



FACULTAD DE CIENCIAS DE LA SALUD
CARRERA PROFESIONAL DE ESTOMATOLOGÍA

**“COMPARACIÓN DE LA EXACTITUD DE CUATRO
LOCALIZADORES APICALES EN PREMOLARES
UNIRRADICULARES CON SIMULACIÓN DE REABSORCIÓN
APICAL EXTERNA Y REABSORCIÓN DENTINARIA INTERNA”**

Tesis para optar el grado académico de:
MAESTRO EN ESTOMATOLOGÍA

Presentado por:
Astrid Vanessa López Maekawa (0000-0002-2126-9127)

Asesor/a:
Carmen Rosa García Rupaya (0000-0003-0657-6011)

Lima – Perú
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4. Copia de Acta de Sustentación



ACTA DE SUSTENTACIÓN DE TESIS

Lima, 17 de marzo de 2022.

Los integrantes del Jurado de tesis:

Presidente: Mg. Esp. Miguel Angel Cabrera Iberico	<input type="checkbox"/>
Miembro: Mg. Esp. Lourdes Rocio Ayarza Florez	<input type="checkbox"/>
Miembro: Mg. Esp. Ronald Gonzales Gonzáles	<input type="checkbox"/>

Se reúnen para evaluar la tesis titulada:

“COMPARACIÓN DE LA EXACTITUD DE CUATRO LOCALIZADORES APICALES EN PREMOLARES UNIRRADICULARES CON SIMULACIÓN DE REABSORCIÓN APICAL EXTERNA Y REABSORCIÓN DENTINARIA INTERNA”

Presentada por el estudiante/bachiller:

Astrid Vanessa López Maekawa

Para optar el Grado Académico de Maestro en Estomatología.

Asesorada por: Mg.Esp. Carmen Rosa García Rupaya

Luego de haber evaluado el informe final de tesis y evaluado el desempeño del estudiante de la Carrera de Estomatología en la sustentación, se concluyen de:

Manera unánime (x)

Por mayoría ()

Calificar a:

Tesis: Astrid Vanessa López Maekawa			Nota (en letras): DIECIOCHO	
Aprobado ()	Aprobado - Muy buena (X)	Aprobado - Sobresaliente ()	Desaprobado ()	

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5. Dedicatoria:

La presente tesis se la dedico a mis padres y hermanos por su apoyo constante a mi educación.

Sobretudo se lo dedico a Dios, "Todo lo puedo en Cristo que me fortalece".

Filipenses 4:13

6. Agradecimientos:

Mis agradecimientos a los Doctores Mg. Esp. Ronald Gonzales, Dr. Esp. Jorge Alamo, C.d. Esp. Bruno Lujan, C.d. Denis Maetahara y C.d. Edwin Espinoza por su gran apoyo en la realización del presente trabajo.

7. Resumen:

Introducción: El objetivo del presente estudio in vitro fue el de comparar la exactitud de las mediciones de la longitud de trabajo de cuatro localizadores de foramen: Root ZX Mini, Raypex 6, Woodpex III y Propex Pixi en premolares unirradiculares con reabsorción radicular simuladas. **Materiales y métodos:** Para este estudio se utilizó 30 premolares permanentes unirradiculares. Las muestras se dividieron en dos grupos: 15 piezas dentarias con reabsorción dentinaria interna y 15 piezas dentarias con reabsorción externa simuladas. Las piezas dentarias fueron posicionadas en envases con alginato, cubriendo únicamente la porción radicular. Se realizaron las mediciones con los cuatro localizadores; y los resultados fueron comparados con las medidas de la longitud de trabajo obtenidas previamente con la técnica visual directa y el uso de un Microscópio usb digital 5x, aplicando para estas la prueba de Shapiro-Wilk. Las pruebas de Anova y T de Student para muestras relacionadas fueron ejecutadas para el análisis de las medidas obtenidas. **Resultados:** En las piezas dentarias con reabsorción apical externa no hubo diferencias estadísticamente significativas en las mediciones obtenidas con los localizadores Raypex 6 y Propex pixi, pero si hubo diferencias estadísticamente significativas con los localizadores de foramen Root zx mini ($p=0.04$) y Woodpex III ($p=0.00$). Por otro lado, en la muestra con reabsorción radicular interna no hubo diferencias estadísticamente significativas en las mediciones con los localizadores de foramen Propex pixi, Root zx mini y Raypex 6. Sin embargo, si hubo diferencias significativas con el Woodpex III. **Conclusiones:** Basado en este estudio in vitro, el localizador de foramen Raypex 6 fue el de mayor exactitud en premolares unirradiculares con reabsorción apical externa simulada y el Root zx mini fue el localizador más exacto en premolares con reabsorción dentinaria interna simulada. Adicionalmente, la reabsorción

