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# Comparative evaluation of accuracy of three different electronic apex locators in the presence of various endodonticirrigants: An in vitro study

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**Abstract**
AIM AND OBJECTIVES. To evaluate and compare the accuracy of Root ZX, Raypex6, and I Root and electronic apex locators in the presence of NaOCl (3%), Citric acid (10%), MTAD and Green tea extract as endodontic irrigants.
MATERIAL AND METHOD. Sixty single rooted human permanent teeth were used for the study. Access cavities were prepared and the teeth were decoronated. Teeth were divided as follows: Group I-Root ZX apex locator ($n=20$), IA – NaOCl 3% endodontic irrigant ($n=5$), IB – Citric Acid 10% endodontic irrigant ($n=5$), IC – MTAD endodontic irrigant ($n=5$), ID- Green Tea extract endodontic irrigant ($n=5$). Group II: Raypex 6 apex locator ($n=20$). IIA – NaOCl 3% endodontic irrigant ($n=5$), IIB – Citric acid 10% endodontic irrigant ($n=5$). IIC – MTAD endodontic irrigant ($n=5$), IID – Green tea extract endodontic irrigant ($n=5$). Group III-i-ROOT apex locator ($n=20$). IIIA – NaOCl 3% endodontic irrigant ($n=5$), IIIB – Citric Acid 10% endodontic irrigant ($n=5$), IIIC – MTAD endodonticirrigant ($n=5$), IIID – Green tea extract endodontic irrigant ($n=5$). The actual working length was determined using a 15 K file and the working model was prepared using Alginate in a rectangular box. The teeth were embedded into the working model and the electronic measurements were made with each electronic apex locator. The data was collected, analyzed and subjected to statistical analysis.
RESULTS. No significant difference was found when Raypex 6 apex locator was used along with all the endodontic irrigants except green tea extract. Root ZXshowed statistically significant difference with green tea extract and MTAD. I-root showed statistically significant difference with all the irrigants except green tea extract.
CONCLUSION. Citric acid 10% was consistently accurate when assessed with all the three apex locators, whereas Green tea extract demonstrated the least accurate readings with all apex locators.

**Keywords:** working length, electronic apex locator, endodontic irrigants, sodium hypochlorite, MTAD, Citric acid, Green tea extract

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# Сравнительная оценка точности трех различных электронных апекслокаторов в присутствии различных эндодонтических ирригантов: in vitro исследование

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**Резюме**
ЦЕЛЬ И ЗАДАЧИ. Оценить и сравнить точность Root ZX, Raypex6 и I Root, электронных апекслокаторов в присутствии NaOCl (3%), лимонной кислоты (10%), MTAD и экстракта зеленого чая в качестве эндодонтических ирригантов.
МАТЕРИАЛЫ И МЕТОДЫ. В исследовании использовались шестьдесят постоянных однокорневых зубов человека. Были подготовлены доступы к полостям, и зубы были декоронованы. Зубы были разделены на следующие группы: Группа I – апекслокатор Root ZX ($n=20$), IA – эндодонтический ирригант NaOCl 3% ($n=5$), IB – эндодонтический ирригант лимонная кислота 10% ($n=5$), IC – эндодонтический ирригант MTAD ($n=5$), ID – эндодонтический ирригант экстракт зеленого чая ($n=5$). Группа II – апекслокатор Raypex 6 ($n=20$), IIA – эндодонтический ирригант NaOCl 3% ($n=5$), IIB – эндодонтический ирригант лимонная кислота 10% ($n=5$), IIC – эндодонтический ирригант MTAD ($n=5$), IID – эндодонтический ирригант экстракт зеленого чая ($n=5$). Группа III – апекслокатор I-ROOT ($n=20$), IIIA – эндодонтический

