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Original Article

Accuracy of two electronic apex locators in locating root perforations in curved canals in dry and wet conditions: A comparative *in vitro* study

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ABSTRACT

Background: The aim of the study was to evaluate the accuracy of iPex and Vdw gold apex locators in detecting simulated root perforations in curved canals in the presence of 3% sodium hypochlorite (NaOCl) and 2% chlorhexidine (CHX).

Materials and Methods: In this comparative *in vitro* study Twenty mandibular molars with curved mesial roots were selected and perforation was made in the danger zone 4 mm from the furcation area. The actual length of the perforation site was measured using stereomicroscope software using a #15 K file, following which the teeth were embedded in alginate molds. The perforation site was electronically measured using two apex locators, iPex and Vdw gold in dry condition and in the presence of 3% NaOCl and 2% CHX. The values obtained were compared using the Friedman and Wilcoxon signed-rank test with level of statistical significance set at $P \leq 0.05$.

Results: In dry condition, Vdw gold showed near accurate values, i.e., 0.25 mm from the manual value whereas iPex showed a significant difference ($P < 0.05$) of 0.76 mm from the manual value. In the presence of 3% NaOCl, both the apex locators showed a significant difference ($P < 0.05$) from the manual value with iPex showing a difference of 0.70 mm and Vdw gold showing a difference of 0.74 mm. The most accurate values were determined by both the apex locators in the presence of 2% CHX with iPex showing a deviation of 0.13 mm and Vdw gold showing a deviation of 0.39 mm from the manual.

Conclusion: In dry condition, Vdw group showed better results than iPex in determining the length of the root perforation. In wet condition, in the presence of 2% CHX, both the apex locators accurately measured the perforation site, whereas in the presence of 3% NaOCl, both the apex locators showed a significant difference ($P < 0.05$) from the manual value in detecting the root perforation.

Key Words: Curved, root canal length, root canal irrigants

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INTRODUCTION

Root perforation is said to be an unnatural communication between the root canal to the supporting tissues of teeth.[1] Although caries or resorptive processes may cause perforations, the most common

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cause of root perforation is iatrogenic, the frequency of which ranges from 3% to as high as 10%.[2] Due to these root perforations, the infection either from the root canal or the periodontal tissues brings about inflammatory sequel which prevents healing.[1] Many factors contribute to the healing of these perforation sites which include time from the perforation detection and its sealing, size, and shape of the perforation as well as its location.[1] A potential detection of these root perforations during endodontic treatment is of utmost importance as it leads to extrusion of irrigation solutions or sealers into the periradicular tissues and instrumentation in the periodontal space.[3]

There are various methods to detect these perforations such as profuse bleeding from root canal during instrumentation and indirect evaluation of bleeding by paper points, radiographic assessment, and electronic apex locators (EALs).[3] Radiographs taken at different angulations are an important supplementary aid along with other diagnostic methods in detecting root perforations. Diagnostic value of radiographs is limited in certain situations such as when perforation is located in buccal or palatal aspects of the root, the superimposing anatomical structures, and radiopaque materials.[1] Electronic working length determining devices are excellent adjunct to radiographs in locating apical foramina, root resorptions, and fractures more accurately (75%–97.5%).[4]

Previously used apex locators were not accurate in the presence of irrigating solutions as they were based on the measurement of resistance between the root canal and the periodontal ligament,[5] whereas the modern generation EALs use two or more different frequencies to calculate the impedance and promise to work even in the presence of irrigating solutions such as saline and sodium hypochlorite (NaOCl) which are most commonly used.[5] Vdw gold is an endomotor with an inbuilt fourth generation apex locator which uses two frequencies of 5.5 kHz and 500 Hz to measure the working length.[6] IPex is a fourth generation apex locator that uses two or more frequencies to measure the difference or ratio in between the currents.[7]

Extensive search of available literature yielded no studies which have compared the accuracy of these two apex locators in determining root perforation in curved canals of molars; therefore, the aim of the present study was to assess the accuracy of iPex and Vdw gold apex locators in detecting simulated root perforations in curved canals in the presence of different irrigating solutions. The null hypothesis of the present study was that there is no difference between the two apex locators in determining the root perforations in different canal conditions when compared to the manual method.