radicular externa afectaría más la exactitud de los localizadores de foramen que la reabsorción dentinaria interna.

Palabras clave: Foramen apical, localizador apical, reabsorción radicular

8. Abstract:

Introduction: The aim of the present in vitro study was to compare the accuracy of the working length measurements of four foramen locators: Root ZX Mini, Raypex 6, Woodpex III and Propex Pixi in uniradicular premolars with simulated root resorption. **Materials and methods:** For this study, 30 single-rooted permanent premolars were selected. The samples were divided into two groups: 15 teeth with simulated external root resorption and 15 teeth with internal resorption. Each sample was immersed in containers with alginate covering only the root part. Measurements were acquired from the four foramen locators and compared with the working length measurements that been previously obtained with the direct visual technique and the use of a Digital Usb Microscope 5x. Next, the Shapiro-Wilk normality test was applied. The ANOVA test and T- Test for related samples were performed, in order to analyze the measurements obtained. **Results:** In the teeth with external resorption, no statistically significant differences in the measurements were obtained with Raypex 6 and Propex pixi foramen locators, but there were statistically significant differences with Root zx mini ($p=0.04$) and Woodpex III ($p=0.00$). On the other hand, in the samples with internal root resorption, there were no statistically significant differences in measurements with the Root Zx mini, Propex Pixi and Raypex 6 foramen locators. However, there were significant differences with Woodpex III. **Conclusions:** Based on this in vitro study, Raypex 6 had the highest accuracy in premolars with simulated external resorption and Root zx mini was the most accurate in teeth with simulated internal resorption. Furthermore, external root resorption affects the accuracy of foramen locators more than internal resorption.

Keywords: Apical foramen, Electronic Apex Locator; Root resorption

9. Versión aprobada para publicar:

ACCURACY OF FOUR APEX LOCATORS IN PREMOLARS WITH ROOT REBSORPTION: AN IN VITRO STUDY

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Abstract:

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Keywords: Apical foramen, Electronic Apex Locator; Root resorption

INTRODUCTION

The determination of the working length is one of the most important factors that contribute to the success of endodontic treatment¹. Thus, determining a correct working length (WL) constitutes an essential step to avoid over-instrumentation, which allows the passage of irritating substances beyond the apical foramen².

In addition, it also avoids underinstrumentation that prevents total sealing of the root canal up to the apical constriction^{1,2}.

The determination of the working length carried out with the radiographic technique presents many limitations, such as: the difficulty in interpretation because it is a two-dimensional image³; and technical errors in angulation and developing made by the operator⁴. This traditional method makes it impossible to accurately determine the position of the apical constriction and the apical foramen⁵.

Currently, Foramen locators are one of the most reliable tools to obtain a more accurate measurement of the working length¹. These instruments reduce the number of required radiographies and minimize the subjectivity involved in radiographic interpretation⁶. In addition, the use of these devices has become widespread today, proving to be indispensable in endodontic practice due to their high levels of accuracy 97.4%⁷; even under conditions in which it would have previously been unthinkable to achieve an accurate measurement, such as in the presence of blood, hypochlorite, or pus⁷.

However, despite its accuracy in locating the apical foramen; there are several anatomical variations such as c-shaped canals, dens invagination, root dilaceration, etc.^{8,9} which

may affect the measurement obtained with the foramen locator. Among these pathologies, we find root resorption.