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ирригант NaOCl 3% ($n$=5), IIIB – эндодонтический ирригант лимонная кислота 10% ($n$=5), IIIC – эндодонтический ирригант MTAD ($n$=5), IIID – эндодонтический ирригант экстракт зеленого чая ($n$=5). Фактическая рабочая длина была определена с помощью файла K 15, и рабочая модель была подготовлена с использованием альгината в прямоугольной коробке. Зубы были закреплены в рабочей модели, и были проведены электронные измерения с каждым апекслокатором. Данные были собраны, проанализированы и подвергнуты статистической обработке.
РЕЗУЛЬТАТЫ. Не было обнаружено значительных различий при использовании апекслокатора Raypex 6 с любыми эндодонтическими ирригантами, за исключением экстракта зеленого чая. Root ZX показал статистически значимые различия при использовании с экстрактом зеленого чая и MTAD. I-Root показал статистически значимые различия со всеми ирригантами, кроме экстракта зеленого чая.
ЗАКЛЮЧЕНИЕ. Лимонная кислота 10% показала стабильную точность при оценке с использованием всех трех апекслокаторов, тогда как экстракт зеленого чая продемонстрировал наименее точные показания при использовании с любыми апекслокаторами.

**Ключевые слова:** рабочая длина, электронный апекслокатор, эндодонтические ирриганты, гипохлорит натрия, MTAD, лимонная кислота, экстракт зеленого чая

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## INTRODUCTION

Appropriate working length determination plays a critical role in determining the accuracy and success of endodontic treatment. A routine endodontic procedure can plague the operator in cases of poorly determined working length [1].

Use of traditional approaches such as radiographs, considering anatomical averages, relying on tactile sensation and using paper points do provide an approximate working length to some degree, but they do have their limitations [2]. Cluster and Suzuki introduced Electronic Apex Locators to overcome these limitations and to standardize the working length determination in endodontics [3]. The 1st and 2nd generation of apex locators provided adequate reading but their efficiency was limited to dry canals. After some modifications, the 3rd and 4th generation apex locators were introduced [4].

Root ZX (J Morita) is a third generation apex locator and it uses the ratio method for measuring the root canal length which was introduced by Kobayashi et al in 1991. It is a dual frequency electronic apex locator. This electronic apex locator has been studied extensively for its accuracy and its efficacy in the presence of various endodontic irrigants [5].

An apex locator with different frequencies of 5 KHz and 500 Hz is the i-Root (S-Denti Co. Ltd Seoul, Korea) apex locator. According to the manufacturer, its accuracy is good, irrespective of canal contents [6].

Raypex 6 (VDW, Munich, Germany) is the last member of Raypex series whose clinical performance was previously found to be successful with the evaluation of Raypex 4 and 5 [7].

It is important to remove the tissue debris and microorganisms within the root canal and hence a wide range of irrigants are used to facilitate proper chemomechanical preparation of the root canal treatment. The most routinely used irrigants in the root canal are sodium hypochlorite, saline, EDTA and Chlorhexidine, MTAD, citric acid.

Sodium hypochlorite (NaOCl) is considered gold standard for root canal irrigation. It is used in various percentages like 1%, 3%, 5.25%. However, it is has certain disadvantages such as irritation, injury to periapical tissues after extrusion from the apical foramen.

Torabinejad and co-workers [8] developed MTAD (mixture of tetracycline, acid and detergent) as a final endodontic irrigant [9; 10] to disinfect the canal [11–14], remove smear layer [15; 16] and to solubilize pulp tissue [17], particularly when used after sodium hypochlorite [10].

In the recent years, there has been a search for herbal alternatives in order to overcomethe shortcomings of conventional irrigants and increase in antibiotic resistant strain.

Natural plant origin compounds like Green tea are proven to be less toxic and less irritant to the tissues and significantly effective against *E. faecalis* [18].

Green tea polyphenols is prepared from the tender shoots of the tea plant *Camellia sinensis* is the customary drink of Japan and China. Green tea polyphenols antibacterial activity against *E. faecalis* biofilm formed on tooth substrate which showed statistically significant. Complete eradication of *E. faecalis* was achieved within 6 min [18].

