



Effect of Smartwatch on Different Electronic Apex Locators on Working Length Determination: An *In –Vivo* Study

Dr. Arnika Maurya¹, Dr. Kiran Keswani², Dr. Pradeep Shetty³, Dr. Vinod Kambli⁴, Dr. Apurva Kamble⁵, Dr. Radhika Gadge⁶.

¹PG Student, Department of Conservative Dentistry and Endodontics. D.Y. Patil Dental School, Lohegaon

²Professor. Department Of Conservative Dentistry and Endodontics. D. Y. Patil Dental School, Lohegaon

³Head of Department, Department of Conservative Dentistry and Endodontics. D. Y. Patil Dental School, Lohegaon

⁴Reader, Department of Conservative Dentistry and Endodontics. D. Y. Patil Dental School, Lohegaon

⁵PG Student, Department of Conservative Dentistry and Endodontics. D.Y. Patil Dental School, Lohegaon

⁶PG Student, Department of Conservative Dentistry and Endodontics. D.Y. Patil Dental School, Lohegaon

(Received: 16 July 2025

Revised: 20 August 2025

Accepted: 20 September 2025)

KEYWORDS

Electronic apex locator, smartwatch, electromagnetic interference, endodontic treatment, working length measurement.

ABSTRACT:

Introduction: The user manuals of specific electronic apex locators (EALs) highlight that electromagnetic radiation can adversely affect their accuracy and functionality. In modern technology era, smartwatches are popularized among the younger generations as well as dentists and staff to monitor certain physical activities including cardiovascular activities and notifications which are directly displayed on smartwatch to avoid the uses of phone in between work. This study aimed to evaluate the impact of a smartwatch on the performance of two distinct apex locators in working length determination during root canal procedures.

Objectives: This study aims to assess effect of Smartwatch in Working length determination using Root ZX-Mini and Endomotor Integrated apex locator i.e E –Connect S.

Methods: Thirty patients recommended for endodontic treatment on incisors, canines, premolars having a single canal and completely developed root apex were selected. K-file was being used to established working length using Root ZX mini (J-Morita) and E-connect S. A standard smartwatch, namely the Samsung Galaxy Fit 3, was utilized to estimate the impact of electromagnetic radiation on the precision of working length measurement. Measurements were conducted under the following clinical conditions: Root ZX mini and E-connect S with smartwatch and without smartwatch.

Results: There was no statistically significant variation in working length measurements between the two different apex locators, irrespective of whether a smartwatch was present ($P > 0.05$)

Conclusions: This study demonstrated that the presence of a smartwatch near an EAL does not significantly affect the accuracy of working length measurements obtained by two different apex locators.



Introduction

The working length is described as the distance between the coronal reference point and the location where chemo-mechanical preparation and obturation should conclude¹. For the success of endodontic therapy, determination of working length plays important role². Various number of methods, including apical anatomy, tactile perception, apical hemorrhage, anesthetic-free patient response, and radiographic interpretation, have been put forth to ascertain the working length^{3,4}. Although radiography has gained popularity, there are a number of drawbacks, including radiation risk, picture superimposition, image distortion, and observer bias, all of which contribute to inaccurate radiographic interpretation⁵.

To tackle this problem, EALs were originally researched by Custer in 1918 popularized among dentists owing to better accuracy and lower exposure to radiation⁶.

An essential supplement to radiography, EALs are well-established device for determining working length⁶. According to Kobayashi, the third generation EAL employs the dual frequency and comparative impedance approach⁶. This electronic technique was called the “ratio method”. It concurrently detects two impedances inside the canal at two different frequencies (8 kHz and 0.4 kHz). Primarily, the Root ZX measures the electrical capacitance shift that takes place close to the alternating current (AC)⁶. The manufacturer claims that the Root ZX mini apex locator and Root ZX apex locator were constructed with the same technology.

In modern technology era, smartwatches are popularized among the younger generations as well as dentists and para-medical staff to monitor certain physical activities including cardiovascular activities and notifications which are directly displayed on smartwatch to avoid the uses of phone in between work⁸. As of 2025, there are 454.69 million smartwatch users worldwide, marking a 41% increase from the 323.99 million users in 2023.

Smart watches operate on the basis of radio waves being transmitted and received via electromagnetic waves. In contrast to ionizing radiation like radio frequency waves, X ray or gamma ray can produce electromagnetic interference, often known as radiofrequency interference (RFI). They can lead to ionization in the human body and destroy chemical bonds^{8,9}. The conduction circuit which was formed by the electronic apex locator may be affected, potentially impairing its functionality or causing it to malfunction^{9,10,11}.

This study aimed to assess the accuracy of two different apex locators in determining working length during root canal treatment, in relation to smartwatch usage.