Root resorption is a loss of hard dental tissues as a result of clastic activity^{10,11}. Root resorption can be broadly classified into external and internal resorption by the location of the resorption in relation to the root surface^{10,11}.

Also, external Root resorption is an irreversible pathological process¹² which can occur in situations as a dental trauma, apical infection, internal bleaching, periodontal treatment, ectopically erupting and most commonly in the presence of orthodontic movements¹³.

In addition, another pathology of endodontic interest is internal root resorption, that was reported as early as 1830^{11,14}. Internal resorption is usually caused by chronic infections, trauma, or inflammatory reactions of the pulp cells. Plus, internal resorption is usually asymptomatic, and is detected on routine radiographic examinations^{10,14}. Compared with root external resorption, it has a rare occurrence, and its etiology and pathogenesis have not been completely elucidated¹¹.

Furthermore, there is little information of the impact in the accuracy of foramen locators in permanent teeth with external root resorption¹⁵. Moreover, there are currently no studies on internal resorption.

As previously explained, it is important to study foramen locators in these types of pathology, as these may alter the working length in our clinical practice.

For this reason, the purpose of the present study is to compare the accuracy of the working length measurements of four foramen locators in single-rooted premolars with simulation of external and internal resorption.

Materials and methods:

The present study was approved by the Ethics Committee of Universidad Científica del Sur Lima, Perú with Evidence N °193-CIEI-SCIENTIFIC-2020. A sample size was determined from the results of the pilot test, after which it was considered to use 30 freshly extracted teeth. Moreover, these had indication for tooth extraction for orthodontic, periodontal or pulp disease reasons and were donated for this study. Plus, periapicals radiographs were taken in buccolingual and mesiodistal directions in each tooth to verify the presence of a single root.

Afterwards, they were subjected to dental calculus removal using an ultrasonic device (UDS-J Woodpecker- China). Then, they were disinfected in 5.25% sodium hypochlorite for 2 hours to remove traces of organic tissue from the outer surface of the root. Finally, they were stored in a sterile 0.9% saline solution until evaluation¹⁵.

The sample were divided into two groups: 15 teeth with external resorption and 15 with simulated internal resorption (n=15). Standard endodontic access was performed with a high speed medium round and fissure diamond burs (Micro Diamonds Technology, Israel) with water cooling.

After endodontic access, the cusps edges of the teeth were flattened with a medium round diamond bur (Micro Diamonds Technology, Israel) by approximately one millimeter, to facilitate measurements by means of a stable reference point⁵.

Next, the coronal portion of each canal was flared⁵ using SX rotary files (Denstply / Maillefer, Ballaigues, Switzerland). Then, a # 10 K-file (Maillefer, Ballaigues, Switzerland) was passed into the canal until the tip of the file emerged from the apical foramen, to determine the location of the apical foramen (central or lateral).

Each of the teeth was stored and codified with correlative numbers to identify them.

First, to create the artificial internal resorptions, the roots were horizontally sectioned with a 7.0 / 2.0 thick diamond disc (New Technology Instruments, Germany) at a distance of 7mm from the apex. Then, semicircular cavities were made with No. 016 low speed steel bur (Denstply-Maillefer USA) near the periphery of each sectioned piece. Plus, they were glued with Superglue (Pelikan cyanoacrylate adhesive; Istanbul, Turkey). Finally, the resorption was verified by means of a periapical radiograph¹⁶. (Figure 1)

Furthermore, to simulate external apical resorption, a 45-degree oblique cut was made at the root apex with a thin 7.0 / 2.0-thick diamond disc (New Technology Instruments, Germany), in such a way that the palatal wall is shorter than the vestibular by 3 mm¹⁵.