In a study by Prabhakar et al, antimicrobial efficiency of green tea polyphenols and 3% sodium hypochlorite were evaluated against *E. faecalis.* The authors concluded that green tea exhibited significantly higher antibacterial effect against 2 week biofilm [19].

There is a concern regarding the effect of various irrigating solutions on the accuracy of electronic apex locators. To the best of our knowledge, there are not many studies assessing the precision of Root ZX apex locator, Raypex 6 apex locator, i-Root apex locators in the presence of Sodium hypochlorite, Citric acid, MTAD, and green tea extract. Hence, the purpose of this study was to investigate whether the presence of such endodontic irrigants affected electronic working length measurements by various apex locators.

## MATERIAL AND METHODS

Sixty human permanent teeth single rooted were selected for the study after excluding specimens with curved roots, resorption, caries or calcification. The teeth were than safely stored in a 2% Buffered Formalin solution.

The study required reduction of the occlusal plane to produce an even surface for a stable and retraceable reference point as required in working length (WL) determination. This was achieved by sectioning the teeth at the cemento-enamel junction using a diamond disc(DSK). Preflaring of the canal orifices using Gates Glidden drills from #1 to #3. The pulpal tissue was extirpated using a barbed broach. (Spirocolorinox, Dentsply).

The specimens were divided into three groups.

**Group I**-Root ZX apex locator ($n=20$)
IA NaOCl 3% endodonticirrigant ($n=5$)
IB Citric Acid 10% endodonticirrigant ($n=5$)
IC MTAD endodonticirrigant ($n=5$)
ID Green Tea extract endodontic irrigant ($n=5$)
**Group II**: Raypex 6 apex locator ($n=20$)
IIA NaOCl 3% endodontic irrigant ($n=5$)
IIB Citric acid 10% endodonticirrigant ($n=5$)
IIC MTAD endodonticirrigant ($n=5$)
IID Green tea extract endodontic irrigant ($n=5$)
**Group III**-i-ROOT apex locator ($n=20$)
IIIA NaOCl 3% endodonticirrigant ($n=5$)
IIIB Citric Acid 10% endodonticirrigant ($n=5$)
IIIC MTAD endodonticirrigant ($n=5$)
IIID Green tea extract endodonticirrigant ($n=5$)

The actual working length of the root canal was determined using a #15 K file (MANI)into the canal until the tip of the file was visible at the apex. To obtain a standardized value 0.5 mm was subtracted from the actual working length for each tooth sample [6].

For measurement of electronic working length, a customized model for the three study groups were prepared using rectangular plastic boxes. The teeth samples were glued and stabilized to the plastic frame using modelling wax. Alginate was mixed and poured into the box and the frame was embedded into the alginate. To complete the circuit, the lip clip of the apex locator was immersed in the alginate, fixed to the plastic box. The model was constructed and within 2 hours all measurements were made.

The working length measurements were conducted in the presence of Sodium hypochloride (NaOCl) (3%), Citric acid (10%), MTAD and Green tea extract root canal irrigants.

The root canals were first irrigated with 3% NaOCl using a 26 gauge bevelled needle in a 2 ml syringe (Unolok, Hindustan Syringes and Medical devices ltd, India). A #15K file (MANI) with the file clip was then inserted into the canal until the apex locator showed the reading of the “APEX”. The Silicon stopper was then adjusted and the K file was removed. The distance between the base of the silicon stopper and file tip was measured to the nearest 0.5mm mark.

The “APEX” as indicated by all devices was chosen as the apical reference. The electronic working length measurements for teeth were recorded with Root ZX followed byRaypex 6 and i Root apex locators.

The above procedure was repeated using10%Citric acid, TAD and Green tea extract root canal irrigants. Each measurement was repeated thrice, and the average was calculated. To prevent cross contamination, each set of the instruments were conducted in a fresh mixture of alginate. Results were then subjected to statistical analysis.

## STATISTICAL ANALYSIS

Statistical analysis was done by descriptive statistics as mean, SD, percentage / proportions.