Materials and Methods

Approval from the Institutional Ethical Committee had been obtained prior to conducting this in vivo investigation (Approval No.:H141/IECDYPDS/2025). Using G*Power Version 3.19.2, the sample size was determined considering the three groups, an alpha error probability of 0.05, a study power of 80%, and an assumed large effect size of 0.5. Thirty sample size was calculated. Consequently, thirty patients were chosen, all over the age of 18 (encompassing both sexes), who needed to undergo endodontic procedure for anterior teeth and premolars with a single canal and completely developed root apex. The study included the teeth that had been diagnosed with irreversible pulpitis that exhibited no evidence of apical pathology. The study excluded patients with cardiac pacemakers, implant-supported prostheses, root fractures, immature apices, root resorption, or canal calcifications. Patients who had given consent to participate in the study received a thorough explanation of the procedure, and their informed consent was obtained. Two separate apex locators were used in this research: Root ZX Mini (J Morita MFG, Kyoto, Japan) and the Endomotor integrated Apex Locator-E –connect S (Eighteeth, Jiangsu

Province, China). The smartwatch employed in the study was the Samsung Galaxy Fit 3. To ensure proper disinfection, patients were instructed to perform an oral rinse using 0.2% chlorhexidine solution to lower microbial load, after which the affected site was cleansed using sterile gauze. Following this, 2 mL of a local anesthetic solution (2% lignocaine with 1:200,000 adrenaline; Cadila Pharmaceuticals Ltd., Ahmedabad, Gujarat, India) was administered to the vital teeth. To facilitate accurate K-file placement during working length determination, a stable reference point was established by performing incisal or occlusal reduction. After securing isolation with a rubber dam (Coltene/Whaledent, Ohio, USA), an access cavity preparation was done, and a glide path was established using a No. 10 K-file till the apical terminus using watch-winding technique (Mani, Inc., Utsunomiya, Tochigi, Japan). Irrigation was conducted with a 5.25% sodium hypochlorite solution (PRIME Dental Products Pvt. Ltd., Thane, Maharashtra, India). Using a No. 15 K-file, the initial working length was determined in conjunction with an electronic apex locator (EAL), and the measurement was subsequently verified using radiovisiography.

The working length was assessed under the specified conditions:

- Using Root ZX Mini Apex Locator with Smartwatch (**Figure.1**)
- Using Root ZX Mini Apex Locator without Smartwatch (**Figure.2**)
- Using E- connect S Apex Locator with Smartwatch (**Figure.3**)
- Using E- connect S Apex Locator without Smartwatch. (**Figure.4**)



Figure.1: Working length determination using Root ZX Mini Apex Locator with Smartwatch



Figure.2: Working length determination using Root ZX Mini Apex Locator without Smartwatch



Figure.3: Working length determination using E- connect S Apex Locator with Smartwatch



Figure.4: Working length determination using E- connect S Apex Locator without Smartwatch

EWL measurements were obtained until the device reached the '0.0' level, according to manufacturer's recommendations. Measurements were deemed valid if the recorded reading remained consistent for a minimum of 5 seconds. Measurements were identified as unstable when the scale indicators on the EAL display fluctuated between points. Three attempts were made at each measurement, and the average result was calculated.

Statistical Analysis

To perform statistical analysis, the Statistical Package for Social Sciences was utilized (IBM SPSS Statistic for window, version 26.0. Armonk, NY: IBM Corp.) at 95% CI and 80% power to the study. Descriptive statistics was performed in terms of, mean and standard deviation, Frequency and Percentage. An Unpaired t test was used to compare the working length determination between apex locator and between groups respectively. Statistical significance was calculated at $p < 0.05$ and $p < 0.001$ was considered highly significant.

Results

Following tabulation of the final numbers, a comparison of the mean and standard deviation was performed. Measurements obtained with the Root ZX-mini apex locator showed no statistically significant difference when used with or without

smartwatch ($p > 0.05$) [Table 1]. Similarly, the working length measured with the E- connect S apex locator showed no statistically significant difference when used in the presence or absence of a smartwatch ($p > 0.05$) [Table 1].

Table 1: Mean value of working length under four conditions

	Groups	N	Mean	Std. Deviation	Std. Error Mean	t value	P value
Root ZX-mini-Apex Locator	With Smart Watch	30	19.0667	1.13512	.20724	0.056	0.955
	Without Smart Watch	30	19.0500	1.15482	.21084		
E-connect S Apex Locator	With Smart Watch	30	19.4833	1.11017	.20269	0.288	0.775
	Without Smart Watch	30	19.4000	1.13259	.20678		

Discussion

Accurate establishment of the working length represents a fundamental step in successful root canal therapy¹². Electronic Apex Locators (EALs) are employed to determine working length, offering enhanced stability and reliability while reducing radiation exposure and treatment time⁶. The accuracy and precision of Electronic Apex Locators (EALs) can be affected by the presence of inflammatory fluids, necrotic or vital pulp tissue, and the use of irrigants and obturation materials within the root canals. In dentistry, smartphones and smartwatches emit radiofrequency waves that may interfere with the electrical system of electronic apex locators (EALs), potentially impacting the correctness of working length measurements¹³. Research by Hayes et al. and Patel et al. has shown that various electronic devices commonly found in dental settings including iPods, mobile phones, smartwatches, electric pulp testers, electronic apex locators, and electrosurgery units emit electromagnetic radiation. Due to this radiation the cardiac pacemaker may not function properly^{13,14}.