MATERIALS AND METHODS

Sample size selection and preparation

In this comparative *in vitro* study Twenty permanent mandibular molars with curved mesial roots (10°–20°) were selected according to the Schneiders method,[8] and disinfection with thymol solution was done. Following this, the samples were stored in saline (Amanta Healthcare Ltd., Gujarat, India) until use. Roots with fractures, calcification, previous root perforations, and root resorption were excluded from the study. Evaluation of the root was thoroughly done by taking radiographic images at 20° mesial and distal angulation. Access cavity preparation was done, and apical patency of mesial canals was checked using #10 K file (Mani Inc., Japan) followed by which the canal was instrumented with #15 K file (Mani Inc., Japan) and working length determined. The contents of the canal were then removed using barbed broach (VDW GmbH, Munchen, Germany), and irrigation with 3% NaOCl (Vishal, Gujarat, India) was done.

Preparation of perforation site and estimation of actual length (manual method)

For the purpose of standardization, perforation of approximately 1.5 mm was made 4 mm from the furcation area in the mesial roots using a #12 round bur (Mani Inc., Japan) directed perpendicular to the long axis of the root. A #15 K file was introduced at the perforation site and visualized under stereomicroscope (Labomed, California, United States) at ×20, and working length was measured using stereomicroscope software. 0.5 mm was reduced from this length and was regarded as the actual length of the perforation site (ALP) [Figure 1a].

Electronic measurement of perforation site

The perforated roots were embedded till the cervical region according to the model developed by Kaufman and Katz[9] in plastic molds that contained freshly mixed alginate [Figure 1b]. Apex locators were then used in dry conditions and in the presence of 3% NaOCl and 2% chlorhexidine (CHX) (Amdent, Manali, India) to electronically measure the perforation site. A #15 K file was held with the file holder of iPex apex

locator (NSK, Japan) and introduced to the perforation site in the dry mesiobuccal canal with the lip clip placed in contact with the alginate till a long beep sound with 0.0 reading was obtained. The electronic length of the perforation site (ELP) was recorded after adjusting the rubber stopper and reducing 0.5 mm from the measured length. With Vdw gold (GmbH, Munchen, Germany) #15 K file was introduced into the perforation site in mesiobuccal root of dry canal till the red light with loud beep sound was obtained, rubber stopper was adjusted and 0.5 mm reduced from the measured length and recorded. To confirm if the file has reached the perforation site, radiographic images were taken in dry canals with both the apex locators used, respectively. This procedure was then repeated by introducing different irrigants into the root canal, and the perforation site was recorded for both the apex locators. Confirmatory radiographic images were taken for both the apex locators in the presence of 2% CHX and 3% NaOCl [Figure 1c]. Saline was used as an intermediate irrigant between the usage of 2% CHX and 3% NaOCl and between the usage of every irrigant, the canals were dried with paper points. An error of ±1 mm was allowed for measuring the perforation site using the two different EALs in different canal conditions. Two blinded evaluators evaluated the readings of the apex locators in dry condition as well as in the presence of the irrigating solutions.

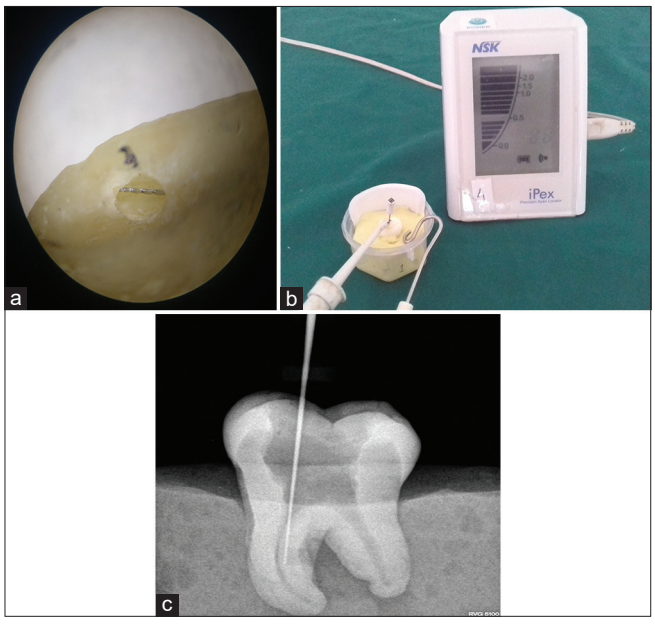

Figure 1: (a) Measurement of perforation site under stereomicroscope (×20). (b) Tooth embedded in the alginate apparatus. (c) Measuring the electronic length of perforation site by radiovisiography.