Comparisons was done by applying Student’s Unpaired ‘t’ test at 5% (p,0.05) and 1% (p,0.01) level of significance.

Also, one way ANOVA test with Tukey Kramer multiple comparison test was applied to test the comparison of all groups together at 5% (p,0.05) and 1% (p,0.01) level of significance.

Statistical analysis software namely SYSTAT version 12 (By Cranes software, Bangalore) was used to analyze the data.

## RESULTS

Root ZX apex locator (Group I) showed no significant difference in actual and electronic working length when used with NaOCl and citric acid as endodontic irrigant. However with MTAD and Green tea extract irrigants there was a significant difference.

**Table 1.** Comparison of mean and SD values of Actuallength (AL) and Electronic Length (EL) in Group A, B, C and D root canal irrigants using Root ZX, Raypex 6 and Iroot apex locators

**Таблица 1.** Сравнение средних значений и стандартных отклонений фактической длины (AL) и электронной длины (EL) в группах A, B, C и D эндодонтических ирригантов с использованием апекслокаторов Root ZX, Raypex 6 и IRoot

| | Root ZX apex locator | | | | Raypex 6 apex locator | | | | I Rroot apex locator | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Group A: NaOCl ($n=5$) | Group B: Citric acid ($n=5$) | Group C: MTAD / QMix ($n=5$) | Group D: Green Tea extract ($n=5$) | Group A: NaOCl ($n=5$) | Group B: Citric acid ($n=5$) | Group C: MTAD / QMix ($n=5$) | Group D: Green Tea extract ($n=5$) | Group A: NaOCl ($n=5$) | Group B: Citric acid ($n=5$) | Group C: MTAD / QMix ($n=5$) | Group D: Green Tea extract ($n=5$) |
| | Mean±SD | Mean±SD | Mean±SD | Mean±SD | Mean±SD | Mean±SD | Mean±SD | Mean±SD | Mean±SD | Mean±SD | Mean±SD | Mean±SD |
| Actual Length | 14.64±1.01 | 12.36±1.64 | 13.84±0.84 | 14.40±2.23 | 11.08±2.12 | 12.92±1.13 | 14.48±1.03 | 11.24±1.41 | 16.82±2.12 | 14.94±2.76 | 16.32±1.87 | 18.14±2.10 |
| Electronic Length | 14.38±0.97 | 12.04±1.75 | 13.04±0.91 | 12.20±2.37 | 12.26±2.04 | 12.82±1.43 | 14.86±1.69 | 12.04±1.39 | 15.40±1.88 | 13.72±2.36 | 14.98±1.85 | 17.88±2.03 |
| Unpaired ‘t’ test value, ‘p’ value | 1.38, $p=0.987$, Not significant | 0.52, $p=0.248$, Not significant | 4.83, $p=0.0014$ Significant | 1.96, $p=0.046$, Significant | 1.41, $p=0.579$, Not significant | 0.24, $p=0.311$, Not significant | 0.66, $p=0.102$, Not significant | 2.07, $p=0.019$, Significant | 2.01, $p=0.0017$ Significant | 1.09, $p=0.311$, Not significant | 1.96, $p=0.012$, Significant | 0.31, $p=0.19$, Not significant |

In Group II i.e. Raypex 6 apex locator there was no significant difference in actual and electronic working length using NaOCl, citric acid and MTAD as endodontic irrigant. Where asGreen tea extract irrigant showed a significant difference.

When i-Root apex locator (GroupIII) was used there was significant difference in NaOCl and MTAD as endodontic irrigants, while citric acid and green tea extract irrigants gave no significant difference between actual and electronic working length (Table 1 and Figure 1).

## DISCUSSION

The development of apex locators has revolutionized endodontics as it is imperative to obtain a high success rate, which allows the clinician to clean, shape, and fill the three- dimensional root canal system as close as possible to the apical constriction. These devices have helped overcome the shortcomings of conventional radiographs [20] while reducing the time and effort by the operator.

