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Ex-vivo Evaluation of the Accuracy of Three Different Apex Locators in the Presence of Sodium Hypochlorite in Root Canals

Kök Kanallarında Sodyum Hipoklorit Varlığında 3 Farklı Apex Bulucunun Doğruluğunun Ex-vivo Olarak Değerlendirilmesi

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ABSTRACT

Objective: To evaluate the precision of three endodontic apex locators-Propex Pixi, Woodpex III, and VDW Gold Reciproc-in vitro and under clinical conditions.

Materials and Methods: Thirty-six single-rooted teeth were decoranated, and actual root canal lengths were measured and recorded with an operating microscope at x20 magnification. The teeth were then embedded in an ex -vivo model, and the measurement of the root canal length was obtained electronically. Each measurement was performed in triplicate, and the mean value was recorded. Data were analyzed statistically. Two paired sample t-tests were used for normally distributed data, and the Wilcoxon test was used for data that did not show normal distribution. A chi-squared test was used to compare categorical variables according to the experimental groups.

Results: Woodpex III showed significantly more accurate results than the other apex locators. Propex Pixi and VDW Gold Reciproc apex locators showed no significant difference.

Conclusions: Under the circumstances of the present study, Woodpex III allowed for more accurate measurements compared with the other tested devices.

Keywords: Apex locators, electronic root canal length determination, root canal treatment

ÖZ

Amaç: Propex Pixi, Woodpex III, ve VDW Gold Reciproc apex bulucu cihazların doğruluğunun klinik koşulları yansıtacak şekilde in-vitro olarak kıyaslanması.

Materyal ve Metot: Otuz altı adet tek köklü diş dekorone edildi ve gerçek kanal boyları 20X büyütme altında operasyon mikroskobu ile belirlenerek kaydedildi. Ardından dişler kanal boylarının elektronik olarak ölçülebilmesi için ex-vivo modele gömüldü. Her ölçüm üçer defa tekrarlandı ve ortalama değerler kaydedildi. Veriler istatistiksel olarak analiz edildi. Normal dağılıma uygun verilerin incelenmesinde ikili paired sample t test ile, uygun olmayan veriler ise Wilcoxon testi ile değerlendirildi. Gruplar arasındaki kategorik değişimlerin incelenmesinde ki-kare testi kullanıldı.

Bulgular: Woodpex III Propex Pixi ve VDW Gold Reciproc cihazlarından istatistiksel olarak anlamlı düzeyde doğru sonuçlar verdi.

Sonuç: Mevcut çalışmanın limitasyonları dahilinde Woodpex III apex bulucu diğer cihazlardan daha tutarlı sonuçlar vermiştir.

Anahtar Kelimeler: Apex bulucular, elektronik kök kanal boyu tespiti, kök kanal tedavisi

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INTRODUCTION

Accurately determining the working length during root canal therapy is one of the most crucial determinants of successful endodontic therapy.[1] Successfully determining the working length prevents procedural errors, such as over-instrumentation and insufficient instrumentation, and reduces the bacterial load of the root canals.[2,3] Root canal therapy might not succeed if the working length is determined incorrectly due to foreign body reactions, tissue destruction, and persistent inflammation.[4-6] Optimal results have been reported when the apical end of the root canal treatment is located at the apical construction.[7,8] In the past, working length was frequently determined using periapical radiography,[9] however, measuring root canal length with periapical X-rays has many drawbacks.[10] These shortcomings include image distortion, superposition of the anatomical structures,[10] and most crucially, the physiological and the radiological apex do not always relate to the same point and might even be at different locations.[11] Furthermore, the patient is exposed to additional radiation.[12]

Apex locators (ALs) are electronic devices used to measure root canal length, surpassing the limitations of radiography and other methods. ALs were first developed by Custer in 1918[13] and since then, their working mechanisms have been improved. The first generation of ALs utilized resistance technique and alternate current, while the second generation relied on single frequency impedance. The third-generation devices used multiple frequencies, as did the fourth-generation. Fifth-generation devices measure electrical differences in the root canal system. The latest sixth-generation devices combine the features of the fourth and fifth-generation devices.[13,14]

This study aims to compare the accuracy of two fifth -generation apex locators (Propex Pixi, Woodpex III) and a fourth-generation apex locator (VDW Gold Reciproc endodontic motor apex locator) in the presence of sodium hypochlorite in the root canals.