The mean of ALP and ELP was calculated, and comparison was done using the Wilcoxon signed-rank test with level of significance set at $P \leq 0.05$. A software version of SPSS 14.1 (IBM, New York, United states) was used for statistical evaluation of the data obtained.

RESULTS

The mean difference between the ALP and ELP of the perforation [Figure 2] with the standard deviation for both the EALs in dry and wet conditions is shown in Table 1.

There were significant differences in the reading of ALP and ELP in different canal conditions between the iPex group and Vdw group. In dry condition, iPex showed a significant difference ($P = 0.002$) of 0.76 mm between the ALP and ELP, whereas Vdw gold showed most accurate values with a difference of 0.25 mm between ALP and ELP ($P = 0.299$). Therefore, in dry condition, Vdw gold proved to be better than iPex. In the presence of 3% NaOCl, iPex showed a significant difference of 0.70 mm between ALP and ELP ($P = 0.008$) and Vdw gold showed a significant difference of 0.74 mm between ALP and ELP ($P = 0.000$). Both the apex locators showed a significant difference from the manual method and therefore less accuracy in determining the perforation site. For iPex in the presence of 2% CHX, there was a difference of 0.13 mm between ALP and ELP ($P = 0.475$), whereas with Vdw gold in the presence of 2% CHX, a difference of 0.39 mm was seen between ALP and ELP ($P = 0.054$). With

Table 1: The mean difference between the actual length and electronic length of perforation site along with the standard deviation for both the apex locators in different canal conditions

Condition	Mean±SD (mm)	*P**
Manual		
Stereomicroscope	13.51±0.70	
iPex		
Dry	12.75±1.07	0.002 (S)
3% NaOCl	12.81±1.39	0.008 (S)
2% CHX	13.38±1.08	0.475 (NS)
Vdw gold		
Dry	13.26±0.90	0.299 (NS)
3% NaOCl	12.77±0.80	0.000 (S)
2% CHX	13.12±0.91	0.054 (NS)

**P* value based on Wilcoxon signed-rank test for comparing each group with manual value. NS: No significant difference from manual; S: Significant difference from manual; NaOCl: Sodium hypochlorite; CHX: Chlorhexidine; SD: Standard deviation

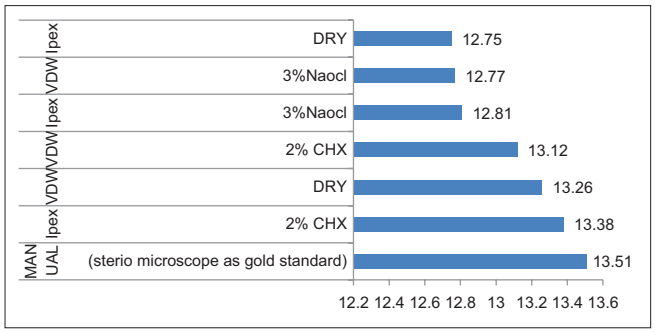

Figure 2: Bar graph showing the mean value of actual length of perforation site to electronic length of perforation site of two apex locators in the presence of two irrigating solutions.

2% CHX, both the apex locators showed near accurate results to the manual method with iPex showing better accuracy than Vdw gold.

DISCUSSION

Root perforations are one of the most common causes of posttreatment endodontic diseases. Perforations located in the buccal and lingual aspect of root are difficult to locate even with the help of angulated radiographs.[3] EALs have proved to be accurate in determining the location of apical constriction, horizontal root fractures, and apical root resorptions.[3] Previous *in vitro* studies proved the efficacy of apex locators as an aid in locating the root perforation under different *in vitro* conditions.[3,10] In the present study, the reliability of iPex and Vdw gold was compared with the manual method in locating root canal perforations with different irrigants and in dry condition in curved canals.

Canal curvature of mesial roots of mandibular first molars was standardized to 10°–20° according to Schneiders method.[8] The perforation was done in the distal side of mesial root as it is regarded as the danger zone of the teeth[11,12] because dentin in this region is thin, posing a greater threat of perforation.[13,14] For the purpose of standardization, these perforations were done 4 mm below the furcation area in the danger zone.