Irrigants can augment mechanical debridement by flushing out debris, dissolving tissue, and disinfecting the root canal system. Chemical debridement is especially needed for teeth with complex internal anatomy such as fins or other irregularities that might be missed by instrumentation [18].

However, the presence of any fluids may hamper the use of apex locators and thus achieving precise measurements. The study included NaOCl, Citric acid, MTAD and green tea extracts to evaluate the accuracy of apex locators. Three modern electronic apex locators, namely, Root ZX Mini, i-Root and Raypex 6 were used in this in-vitro study to estimate the length of the root canal. The design of this in vitro study was to allow determination of the length of the tooth easily. In order to achieve accurate readings, the media for mounting the teeth should have an electrical resistance similar to that of the periodontal ligament. The ideal medium for embedding teeth and being a conducting medium is alginate due to its relatively high viscosity which prevents blockage of substance into the apical foramen and withstands forces that are exerted by the movement of the file, enabling the operator to precisely assess the working length [6].

Alginate allows ions to circulate despite its firm consistency [21]. The main disadvantage of alginate is its limited working time because the alginate tends to desiccate unless it is kept moist. Hence, the electronic calculations were carried out within 2 hours after the apparatus was prepared as this allows to achieve sufficient humidity of the alginate for the conductivity.

To evaluate the accuracy of apex locators, a range of ±0.5 was used in the study. This range is clinically acceptable and highly accurate [6].

In the current study, Root ZX Mini provided working length close to actual length readings when used with 3%NaOCl ($p=0.987$) and 10% Citric acid ($p=0.248$) asirrigants, andasignificant difference in working length determination was observed with the use of MTAD ($p=0.0014$) and green tea extract ($p=0.056$).

These results are in accordance with a study done by Khattak O et al which concluded that the accuracy of Root ZX apex locator was consistently high in the presence of normal saline, 0.2% chlorhexidine and 2.5% NaOCl. They inferred that 2.5% sodium hypochlorite had no effect on accuracy of Root ZX apex locator which was more precise than the iPex in achieving the working length [22].

