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Comparison of The Accuracy in Working Length of Electronic Foraminal Locators After Cervical Preflaring: An in Vitro Study

[1]Ana Gabriela Largacha Giler, Faculty of Dentistry, Universidad Hemisferios, Quito-Ecuador

[2]Soo Nam Jang Jaramillo, Faculty of Dentistry, Universidad Hemisferios, Quito-Ecuador

Corresponding Author: Ana Gabriela Largacha Giler, Faculty of Dentistry, Universidad Hemisferios, Quito-Ecuador.

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Abstract

To evaluate the influence of cervical preflaring on the accuracy of working length determination using electronic foraminal locators.

Forty single-rooted premolars classified as Vertucci type I were used to analyze the accuracy of three electronic foraminal locators (Root ZX Mini, Raypex 6, and Minipex). The actual working length was determined visually under a microscope, and the electronic measurements were performed in alginate. These measurements were recorded both before and after cervical preflaring. The preflaring was performed using an ORIFICE SHAPER (ONE FLARE) at 400 RPM and 3 N, with irrigation using 5.25% sodium hypochlorite. The purpose was to evaluate the effect of preflaring on the accuracy of electronic foraminal locators.

The results showed significant differences in working length measurements before and after cervical preflaring. The accuracy of Raypex 6 and Minipex was affected, but not that of the Root ZX mini. Raypex 6 and Minipex improved their precision after cervical preflaring. Root ZX mini was more accurate before preflaring, although Raypex 6 surpassed it afterward. The accuracy of electronic foraminal locators varies depending on the method used.

This research concludes that cervical preflaring affects the accuracy of the studied foraminal locators differently. Raypex 6 and Minipex improved their accuracy with cervical preflaring, while Root ZX mini consistently maintained its precision. These results suggest that the advantage of cervical preflaring depends on the locator used and is more beneficial for devices whose accuracy improves after its application.

Keywords: Apical locator, Cervical preflaring, Minipex, Raypex 6, Root ZX, Working length.

Introduction

One of the fundamental complications in endodontics is the accurate location and preservation of the ideal

working length of the root canal system, which promotes proper periapical healing by limiting the contact of the filling material with the periapical tissues when the treatment ends at the level of the apical constriction.[1]

The working length (WL) in endodontic terms is defined as: "the distance from a coronal reference point to the point at which canal preparation and obturation should terminate"[2]. The WL is essentially influenced by the apical anatomy, which includes structures such as the apical foramen (AF) and the apical constriction (AC) [3]. The AC is normally located between 0.5 mm and 1.0 mm below the apical foramen [4]. The WL has been effectively measured using electronic devices with the apical foramen as a reference; however, the AF is not always reachable, which limits the ability to establish the ideal working length. [5].

During the analysis and evaluation of the WL, numerous anatomical changes may occur, which can lead to debris extrusion or over instrumentation [6]. Investigating these anatomical variations is essential to minimize potential complications and enhance our treatments.

With technological advancements, in 1962 Sunada proposed a new system for determining the working length using an electronic apex locator. [7]. From that point on, several generations of foraminal locators were developed, allowing for more accurate measurement of the canal length. [8]. Thanks to these innovations, the approach used in endodontic treatment has been transformed, optimizing therapeutic effectiveness and the accuracy in determining clinical variables.

Electronic apical locators (EALs) provide greater accuracy by measuring the electrical resistance between the root canal and the surrounding tissues, making them safer and more reliable than conventional methods. [9]. EALs can be used as essential diagnostic tools to identify fractures, cracks, and resorptions of the root canal [10]. Several factors can affect electronic measurements, including the diameter of the apical constriction, the instrument gauge, cervical preflaring, and the irrigating solution used during the procedure [11].

Cervical preflaring of root canals aims to achieve a canal shape that is both adequate and safe. [12]. It offers many benefits throughout the disinfection and shaping procedures, such as facilitating the insertion of manual and rotary instruments into the apical portion of the root canals [13]

The objective of this study was to evaluate the influence of cervical preflaring on the accuracy of working length determination using electronic foraminal locators.