Actual Working Length

All the canals were measured with a # 15 K-file (Maillefer) to have an *actual working length* (AWL) with the direct vision technique and the use of a digital usb microscope with a magnification of 50X (Fuzhou conic industrial Co, LTD Fujian, China):

First, in premolars with external resorption, the file was passively introduced through the canal until the tip of the file was visible through the palatal wall¹⁵. Second, the silicone stop was carefully adjusted to the reference point and proceeded to remove the file from the root canal. Third, it was measured with a digital vernier caliper (Ubermann®, Chile) from the

silicone stop to the tip of the file. From this measurement obtained, 1mm was subtracted manually and the measurement was registered.

In the case of teeth with internal root resorption, the file was introduced until the tip was visible through the apical foramen. Then, the silicone stop was then adjusted to the reference point and the file was removed from the canal. Next, it was measured with an Ubermann digital caliper(Chile) from the top to the tip of the file. Finally, from this measurement, 1mm was subtracted.

Subsequently, all the teeth were placed in an alginate mold, in which once the impression material had set, the labial electrode of the locator was inserted in the mold in order to perform the measurements. These measurements are performed within the first 30 minutes of preparing the models to ensure that alginate retains enough moisture¹⁷.

Prior to electronic measurement, training and calibration intra and inter-observer were performed in the pilot study. The inter-observer calibration was carried out with a professor with more than 10 years of Specialist in Endodontics from Universidad Científica del Sur.

Electronic measurement

Before electronic measurement, the canal was irrigated with 0.5 ml of 2.5% sodium hypochlorite to maintain humidity. The excess solution present in the root canal was dried using a # 50 paper cone¹⁸.

For electronic measurement, we used the following foramen locators: Raypex 6 (VDW), Woopex III (Woodpecker), Propex Pixi (Dentsply-Maillefer) and Root zx Mini (Morita) with

K-files #15 (Dentsply-Maillefer). All foramen locators were calibrated according to the manufacturers' instructions before measurements.

The foramen locator electrode was attached to a file and carefully inserted into the root canal. The measurements were taken according to the manufacturers' instructions:

In the Root zx Mini (Morita-Japan), which is based on the same functioning method of the Root Zx but has a compact size¹⁸, the file was carefully inserted into the canal until it passed through the apical foramen; in this case a single sustained beep will sound, and the word "APEX" and the little triangle next to the Flash Bar will start to flash on and off. Then the file is moved back until the LCD screen shows us that the file is in the first green bar (the bar color changes to green to indicate you have reached a critical area), that indicates the file tip reaches a position near the apex¹⁹.

In the case of the Propex Pixi, the file was carefully inserted into the root canal until it passed the apical foramen, which was showed in the foramen locator with a red "OVER" segment and an audio warning signal (rapid intermittent signal), and the file was moved back where the Propex Pixi indicates '0.0'. Then the file was placed onto an endodontic ruler and the apical length was measured. Finally, a minimum of 0.5 mm was subtracted from the measured file length. This is a safety precaution suggested by the manufacturer to avoid over-instrumentation and allowed us to make sure that we are in the apical zone²⁰.

In the case of Raypex 6, the file was carefully inserted into the canal until it passed through the apical foramen, this was indicated on the screen by the appearance of a red warning point underneath the apical zoom image and brief warning sounds. Then, The file was moved backward until the locator screen indicated that we were within the first two green bars. This

corresponds to the section of the apical constriction up to the apical foramen, that is, this is the relevant region for determining the working length²¹.

In Woodpex III, the file was carefully inserted into the root canal until it passed through the apical foramen. This is indicated when red bars are displayed on the foramen locator, along with a continuous sound “beep” sound. Then the file was retracted until the screen indicated that the file is within the first green bar, which indicates the file has gone the position near by the apical foramen²².

All the measurements were considered valid if the reading remained stable for 5 seconds¹⁸. The file was then removed and measured with an Ubermann digital caliper (Chile) from the silicone stop to the tip of the file.

Statistical Methods

Each sample was evaluated twice: one for measuring the actual working length and then using the four foramen locators. Later, we proceeded to compare both measurements.

All the measurements were collected in a Database in Excel. Then, all the data was recorded in the STATA statistical program (STATA version 14; STATA, Texas, USA) and statistical analysis was performed.