MATERIALS AND METHODS

Ethical Statement: The study protocol was evaluated and approved by the Invasive Research Ethics Committee at Sakarya University (Date: 09.08.2023, decision no: E-16214662-050.01.04-276216-95). The study was carried out following the principles of the Declaration of Helsinki.

Sample Size Calculation: An initial power analysis was conducted at a 95% confidence level. The minimum sample size for each group was determined to be 12, resulting in a total sample size of 36 for three groups.

Study Design: For the study, 36 single-rooted human teeth with straight root canals were used. These teeth were stored in 1% thymol solution until use. Any remaining soft tissue and calculus were removed using an ultrasonic scaler.[15] To ensure the presence of a single root canal, digital periapical radiographs were taken from the buccolingual and mesiodistal inclinations. The root surfaces were examined under an operating microscope (Zumax OMS2350, Zumax Medical Co. Ltd, Jiangsu, China) at x20 magnification. A standard reference point was created by decorating the teeth under the cementoenamel junction and preparing the root canal orifices with an SX rotary file (ProTaper, Dentsply Maillefer, Ballaigues, Switzerland).

Teeth were placed in acrylic, exposing the root at least 5 mm. Then, the samples were kept in position until the acrylic solidified. Apical patency was checked with a size 10 K file (Micro Mega, Beascon, France). During working length measurements, two stoppers were employed to prevent stopper movement. The file was advanced through the root canal until it was visible at the apical foramen under an operating microscope at x20 magnification. After removing the file, the distance between the tip and stopper was measured using a digital calliper. Each measurement was made three times, and the mean was used to determine the actual root canal length (ARCL), which was then recorded.

The apical portions of the roots were embedded in alginate for electronic measurements, and a labial clip was inserted into the alginate (Figure 1). All electronic measurements were completed within 2 hours. Three different apex locators—Woodpex III, Propex Pixi, and VDW Gold Reciproc Endomotor—were used for the electronic measurements. All measurements were taken under the operating microscope at x20 magnification, before which the root canals were irrigated with 2.5% NaOCl to mimic clinical conditions. Then, the distance between the file tip and the coronal reference point was measured using a digital calliper. Electronic measurements were recorded as electronic root canal length (ERCL). All measurements were recorded in triplicate, and the median values were collected for statistical analysis in a manner identical to the ARCL measurement methods.

Statistical Analysis: The statistical analysis was conducted using SPSS software (version 23; IBM Corp, Armonk, NY). The normal data distribution was assessed using the Shapiro–Wilk test. When the data was found to be non-normally distributed, the Kruskal–Wallis test was used to compare it. When the data was normally distributed, one-way variance analysis was used to compare it. To compare manual and electronic measurements within the groups, two paired-sample t-tests were used for normally distributed data and the Wilcoxon test was used for non-

Figure 1. Stages of the setup. **a:** Setup of the samples before alginate placement; **b:** Setup of the samples after alginate placement.

normally distributed data. The categorical variables were compared according to the groups using the chi -squared test. Statistical significance accepted $p<0.05$.

RESULTS

Double stoppers were used to prevent stopper movement when recording working length measurements. The file was advanced through the root canal until it was visible at the apical foramen under an operating microscope at x20 magnification. After removing the file, the distance between the tip and stopper was measured using a digital calliper. Each measurement was made three times, and the mean was used to determine the actual root canal length (ARCL), which was then recorded.

Table 1 shows the mean differences between ARCL and ERCL measurements. The data from the study demonstrated a significant difference between the Propex Pixi and VDW Gold Reciproc groups ($p<0.05$) regarding ARCL and ERCL measurements. However, the Woodpex III group showed statistically similar results to ARCL measurements ($p>0.05$). Moreover, in the Woodpex III group, 66.67% of the samples had a variation of less than 0.5 mm from the ARCL compared to 58.33% in the other groups. The difference in the remaining samples was more significant than 0.5 mm. Furthermore, all groups had statistically significant agreement between ARCL and ERCL measurements ($p<0.001$).

Table 1. Distribution of the actual and electronic working length measurements.