Materials and Methods

This is a comparative experimental In Vitro study in which 40 premolars were used. Only single-rooted teeth classified as Vertucci type 1 were included, with no pronounced curvatures, with canal patency, free of root caries, fractures, open apices, calcifications, or prior endodontic treatment.

Periapical radiographs were taken of the teeth along with clinical evaluations to confirm the absence of root resorption or root canal curvature.

Teeth that did not meet the established criteria were replaced. All teeth were stored in 0.9% saline solution until use to prevent dehydration.

Access cavities were prepared in each tooth using #1013 round diamond burs (JOTA AG, Rüthi, Switzerland) at high speed under copious water cooling. Remaining tissue and debris were removed using a stainless steel K-file size #15 (Dentsply-Maillefer, Ballaigues, Switzerland). The root canals were irrigated with 5.25% sodium hypochlorite (NaOCl) using a 30G side-vented Navitip® needle (Ultradent Products Inc., South Jordan, Utah, USA).

The samples were standardized to a root length of 16 mm. A size #15 K-file with a silicone stop was introduced into the root canal until its tip became visible at the apical foramen, using a surgical microscope with 10× magnification (Alliance Microscopia, São Paulo, Brazil). Once the tip of the file was observed at the apical foramen, the silicone stop was adjusted to the incisal edge of the tooth to establish a reference point. The file was then carefully removed, and the distance between the silicone stop and the tip of the file was measured using a millimetric endodontic ruler. This measurement was recorded as the total canal length, and 1 mm was subtracted to establish the working length.

To calculate the working length using the foraminal locators, the teeth were placed in a plastic container that contained freshly mixed alginate; two openings were made in the experimental container: one designed for the insertion of the tooth and another for connecting the lip clip of the EALs.

Prior to the electronic measurement, the root canals were irrigated with 5.25% sodium hypochlorite (NaOCl) and dried with paper points. Measurements were taken by inserting size #15 K-files until the screen of the locator displayed the signal (APEX or 0.0 mm), the rubber stop was adjusted to the reference level, and the K-file was carefully withdrawn. The length was then measured with a millimetric endodontic ruler (Dentsply-Maillefer), subtracting -1 mm. This technique was performed three times, alternating the order of use of the electronic foraminal locators, with the aim of electronically measuring the root canals using each of the three devices: Root ZX Mini (J. Morita, Japan), Raypex 6 (VDW, Germany), Minipex (Woodpecker, China).

Measurements of all root canals were taken before and after cervical preflaring. For this, the coronal and middle thirds of the root canals were prepared using an ORIFICE SHAPER (ONE FLARE), which was inserted 4 mm into the root canal, using the E-value motor at 400 RPM and 3N with a brushing motion, employing continuous rotation kinematics. Irrigation was carried out with 3 ml of 5.25% NaOCl after the use of each rotary instrument.

A. Statistical Analysis of the Accuracy of Foraminal Locators

To analyze and compare the accuracy of the foraminal locators Minipex, Raypex 6, and Root ZX Mini, with and without cervical preflaring, measures of central tendency and dispersion (median and interquartile range) were calculated for the working length measurements determined by each locator, both before and after the procedure.

Since the length variables did not show a normal distribution ($p < 0.05$ in the Shapiro-Wilk test for all conditions), the Wilcoxon signed-rank test was applied to compare the pre- and post-preflaring measurements for each device. The non-parametric test detected statistically significant differences in the measurements of the foraminal locators after cervical preflaring.

To analyze the data and assess whether cervical preflaring affects the accuracy of working length determination, accuracy was evaluated by calculating the absolute error. The deviation of each locator from the real value obtained via microscopy was measured before and after preflaring, and these errors were expressed as mean and standard deviation.

The paired Wilcoxon test was used to analyze the variations in absolute errors before and after cervical preflaring. This test allowed for determining whether the differences were statistically significant and whether preflaring significantly affected the precision of each locator.

To establish which of the three locators was the most accurate, the mean absolute errors were compared between devices under both pre- and post-preflaring conditions. A smaller error indicates higher accuracy, so this comparison allowed for identifying which locator was closest to the actual value in each condition.

Results

Significant differences were observed after cervical preflaring in Minipex and Raypex 6, whereas Root ZX Mini did not show a significant change (Figure 1, Table 1). These results indicate that preflaring has a variable influence on working length, depending on the locator used.

