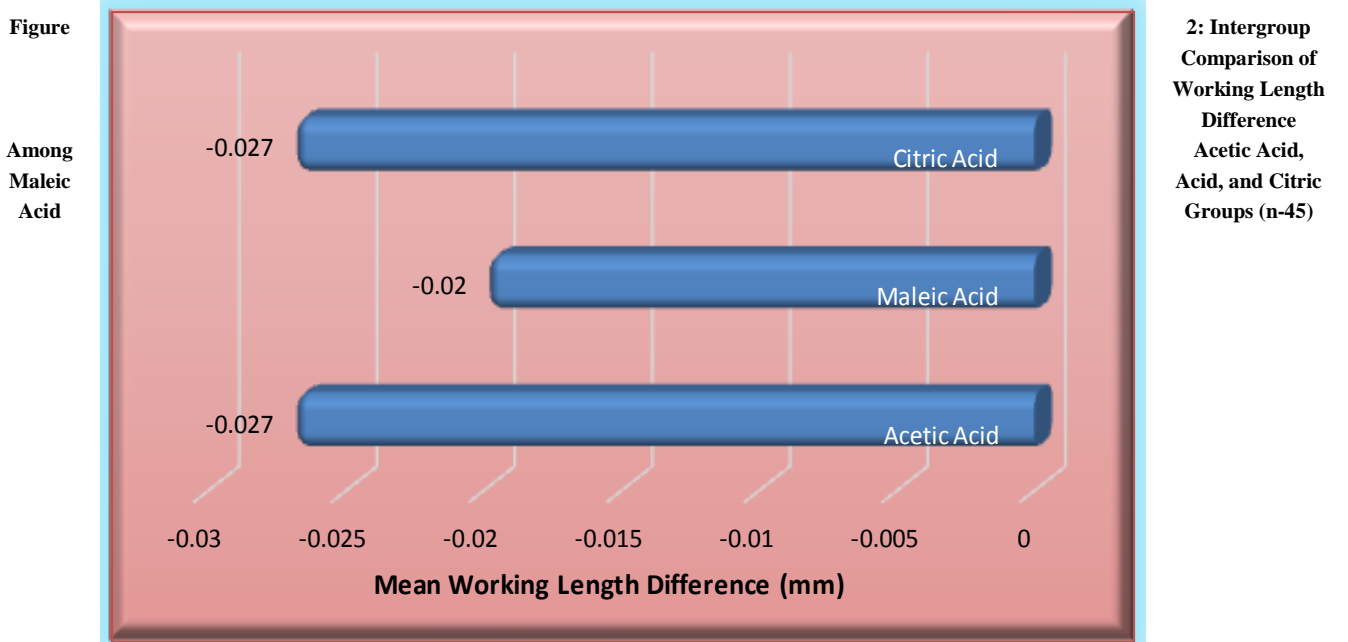
**Table 1: Intragroup Comparison of Pre- and Post-Retreatment Working Length Measurements in Acetic Acid, Maleic Acid, and Citric Acid Groups (n = 45)**

<i>Solvent</i>	<i>N</i>	<i>Pre WL (Mean ± SD) mm</i>	<i>Post WL (Mean ± SD) mm</i>	<i>Mean Difference (mm)</i>	<i>95% CI (Lower–Upper)</i>	<i>t value</i>	<i>df</i>	<i>p value</i>	<i>Effect Size (Cohen's d)</i>
<i>Acetic Acid</i>	15	$20.25 \pm 0.52$	$20.22 \pm 0.47$	0.026	-0.052 to 0.106	0.718	14	0.484	0.185
<i>Maleic Acid</i>	15	$20.35 \pm 0.52$	$20.33 \pm 0.45$	0.020	-0.0717 to 0.111	0.468	14	0.647	0.121
<i>Citric Acid</i>	15	$20.45 \pm 0.52$	$20.42 \pm 0.43$	0.026	-0.0680 to 0.121	0.604	14	0.556	0.156

CI: Confidence Interval; WL: Working Length.  $p < 0.05$  considered statistically significant

**Figure 1: Intragroup Comparison of Pre- and Post-Retreatment Working Length Measurements in Acetic Acid, Maleic Acid, and Citric Acid Groups (n = 45)**





<i>Solvent</i>	<i>N</i>	<i>WL Difference</i> <i>Mean ± SD</i> <i>(mm)</i>	<i>95% CI</i>	<i>Min–Max (mm)</i>	<i>F-value</i>	<i>p-value</i>
<i>Acetic Acid</i>	<i>15</i>	<i>-0.027 ± 0.144</i>	<i>-0.106 to 0.053</i>	<i>-0.2 to 0.2</i>	<i>0.009</i>	<i>0.991</i>
<i>Maleic Acid</i>	<i>15</i>	<i>-0.020 ± 0.166</i>	<i>-0.112 to 0.072</i>	<i>-0.2 to 0.2</i>		
<i>Citric Acid</i>	<i>15</i>	<i>-0.027 ± 0.171</i>	<i>-0.121 to 0.068</i>	<i>-0.2 to 0.2</i>		

CI: Confidence Interval; WL: Working Length

**Table 2: Intergroup Comparison of Working Length Difference Among Acetic Acid, Maleic Acid, and Citric Acid Groups (n-45)**