Specifications	Group						Test	p
	Propex Pixi		Woodpex III		VDW Gold Reciproc			
	Mean ± SD	Median (Min-Max)	Mean ± SD	Median (Min-Max)	Mean ± SD	Median (Min-Max)		
Actual root length (mm)	15.25±1.67	16.00 (12.00-17.50)	15.12±1.92	15.75 (12.00-18.00)	16.29±1.91	16.50 (13.00-20.00)	1.457[1]	0.248
Elektronik root length (mm)	14.93±1.62	15.92 (11.66-16.66)	14.87±2.00	15.33 (12.00-18.00)	15.92±2.17	16.00 (12.00-20.00)	2.117[2]	0.347
Difference (Actual-Electronic root length)	0.32±0.35	0.26 (0.00-1.00)	0.25±0.52	0.00 (-0.50-1.17)	0.38±0.44	0.26 (-0.16-1.00)	0.704[2]	0.703

[1]: Oneway variance analysis; [2]: Kruskall Wallis H test.

DISCUSSION AND CONCLUSION

Various studies have been conducted to test the accuracy of electronic apex locators. These studies involved methods such as immersion in agar solutions or gels,[16] embedding in alginate,[17] and contacting roots with a saline solution-soaked sponge.[18] In contrast to the study by Venturi et al.,[19] the present study used a setup where teeth were embedded in alginate instead of immersed in a NaOCl solution. This was done due to concerns about intracanal and extracanal sodium hypochlorite contact and its possible effect on the measurements. Similar studies have used alginate models to determine the accuracy of electronic apex locators.[20,21] This is because it is a simple, accurate, easily reproducible, and affordable method.[9,16,17]

Previous studies have used the same teeth to compare two different apex locators.[16-18] In the present study, to avoid disrupting the major apical foramen by repeated measurements, different teeth were used for each apex locator, while the same protocol was used from previously published studies.[19,20]

The current study conducted electronic root length measurements while sodium hypochlorite solution was inside the root canal. This solution is most widely used as an irrigation solution,[21]. However, the accuracy of these measurements performed by ALs depends on several factors, including the instrument's size and the canal's diameter.[22] Furthermore, irrigants within the root canals can lead to incorrect measurements.[23] Thanks to recent advances in AL technology,[24] these devices can now be used with irrigation solutions in the root canal. It's important to note that using files in dry root canals is unacceptable in root canal treatment.

Cimpean et al.[25] applied different concentrations of NaOCl inside the canal before using three different ALs and found that NaOCl concentration affects readings of the devices. This study took the readings with 2.5% NaOCl to mimic clinical conditions. However, the effect of different NaOCl concentrations on the readings of ERCL was not examined, which means that the findings of this study cannot be compared to the previously published study.[25]

There is a considerable amount of research on using ALs in endodontics, with some studies focusing on the impact of irrigation solutions on ALs.[14,26] Studies have also focused on the effect of different canal conditions and file sizes on the working mechanism of the ALs.[27,28] In contrast, others have focused solely on the accuracy of different ALs.[16,17,19]

Previous studies that have compared the accuracy of ALs have found significant differences among the tested devices,[15,16] whereas others have found no difference.[19,20] In the present study, Woodpex III, Propex Pixi, and VDW Gold Endodontic Motor apex locators were used, and Woodpex III showed significantly better accuracy than the other tested devices. However, no studies have compared these results because, as far as we know, no previous accuracy tests have compared these three particular devices. The closest study in terms of devices that are used was by De Deus et al.,[15] where they compared Propex Pixi, Woodpex III, and Root ZX II apex locators, where it was reported that Woodpex III takes significantly more accurate measurements. This finding is compatible with the findings of the present study.

The goal of the current study was to replicate clinical conditions as much as possible. To achieve this, acrylic insulation was created such that the apical foramen and coronal access were disconnected, and teeth with similarly sized root canals were chosen. However, in clinical settings, variables such as pulp conditions, apical foramen diameter, and root canal width may alter the outcome. Because it is not feasible to replicate clinical conditions one-on-one, the current study has the limitation of being an in-vitro investigation.

In conclusion, it was found that Woodpex III provided more precise readings compared to Propex Pixi and VDW Gold Reciproc Endodontic Motor apex locator under the conditions of the present in-vitro study. However, it is recommended that further in-vivo and in-vitro studies be conducted that consider different clinical conditions under which measurements are taken to obtain more comprehensive and reliable results.

Ethics Committee Approval: Our study was approved by the Sakarya University Ethics Committee (Date: 09.08.2023, decision no: E-16214662-050.01.04-276216-95). The study was carried out following the principles of the Declaration of Helsinki.

Conflict of Interest: No conflict of interest was declared by the authors.

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