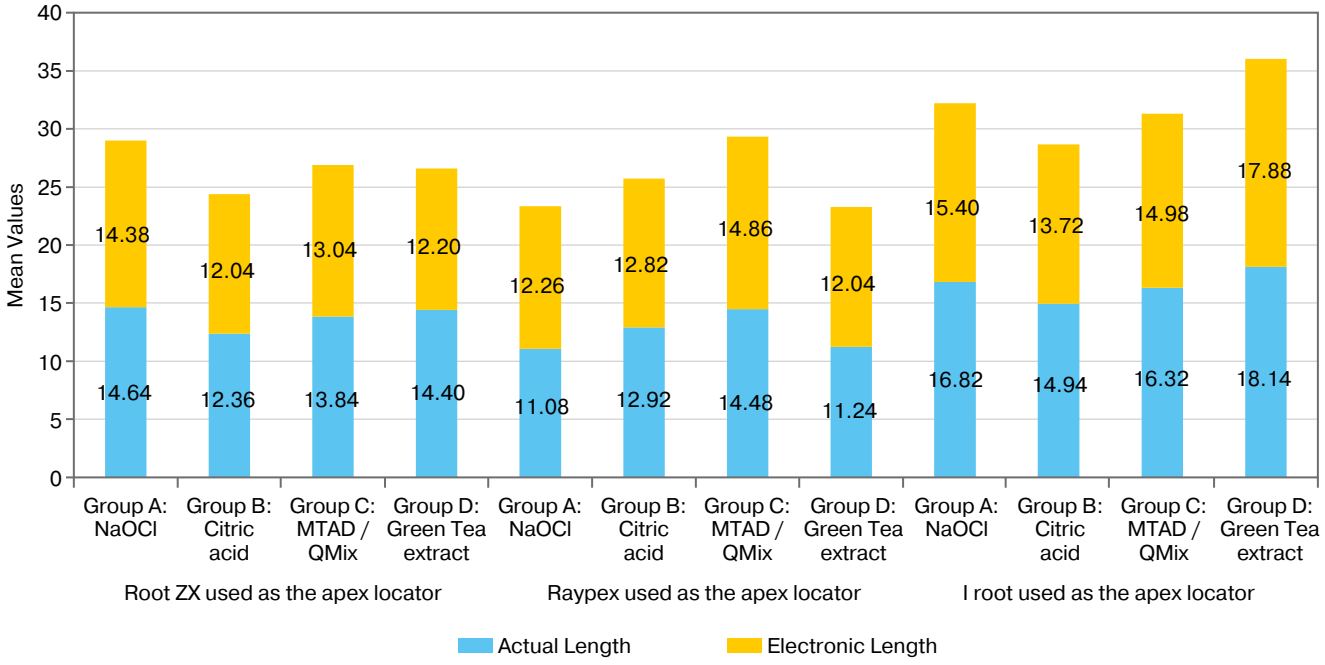


**Fig. 1.** Comparison of mean and SD values of Actuallength (AL) and Electronic Length (EL) in Group A, B, C and D root canal irrigants using Root ZX, Raypex 6 and Iroot apex locators

**Рис. 1.** Сравнение средних значений и стандартных отклонений фактической длины (AL) и электронной длины (EL) в группах A, B, C и D эндодонтических ирригантов с использованием апекслокаторов Root ZX, Raypex 6 и IRoot

Certain authors [23–26] accept that the least remarkable discrepancy is obtained while using NaOCl irrigant no matter what the concentration is. The reality is this irrigant has a high electrical conductivity and has the capability to seep into the dentinal tubules and reduce electrical impedance of the root canal boundaries along with generating better electrical contact with periapical tissues [27].

Raypex 6 (VDW) is the sixth variant in the Raypex series of apex locators and there are not many studies evaluating its accuracy in the presence of various endodontic irrigants and thus it was used in the present study.

This study has shown Raypex 6 with close to accurate readings when used with 3% NaOCl ($p=0.579$), 10% Citric acid ($p=0.311$) or MTAD ($p=0.102$) as the endodontic irrigants. The results showed significant difference in the working length when it was used in the presence of green tea extract ($p=0.019$).

However, in a study done by Luca Mariago et al, Raypex 6 demonstrated poor mean results in the presence of sodium hypochlorite [28]. Other than a study done by Reynoso RF, some studies showed higher accuracy with Raypex 6 [29].

Research by Tamil Selvan used Root ZX Mini and Raypex 6 electronic apex locators in the presence of 5% NaOCl, 2% chlorhexidine and normal saline. They inferred that both the apex locators had similar accuracy and the irrigating solutions did not affect the accuracy of the apex locators [20].

J.A. Kang, S.K. Kim [30] tested the precision of seven apex locators under clinical conditions. The apex locators used were Apit, Bingo-1020, Apex Finder 7005, ProPexi-Root, Smarpex and Root ZX. The measurements were acquired with dry canals and the canals irrigated successively with saline, 5.25% NaOCl, 15% EDTA and 0.1% chlorhexidine. The tested apex locators were validated in the presence of the irrigants.

N. Sakkir et al. [31] demonstrated that statistically no difference was found between the apex locators tested (i-Root, Root ZX II, Triauto ZX, Endo Master, Elements and Triauto ZX) and the working length which was obtained manually.

In another study by A.B. Prasad et al. demonstrated approximate results in comparison to the working length obtained manually. Most accurate results were obtained with i-Root and Root ZX [6].

However, in this study, i-Root provided inaccurate readings with the use of 3% NaOCl ($p=0.0017$) and MTAD ($p=0.0102$); whereas the readings were accurate when tested with 10% citric acid ($p=0.311$) and green tea extract ($p=0.19$).

A confounding factor for inaccurate readings in the study could be the tested endodontic irrigants. A. Rana et al. [32] compared the accuracy of different electronic apex locators in the presence of herbal irrigants and they concluded that the contents of the root canal system affected the results of the electronic apex locators, but the differences were not statistically significant.