A descriptive analysis was carried out in which the measurements obtained with the different locators were described: means, standard deviation and range were obtained. Subsequently, an inferential analysis was performed, where the real length measurements were compared with the measurements obtained with all the foramen locators in both types of resorption. First, the Shapiro-Wilk normality test was applied. Then, as the results were within a normal distribution, the ANOVA test was performed, and T Test for related samples, in order to analyze the measurements obtained.

Results:

In the comparison of the measurement of the working length obtained with the foramen locators, regarding the real length in the teeth with external resorption. It was found that there were no statistically significant differences in measurements obtained with Raypex 6 ($p = 0.58$) and Propex Pixi ($p = 0.07$) locators; while there were significant differences in the measurements of the Root ZX MINI ($p=0.04$) and Woodpex III ($p=0.00$) compared to the RL. The most accurate foramen locator in this group was the Raypex 6. In the Intraclass Correlation coefficient all the values obtained with all the foramen locators were more than 0.90 ($p=0.00$), that means that there is a good correlation among the foramen locators (Table 1). Bland-Altman plots show the accuracy of the foramen locators in relation to the actual working length, proving to be a good estimator of the real value of the variable. (Figure 2)

On the other hand, in the comparison of the measurement of the working length obtained with the foramen locators related to the actual working length in teeth with internal root resorption, it is evident that there were no statistically significant differences in the measurements obtained with the foramen locators Root zx mini ($p = 0.18$), Propex Pixi, ($p = 0.07$), Raypex 6 ($p = 0.05$), but there were significant differences in the measurements obtained with the Woodpex III ($p=0.02$) compared to the real length in this group. Root Zx Mini was the most accurate foramen locator in this group. In the Intraclass Correlation coefficient all the foramen locators obtained values more than 0.90 ($p=0.00$), that means that there is a good correlation between the foramen locators (Table 2). Bland-Altman plots show the accuracy of the foramen locators in relation to the reference measurements, proving to be a good estimator of the real value of the variable. (Figure 3)

Furthermore, regarding the accuracy obtained by the foramen locators in teeth with external root resorption, there is statistically significant difference ($p = 0.00$) between the four foramen locators (Table 3).

Finally, according to the accuracy obtained by the foramen locators in teeth with internal root resorption, there is no statistically significant difference ($p = 0.88$) between the four foramen locators. (Table 4).

Discussion:

The purpose of this study was to determine the accuracy in the measurements of the working length of four foramen locators in premolars with two different pathological variants. Likewise, there is little research in the use of foramen locators in teeth with external resorption and no studies in teeth with internal root resorption. Therefore, this study is of relevance for being the first to investigate the accuracy of foramen locators in teeth with internal resorption.

The methodology for preparing the teeth with external root resorption in this research is based on the study of Jadhav et al¹⁵ who performed the simulation of the external resorption through a 45 degrees cut in the apex, and alginate was used as an electroconductive medium. Moreover, they obtained the accuracy of Raypex 6, Root zx and Ipex (NSK, Nakanishi Inc., Tochigi, Japan) As a result, it was found that Raypex 6 showed significant accuracy in teeth with simulated external root resorption. Plus, these findings matches the results of the present study in which the Raypex 6 show the greatest accuracy in teeth with simulated external root resorption.

Various factors may influence the accuracy of foramen locators such as the diameter of the apical foramen²³, the foramen locator used²⁴ and the moisture content of the root canal²⁵.

In a study of Herrera et al.²³, artificial enlargement of the diameter of the apical constriction was made in 10 single-rooted teeth. They found that the accuracy of Root ZX varies depending on the diameter of the apical constriction. This study coincides that of Aydin et al²⁶, which found that the accuracy of Root ZX decrease with the increase of the apical diameter. Furthermore, according to the manufacturer of the Root zx mini, this locator can show short measurements in the presence of an exceptionally large apical foramen¹⁹.

Plus, according to Pawar et al, the Raypex 6 is the locator with the best performance in teeth with wide apical diameters²⁷. This agrees with our results in which the accuracy of the Raypex 6 was not altered in teeth with external resorption.