**Table 3: Pairwise Comparison of Mean Working Length Differences Between Groups (Post Hoc Analysis)**

<i>Comparison</i>	<i>Mean Difference</i>	<i>p value</i>	<i>95% CI</i>
<i>Acetic vs Maleic</i>	<i>-0.0067</i>	<i>0.993</i>	<i>-0.149 to 0.136</i>
<i>Acetic vs Citric</i>	<i>0.0000</i>	<i>1.000</i>	<i>-0.142 to 0.142</i>
<i>Maleic vs Citric</i>	<i>0.0067</i>	<i>0.993</i>	<i>-0.136 to 0.149</i>

0.522 mm to  $20.333 \pm 0.453$  mm, with a mean difference of 0.0200 mm, which was also not statistically significant ( $t = 0.468$ ,  $p = 0.647$ ; 95% CI: -0.0717 to 0.1117). In the citric acid group, the working length reduced slightly from  $20.453 \pm 0.522$  mm to  $20.427 \pm 0.437$  mm, with a mean difference of 0.0267 mm, which again showed no statistically significant difference ( $t = 0.604$ ,  $p = 0.556$ ; 95% CI: -0.0680 to 0.1214). The effect sizes for all groups were small (Cohen's  $d$  ranging from 0.121 to 0.185), suggesting negligible clinical impact of solvents on apex locator readings. **(Figure 1)**

The intergroup comparison of working length differences is shown in **Table 2**. The mean differences were very similar across all groups, with acetic acid showing  $-0.027 \pm 0.144$  mm, maleic acid  $-0.020 \pm 0.166$  mm, and citric acid  $-0.027 \pm 0.171$  mm. The 95% confidence intervals for all groups overlapped considerably (Acetic: -0.106 to 0.053; Maleic: -0.112 to 0.072; Citric: -0.121 to 0.068), indicating no distinct variation between the groups. The range of differences was consistent across all groups (-0.2 to 0.2 mm), reflecting uniform measurement variability. One-way ANOVA analysis demonstrated no

statistically significant difference among the groups ( $F = 0.009$ ,  $p = 0.991$ ), confirming that the type of solvent did not influence working length determination. **(Figure 2)**

Post hoc analysis using Tukey's HSD test (**Table 3**) further supported these findings, as no statistically significant pairwise differences were observed between any of the groups. The mean difference between acetic acid and maleic acid was -0.0067 mm ( $p = 0.993$ ; 95% CI: -0.149 to 0.136), between acetic acid and citric acid was 0.0000 mm ( $p = 1.000$ ; 95% CI: -0.142 to 0.142), and between maleic acid and citric acid was 0.0067 mm ( $p = 0.993$ ; 95% CI: -0.136 to 0.149). All confidence intervals included zero, indicating no significant differences between any solvent combinations.

Overall, the results indicate that there was no statistically significant difference in working length measurements either within or between groups. All three solvents demonstrated comparable performance, with minimal mean differences and negligible effect sizes, suggesting that the type of solvent does not affect the accuracy of the electronic apex locator during retreatment procedures.

## **Statistical Analysis**

Statistical analysis was performed using IBM SPSS Statistics. Data were expressed as mean  $\pm$  standard deviation. Normality was assessed using the Shapiro–Wilk test. Intragroup comparisons between pre- and post-retreatment working length were analysed using paired t-test, while intergroup comparisons were performed using one-way ANOVA followed by Tukey’s post hoc test. A p-value  $< 0.05$  was considered statistically significant.

## **Discussion**

The influence of different solvents on the electrical conductivity within the root canal system, which in turn can affect the functioning of electronic apex locators. Since apex locators operate on the principle of impedance measurement, any alteration in the intracanal environment (particularly changes in ionic concentration and conductivity) has the potential to influence the accuracy of working length determination. Findings of this study demonstrate that the use of organic acids such as maleic acid, acetic acid, and citric acid does not significantly interfere with the accuracy of apex locator readings. Although these solvents may modify the electrical characteristics within the canal, their effect was not considerable enough to produce clinically relevant deviations.

The accuracy of Electronic Apex Locators (EALs) is fundamentally rooted in their ability to measure electrical impedance between the endodontic file and the periapical tissues. Because the root canal serves as a conductive pathway, the introduction of various irrigation solvents can alter the ionic concentration and

overall conductivity of the environment, theoretically risking a "short circuit" or an inaccurate reading. However, current findings suggest that organic acids, including maleic, acetic, and citric acid, do not significantly compromise the precision of these devices. While these solvents do technically shift the electrical profile within the canal, the magnitude of this change is insufficient to bypass the advanced multi-frequency algorithms used by modern EALs. Consequently, any deviations in working length determination remain within a clinically acceptable range (typically within  $\pm 0.5$  mm), ensuring that the presence of these specific organic acids does not impede the clinician's ability to achieve a predictable apical limit.

## **Conclusion**

Within the limitations of this study, it can be concluded that the presence of solvents may influence the accuracy of Electronic Apex Locators to a minor extent; however, the differences observed are minimal and not clinically significant. The organic acids evaluated in this study—maleic acid, acetic acid, and citric acid—showed good compatibility with apex locator functioning and did not adversely affect working length determination. Care should be taken while determining working length during retreatment procedures, and solvent selection may influence the reliability of apex locator readings.

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