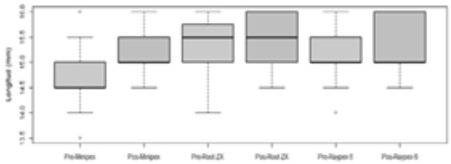

Figure 1: Comparison of working lengths before and after cervical preflaring.

Table 1: Medians, interquartile ranges (IQR), and *p* values (Wilcoxon signed-rank test) of the estimated working lengths pre- and post-cervical preflaring

Device	Median Pre (IQR)	Median Post (IQR)	*p*-value
Minipex	14.5 [14.5–15.0]	15.0 [15.0–15.5]	0.00025
Root ZX mini	15.5 [15.0–15.62]	15.5 [15.0–16.0]	0.286
Raypex 6	15.0 [15.0–15.5]	15.0 [15.0–16.0]	0.0110

The analysis of absolute error, calculated as the difference between the microscopic reference and the measurements from the locators, showed the following (Table II):

Table 2: Mean absolute error (± standard deviation) between each locator and the reference measurement, before and after cervical preflaring, along with their respective *p* values.

Device	Pre Error (mean ± SD)	Post Error (mean ± SD)	p-value (Wilcoxon)
Minipex	0.812 ± 0.387 mm	0.350 ± 0.343 mm	0.00001
Root ZX mini	0.355 ± 0.368 mm	0.367 ± 0.332 mm	0.0049
Raypex 6	0.428 ± 0.389 mm	0.260 ± 0.312 mm	0.00001

This table shows the accuracy of the locators (Minipex, Root ZX, and Raypex 6) in estimating the working length compared to the microscopic reference. The mean error before and after cervical preflaring is reported. The smaller the error, the more accurate the measurement.

Minipex showed a notable improvement in accuracy after preflaring, reducing its average error from 0.812 mm to 0.350 mm.

Root ZX was the most accurate from the start at 0.355 mm, and although its error slightly increased after preflaring to 0.367 mm, the difference is not significant.

Raypex 6 reduced its initial error of 0.428 mm to 0.260 mm after preflaring, improving its accuracy.

Before preflaring, Root ZX Mini showed the lowest error, followed by Raypex 6 and Minipex. After the procedure, Minipex and Raypex 6 improved their accuracy, with Raypex 6 becoming the most accurate, followed by Minipex and Root ZX Mini, demonstrating that the performance of the locators varies depending on the measurement condition.

Discussion

Accurately establishing the working length is a fundamental aspect of endodontics. Relying solely on a

prior radiograph to perform root canal obturation increases the risk of unfavorable treatment outcomes. Histological studies have revealed that overfilling can lead to a prolonged inflammatory state[14]

How it is evaluated in other studies that use alginate to assess the accuracy of foraminal locators [15]. In some studies, the results with the use of alginate were beneficial; it is indicated that this medium not only has good electroconductive properties but also, thanks to its colloidal consistency, can adequately simulate the periodontal ligament. [16].

There are other ways to determine the working length, aiming to simulate the oral cavity, where teeth were placed in a conductive gel medium (Carbopol Gel, 0.9% NaCl, and 2% KCl – Farmacia FarmaVie, Fortaleza, Brazil).[17]. Another study with a comparable methodology involved placing the tooth in a plastic device containing 0.9% saline solution to perform the working length measurement. The lip clip was kept in direct contact with the saline solution, while the other clip was connected to the file. [18]

Accurately establishing the working length (WL) is essential in endodontic therapy, as it must correspond to the location of the apical constriction, which is considered the ideal point for instrumentation. Operating within this anatomical limit minimizes the risk of over-instrumentation and facilitates the regeneration of periapical tissues. [19].

Several studies have reported that, when determining the location of the apical constriction, electronic measurements are considered reliable when they fall within a margin of ±0.5 mm. [20], or even up to 1 mm away, which is often considered to be more accurate. [21]. Microscopic studies have observed that the apical constriction can vary within this range [4]. From this perspective, the Root ZX has been established as the gold standard against which other foraminal locators are evaluated, achieving an accuracy of 97.5% at 1 mm from the foramen. This is largely consistent with the findings of previous studies that support its high level of accuracy [22].