These days Cell phones and smartwatches are frequently used by patients, dentists, and dental staff in close proximity to dental equipment¹². However, there is not enough data in the literature at this time to determine how wearing a smartwatch near an EAL affects the electronic working length evaluation. The lack of information makes it more difficult for dentists to determine whether wearing smartwatches while using Electronic Apex Locators (EALs) is safe or if it could compromise the precision of working length measurements.

This study included the teeth with single root canal to eliminate potential interference from complex anatomical structures when measuring working length. A third and fifth-generation electronic apex locator (EAL) and a recent smartwatch with a higher frequency band count were utilized. As 3rd generation apex locator is gold standard for working length determination with 74 % to 97.37 % accuracy rate and it has been chosen to be studied¹⁵. To avoid the chair side time, endomotor integrated apex locators (E-connect S) has been evolved which is 5th generation apex locator and it is a multi-frequency-based EAL¹⁵. These integrated motors with an Integrated EAL have AAR-Automatic Apical Reverse function. Thus, when the file tip reaches the predetermined point, the Automatic Apical Reverse (AAR) function stops and reverses rotation. This characteristic enables accurate instrumentation in the apical region of the canal¹⁵. The AAR function can be modified to determine whether the file should be positioned nearer to or further from the apical constriction. The '0.5 mm' mark on the AAR function is designated to indicate the position of the apical constriction (AC), while the 'APEX mark' signifies the tip of the file at the apical foramen. This also eliminates requirement for visual monitoring of the EAL display¹⁵. According to studies, electromagnetic radiation from surrounding electronic gadgets may disrupt the operation of such equipment.

In order to replicate a realistic clinical scenario, the watch was placed within two feet of the EALs. The findings of our study indicate a variation in working length determination when using the Root ZX-mini and E-connect S apex locators, both in the presence and absence of a smartwatch. Although the statistical analysis revealed that electromagnetic radiation from the smartwatch influenced the working length determination by the EAL, this interference was not statistically significant ($p > 0.05$). These results correspond with previous in vitro research conducted by Hurstel et al. (2005)¹⁶ and Sidhu et al. (2016)¹⁷, as well as Jain A S et al. (2017)¹¹, along with in vivo investigations by Nishanthine et al. (2019)¹⁸ and Gohil et al. (2017)⁷, all of which reported no notable disruption caused by cell phones on EAL measurements. Lawentschuk N et al. (2004) conducted a study on the effect of mobile phones on medical devices and determined that restrictions on mobile phone usage in hospitals should be implemented when the distance is less than 1 m. However, when the distance exceeds 1 m from the equipment, restrictions in clinical areas are the most frequently observed¹⁹. A study conducted by Francis J. and Niehaus M. in 2006 examined the interference between cellular telephones and implantable rhythm devices, concluding that cellular phones may disrupt the functioning of these devices when used in close proximity or during their programming⁴. A study conducted by Dr. Madhureema De Sarkar and colleagues in 2018 assessed the effect of cell phone radiation on the performance of electronic apex locators. The study concluded that cell phone radiation can interfere with the accuracy of working length measurements when the devices are positioned in close proximity. Therefore, it is advised that all cell phones remain in standby mode during root canal procedures, particularly when electronic dental devices are being used¹⁰. However, Parirokh et al. conducted an in vitro study to demonstrated that several electronic devices excluding FM radios



significantly affected the working length measurements obtained by electronic apex locators (EALs), suggesting that differences in frequency ranges may contribute to this interference²⁰.

Despite the observed interference, this study did not find any significant impact on the working length determination using the Electronic Apex Locator (EAL), indicating that subsequent endodontic procedures including biomechanical preparation, obturation, and overall treatment outcomes remain unaffected. The outcome of this study could have been influenced by the use of a fifth-generation EAL, which is noted for its superior safety, accuracy, and reliability. It is essential to note that this study utilized a smartwatch in conjunction with a fifth-generation apex locator; the use of different generations of apex locators or alternative devices may yield varying results

Additionally, outcomes could vary when examining multi-rooted teeth. EWL measures were taken in the current study while the smartwatch was in active mode. This study was carried out at a same location to ensure consistent signal strength. Future research should use EWL measurements taken while the phones and watches are connected to Wi-Fi, as this could produce different findings. In conclusion, the smartwatch employed in this investigation had no impact on the accuracy of the in vivo electronic working length measurement. Further investigations into the magnetic interference caused by different electronic devices on various dental instruments should be considered.