There is paucity of literature on research assessing the accuracy of apex locators in the presence of green tea extract and hence it was used in this study.

Biopure MTAD consists of a powder-liquid system. Part A is the liquid which is supplied in the form of syringes and consists of 4.25% citric acid and 0.5% polysorbate 80 detergent (Tween 80). Part B is the powder which contains 3% doxycycline hyclate. It is highly biocompatible and least cytotoxic. Also it demonstrated the greatest antibacterial efficacy against *E. faecalis* [10]. The pH of MTAD is 2.15 and plays an important role in chelating calcium ions.

Not many studies have assessed the accuracy of MTAD with electronic apex locators. Most of the studies assessed the accuracy of apex locators in the presence of routinely used endodontic irrigants such as sodium hypochlorite and chlorhexidine.

In a study done by E. Cicek et al., the accuracy of Root ZX mini and Propex II was 89.3% in the presence of MTAD while with Raypex 5 the accuracy in the presence of MTAD was 83.3% [33].

Citric acid is a chelating agent and studies have shown that 10% citric acid removes the smear layer better than 17% EDTA. Its effect has not been widely studied along with the use of electronic apex locators.

M. Janeczek et al. [27] comparedEndopilot® and iPex® apex locators. The following irrigation solutions were used: 2.0% sodium hypochlorite, 5.25% sodium hypochlorite, 40.0% citric acid, 0.2% chlorhexidine digluconate, 0.9% NaCl, 3.0% hydrogen peroxide, 15.0% disodium edentate, and 70.0% isopropyl alcohol – 2-propanol. The study demonstrated the highest stability of working length readings in NaOCl environment in both 2.0% and 5.25% concentration.

Researchers inferred that the least significant difference was achieved when NaOCl endodontic irrigant was used in any concentration. As sodium hypochlorite solution has high electrical conductivity and it has the potential to infiltrate into dentinal tubules and reduces electrical impedance of root canal walls along with generation of better electrical contact with periapical tissues.In the 40% citric acid group, electrical conductivity was altered which increased the distance between the file tip and apical foramen [27].

Electronic apex locator (EAL) and gold standard (GS) technique was compared by Jha et al with respect to working length determination method using various endodontic irrigants. They inferred that the least effect on accuracy of EAL was noted with chlorhexidine 2%, followed by 17%EDTA, then 3% NaOCl and the highest effect was recorded with 5% NaOCl [34].

Sanda Ileana Cîmpean in their research found that rise in the concentration of the irrigation solution had direct impact on the accuracy of Root ZX II and Apex ID apex locators. The highest precision in working length determination was observed in Root ZX II when using 2% NaOCl solution and Dual Pex for 5.25% NaOCl solution. However comparison of both showed no statistically significant difference [35].

Evaluationof the effect of 2% chlorhexidine (CHX) and 2.5% sodium hypochlorite (NaOCl) on the accuracy and consistency of three Electronic Apex Locators (EALs)was done by Fabia et al. The study results revealed that 2% chlorhexidine gluconate and 2.5% sodium hypochlorite had no influence on the performance of Mini, iPex or Root ZX II apex locators. These apex locators were found to detect apical constriction predictably [36].

Alothmani OS et al in their publication suggested that the most accurate estimation of root canal working length was obtained when using Root ZX apex locator, according to the manufacturer's protocol and recommendations [37].

However, there are certain limitations of this study which include inability to fully simulate in vivo conditions for determining working length of root canal and relatively small sample size.

## CONCLUSION

Within the limitations of this study, it can be concluded that Root ZX and Raypex 6 apex locators are accurate in the presence of 3% NaOCl endodonticirrigant. Raypex 6 was highly accurate with 3% NaOCl, MTAD and 10% Citric acidirrigants. Citric acid 10% was consistently accurate when assessed with all the three apex locators, whereas Green tea extract demonstrated the least accurate readings with all apex locators.

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