Teeth with external root resorption offer difficulties to contemporary methods of determining working length. Moreover, apical constriction, which is considered the most appropriate place to end endodontic therapy, is not present in teeth with root resorption and open apices^{28,29}. Thus, it can be infer that with the increase of the apical foramen, the taper towards the apex disappears and the walls of the root canal become more parallel²⁶, this may be the reason that the accuracy of the Root ZX mini was altered.

Other factor that influence the measurement of the foramen locator is the device used. Root zx mini is a fourth locator generation which measures the impedance of tooth at two different frequencies³⁰; and its disadvantage is that it need to be in a relatively dry or partially dry canal. In some cases additional drying is required; and it cannot function in a root canal with high exudate and blood^{19,31}.

Raypex 6 is a sixth generation foramen locator³² that overcome the disadvantages of 4th generation foramen locators. The foramen locator sixth generation adapts immediately in a dry or wet canal. In this way, it can be used in dry and wet canals, root canals with blood or exudates³³.

All the samples both with internal and external root resorption followed the same irrigation and drying protocols previous to the electronic reading. Root canals with external resorption are more difficult to dry, because the roots canals at the apical level are wider than the root canals with internal resorption. In this study, the moisture content in the canal at the apical level possibly modified the results. For this reason, the Raypex 6 locator obtained the best accuracy in teeth with external root resorption.

On the other hand, in regard to teeth with internal root resorption, the Root zx mini was the locator that achieved the highest accuracy. Morita's Root Zx mini, which is considered the gold standard of locators, has obtained excellent results in studies on permanent teeth with mature apices³⁴.

In an in vivo study by Serna Pena et al¹⁸ the accuracy of the Root zx mini and Propex Pixi in single rooted teeth was studied. They found that the accuracy of the Root ZX mini in establishing the AWL was 100% range of ± 1 mm. Then, the accuracy of Propex Pixi in establishing the AWL was 89.99% range of ± 1 mm. This result coincides with our study in which the Root zx mini was the most accurate foramen locator, followed by Propex Pixi in teeth with internal resorption.

Additionally, in clinical practice we find various morphological variants such as C-shaped canals and root curvatures. The Root zx mini foramen locator has also been shown to have

good accuracy against these anatomical variants³⁵⁻³⁷ where the diameter of the apical foramen was not altered.

Even though there is loss of surrounding dentine and this tissue is thinner in the site of the resorption, internal resorption did not affect the accuracy of the foramen locators. The reason is the presence of dentin. Root canals are surrounded by dentine and cementum that are insulators to electric current. Plus, insulators cannot conduct electric currents because all their electrons are tightly bound to their atoms³⁸. In the present study, internal resorption has no communication with the periodontal ligament that is a conductor of electric current. Further studies with perforating internal root resorption are necessary, in these cases where there is communication with the periodontal ligament.

On the other side, when comparing the accuracy obtained by all the foramen locators in this study, it can be seen that the four foramen locators obtained greater accuracy in teeth with internal resorption than in teeth with external resorption

Underestimation of length by apex locator may be explained by the fact that the device alarms when the file tip contacts the periapical tissue. In many cases, the periapical tissue penetrates into the canal to some extent. This penetration is greater in open apex teeth and those with a wide apex and thus file tip contacts the tissue penetrated into the canal before reaching the apical foramen resulting in underestimation of the length.³⁹

All in all, the results of this study will guide the operator in selecting the ideal foramen locator to use in teeth with external root resorption and internal dentin resorption; and in this way, provide the dentist with greater accuracy in determining the working length, which is the key factor in the success of root canal treatment⁴⁰. In addition, this study will encourage an

increase in the use of foramen locators in the management of various clinical situations such as pathological variants.

Conclusions:

Based on this in vitro study, the most accurate locator in teeth with external resorption is the Raypex 6 and the most accurate foramen locator in teeth with internal resorption is the Root zx mini.

External root resorption affects more the accuracy of the foramen locators than internal resorption.