Electronic foraminal locators have gained considerable importance in current clinical practice due to their effectiveness, reliability, and speed in determining working length. The locator proves to be a valuable tool, even in cases where radiographic interpretation may be significantly limited [23].

In the present In Vitro Study, the effect of cervical preflaring on the accuracy of three foraminal devices Minipex, Raypex 6, and Root ZX Mini, was evaluated. The results demonstrated that cervical preflaring has a differential impact depending on the device used. Minipex and Raypex 6 showed a significant improvement in accuracy after cervical preflaring, whereas Root ZX Mini did not exhibit significant changes, maintaining consistent accuracy throughout the procedure. This difference suggests that the effect of preflaring may depend on the design of each device.

Recent studies are consistent with these findings, showing that cervical preflaring enhances the accuracy of foraminal locators by facilitating a more direct and stable access to the apical region, which enables more precise working length determinations. [24].

In fact, it has been observed that cervical preparation allows files to reach the apical region more easily, reducing the risk of exceeding the foramen. [25];[26]. Some authors suggest that such procedures could structurally damage the teeth, indicating that cervical preflaring should be performed with caution or even avoided altogether [27].

The Raypex 6 achieved the best results after preflaring, with a consistent accuracy of 97.5% in the current study,

where this foraminal locator showed an increase in accuracy for determining the working length after preflaring.[28]. This locator, thanks to its stable reading algorithm that quickly adapts to the canal conditions, whether dry or wet, including the presence of blood or exudate, has proven to be optimal in various clinical contexts.[10]. It is worth mentioning that this foraminal locator has advantages; it showed significant accuracy in teeth with root resorption [29].

There are studies that have shown that the Raypex 6 can identify the apical foramen with an accuracy of 88.22% within a range of ± 0.5 mm and achieves 100% accuracy within ± 1 mm in the cases analyzed [30].

Studies evaluating the working length accuracy of different latest-generation locators using CBCT and classic radiographic techniques (Propex IQ, Raypex 6, Root ZX, and Apex ID) determined that Propex IQ was the most accurate. Although the other locators did not show significant variations, their values were lower than those recorded with Propex IQ [31].

On the other hand, the Root ZX mini, a fifth-generation device, has provided evidence supporting its effectiveness in various anatomical and clinical scenarios. Its multifrequency impedance technology, which individually assesses resistance and capacitance, ensures stable and consistent measurements even in situations involving curvatures, perforations, or different irrigants [32] [33].

The literature also shows that when coronal preflaring was performed, the accuracy of the Root ZX device improved. [34]. In this study, its performance was consistent both in preflared and non-preflared canals. This can be attributed to its high sensitivity in detecting impedance changes without requiring a wider access in the cervical third. Furthermore, it was noted as the most accurate, minimizing the likelihood of instrumentation or obturation beyond the apical foramen [35]

However, other studies did not identify the Root ZX mini as the most accurate, which highlights how differences in experimental models, tooth types, the use of irrigants, and insertion technique can influence the results [36]. This highlights the importance of standardizing methodological variables when evaluating the performance of electronic locators. Likewise, other studies suggest that this device provides inconsistent and erroneous measurements under conditions of limited conductivity [37].

Regarding the Minipex, a third-generation device that operates on the principle of comparative impedance, its results showed improved performance after preflaring. This could be attributed to the device's high sensitivity, highlighting the importance of ensuring proper coronal access to enhance its accuracy in determining the working length [33].

Conclusions

The results revealed that the effect of cervical preflaring varied depending on the locator evaluated. Raypex 6 and Minipex demonstrated statistically significant differences in working length measurements before and after preflaring, indicating an improvement in accuracy following the procedure. Root ZX Mini showed no significant difference in the determined length and exhibited minimal change without improving accuracy.

Without cervical preflaring, Root ZX Mini was the most accurate locator, but after the procedure, Raypex 6 became the most precise. These results indicate that the influence of cervical preflaring on accuracy varies according to the type of locator used.

Among the limitations of this study, future research is suggested to further clarify and strengthen the scientific evidence.

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