Conclusion

The findings of this study indicate that the presence of smartwatches in close proximity does not significantly impact the working length determination by the two electronic apex locators.

Limitations of study

The dentist did not wear the smartwatch during the procedures. The smartwatch was worn by the patients undergoing root canal treatment.

References

1. Glossary of endodontic terms. AAE 10th ed 2020
2. Kim E, Lee S J. Electronic apex locator Dent Clin N Am 2004;48:35–54.
3. Gordon M P J , Chandler N P Electronic apex locators. IEJ 2004;37:425–437.
4. Francis J , Niehaus M Interference Between Cellular Telephones and Implantable Rhythm Devices: A Review on Recent Papers, IPEJ. 2006;6(4): 226-233.
5. Chhabra, Swati & Singh, Gagandeep & Kukreja, Navneet & Sharma, Ankita & Thakur, Anamika & Gugnani, Megha & Sachdeva, Surinder. (2022). Effect of cell phone radiation on determination of exact working length with two different generations of electronic apex locator"- an in-vivo study. Journal of Applied School Psychology.
6. Khadse A, Shenoi P, Kokane V, Khode R, Sonarkar S, Electronic Apex Locators- An overview. *IP Indian J Conserv Endod* 2017;2(2):35-40
7. Gohil UK, Parekh VV, Kinariwala N, Oza KM, Somani MC. Can active signals of cellphone interfere with electronic working length determination of a root canal in a dental clinic? An in vivo study. *J Conserv Dent* 2017;20:170-3.
8. Masoumian Hosseini, M., Masoumian Hosseini, S.T., Qayumi, K. *et al.* Smartwatches in healthcare medicine: assistance and monitoring; a scoping review. *BMC Med Inform Decis Mak* **23**, 248 (2023)
9. Patel S et al. Evaluation of Electromagnetic Interference of Smartphone on Apex Locators: An in Vivo Study. *IJRR* 2020;7(2):192-200.



10. Dr. Madhureema De Sarkar, Dr. Kundabala M., Dr. Neeta Shetty, . “Effect of cell phone radiation on electronic apex locator” *International Journal of Development Research*, 2018; 8(02): 19056-19058.
11. Jain AS, Asrani H, Singhal AC, Asrani A, Deshmukh P, Jain D. Do mobile phones cause interference on electronic apex locators? An in vitro study. *J Endod* 2017; 29:142-145
12. Shruti Patel et.al. Evaluation of electromagnetic interference of smartphone on apex locators: an in vivo study, *International Journal of Research and Review Vol.7; Issue: 2; February 2020*
13. Hayes DL, Wang PJ, Reynolds DW, Estes M 3rd, Griffith JL, Steffens RA, et al. Interference with cardiac pacemakers by cellular telephones. *N Engl J Med* 1997;336:1473-9.
14. Patel MB, Thaker JP, Punnam S, Jongnarangsin K. Pacemaker interference with an iPod. *Heart Rhythm* 2007;4:781-4.
15. Urooj I, D., Joshi, C., Sweety, T., Mustafa Z, H., Dritali V, P., & Tejal , K. (2022). Working length determination: comparative analysis of integrated & electronic apex locator in various irrigating solutions. *International Journal of Health Sciences*, 6(7).
16. Hurstel J, Guivarc'h M, Pommel L, Camps J, Tassery H, Cohen S, Bukiet F. Do cell phones affect establishing electronic working length? *J Endod*. 2015 Jun;41(6):943-6.
17. Sidhu P, Shankargouda S, Dicksit DD, Mahdey HM, Muzaffar D, Arora S. Evaluation of Interference of Cellular Phones on Electronic Apex Locators: An In Vitro Study. *J Endod*. 2016 Apr;42(4):622-5.
18. Nishanthine C, Priyanka B, Devi R, Diana D, Duraivel D, Srinivasan MR. Assessment of Smartphone Interference with Electronic Apex Locator in Working Length Determination: A Clinical Study. *Journal of Operative Dentistry and Endodontics*. 2019 Jul;4(2):81.
19. Lawrentschuk N ,Bolton D M ,mobile phone interference with medical equipment and its clinical relevance: a systemic review *MJA* 2004;181(4):145-149.
20. Parirokh M, Manochehrifar H, Abbott PV, Borna R, Haghdoost AA. Effect of Various Electronic Devices on the Performance of Electronic Apex Locator. *Iranian Endodontic Journal*. 2019 Jan 1;14(4):278-82