These teeth with artificially made perforation were kept in alginate models prepared as per Kauffman's method which have been used in several studies.[3,9] There are several other medias available that can be used as an electroconductive medium such as agar, gelatin, saline, and sponge. However, in this study, alginate was used as it is a good electroconductive medium that stays around the tooth due to its colloidal gel form and simulates the periodontal condition. In addition to this, it can be easily manipulated and is cost-effective.[15]

Vdw gold was used in the present study as it is an endomotor with an attached apex locator that makes the measurement of the working length quicker and easier when compared to the two types of equipment being used separately. It was compared with iPex as both works on the same principle but at different frequencies[6,16] and iPex is a readily available cost-effective apex locator.

In the previous studies, perforations measuring 0.25–0.40, 0.55–0.6, and 1 mm have been made.[4,10] In our study, perforation of approximately 1.5 mm was done with the help of a round bur. Such large perforations can practically occur iatrogenically while searching for a calcified canal, while using large files or coronal shapers, during postplacement or naturally in cases of resorption.[7] To assess if the K file has reached the perforation site, intraoral periapical radiograph along with radiovisiographic images was taken using paralleling angle technique which helps in measuring the root length accurately.[17]

A study done by Koçak *et al.* for measuring the working length using Vdw gold apex locator in dry condition showed accurate results and 83.5% of acceptable quality of root canal filling.[18] In the presence of NaOCl, Shabahang *et al.* evaluated the accuracy of EALs in detecting root perforations and concluded that largest deviation from ALP was reported with NaOCl.[19] As might be expected, electrical conductivity of solutions such as NaOCl and CHX depends on its concentration of dissolved ions. According to Shin *et al.*, electrical conductivity of tap water is 100–1000 μS/cm and 1% NaOCl is 1,72,420 μS/cm, and such differences in the electrical conductivity among different irrigating solutions are said to affect the determination of the working length.[20]

iPex showed a deviation of 0.76 mm from ALP in dry condition ($P < 0.05$), and in the presence of 3% NaOCl, it has shown 0.70 mm from ALP. Most accurate results were obtained by iPex in the presence of 2% CHX, that is, 0.13 mm from ALP. In the previous studies, the influence of CHX liquid on accuracy of EAL was tested which was found to be similar to that of NaOCl.[21] However, according to Shin *et al.*, electrical conductivity of CHX was much lower than other liquid type of irrigants.[20] This can

be presumed to be the main contributing factor in our study.

In the previous studies, acceptable range of ± 0.5–± 1 mm error while measuring the working length with EAL has been considered as accurate.[20,22] A range of ±1 mm was considered acceptable in the current study due to the possibility of various errors such as measuring the tip of the file to the external surface of the perforation with the naked eye. Even under the stereomicroscope, it was difficult to visualize the coronal site of the perforation.

In the presence of 3% NaOCl, both the apex locators showed greater deviation from the ALP, whereas in the presence of 2% CHX, both the apex locators showed very less deviation from the actual length of the perforation site. In dry condition, iPex showed a significant deviation from the ALP. However, the results of the present study differ from the previous *in vitro* study which proved that irrigants had no impact in determining the root perforations.[23] This may be attributed to the principles on which these devices work, methodology applied, and the manner in which these apex locators act in the presence of different irrigating solutions.

Comparing both the apex locators in the presence of 3% NaOCl and 2% CHX, 3% NaOCl showed very strong evidence against null hypotheses ($P < 0.05$), and with 2% CHX, both the apex locators showed a strong evidence against the null hypotheses ($P = 0.054$–0.475). In dry condition, iPex showed very strong evidence against the null hypotheses ($P = 0.02$), whereas Vdw gold showed strong evidence against the null hypotheses ($P = 0.299$).

Extrapolating these results to clinical practice, it may be inferred that retaining these irrigating solutions at the perforation site is a challenge, and the material used to mimic the periodontal ligament (PDL) may not provide the same resistance as natural PDL. Therefore, more *in vivo* studies should be conducted to correlate these results to different clinical conditions.

CONCLUSION

Within the limitation of this *in vitro* study, it can be concluded that in dry condition, Vdw gold can accurately locate the perforation site. iPex is better than Vdw gold in wet condition in the presence of 2% CHX, whereas both the EALs in the presence of 3% NaOCl have shown a deviation from ALP in locating the perforation site.

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Conflicts of interest
The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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