Acknowledgment

The authors wish to thank Mg. Esp. Ronald Gonzales, Ph.D. Esp. Jorge Alamo, C.d. Esp. Bruno Lujan and C.d. Edwin Espinoza for their great academic assistance. We want to thank our family for their support. Above all, we want to thank God for all his blessings.

Conflict of Interest: "None Declared"



Fig 1. Tooth with internal resorption preparation verified by periapical radiography

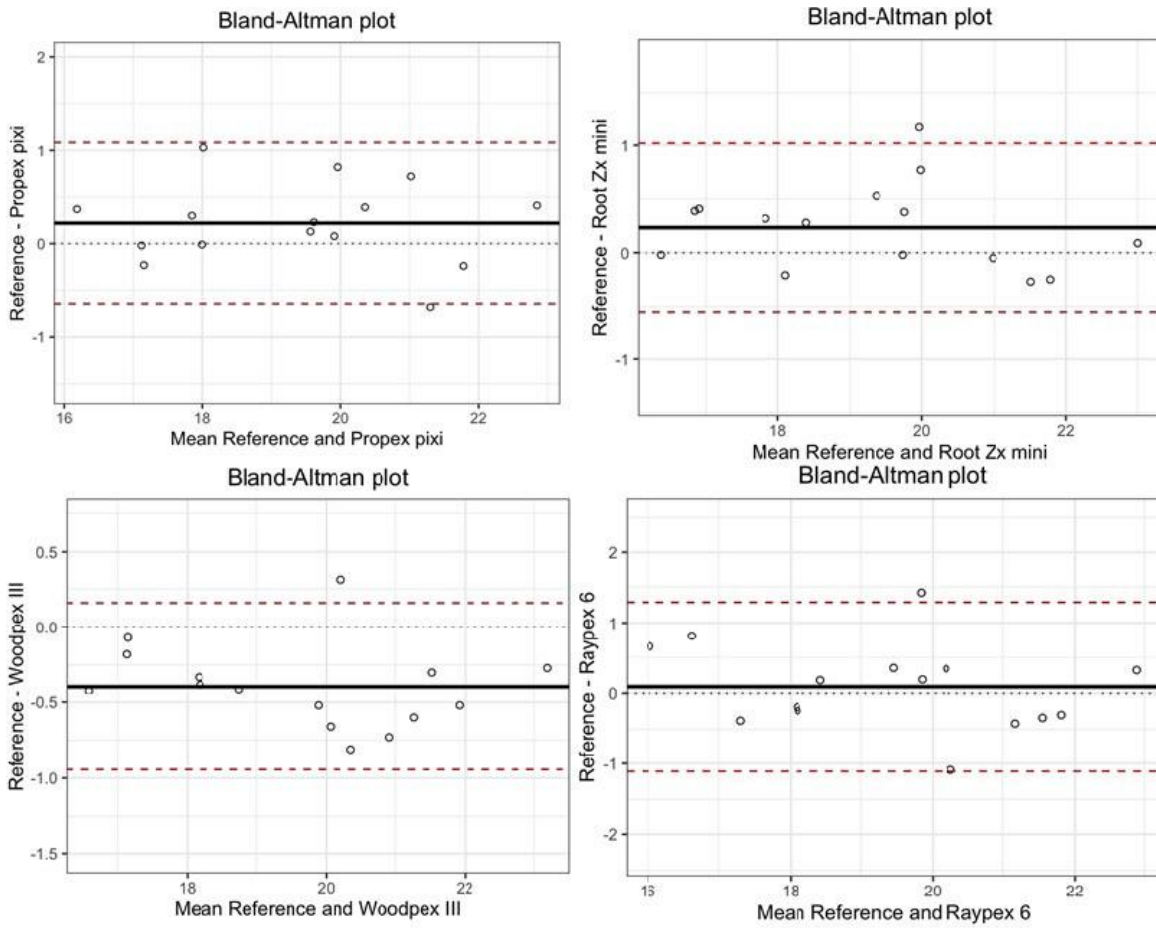


Fig 2. Bland-Altman plot in External Resorption

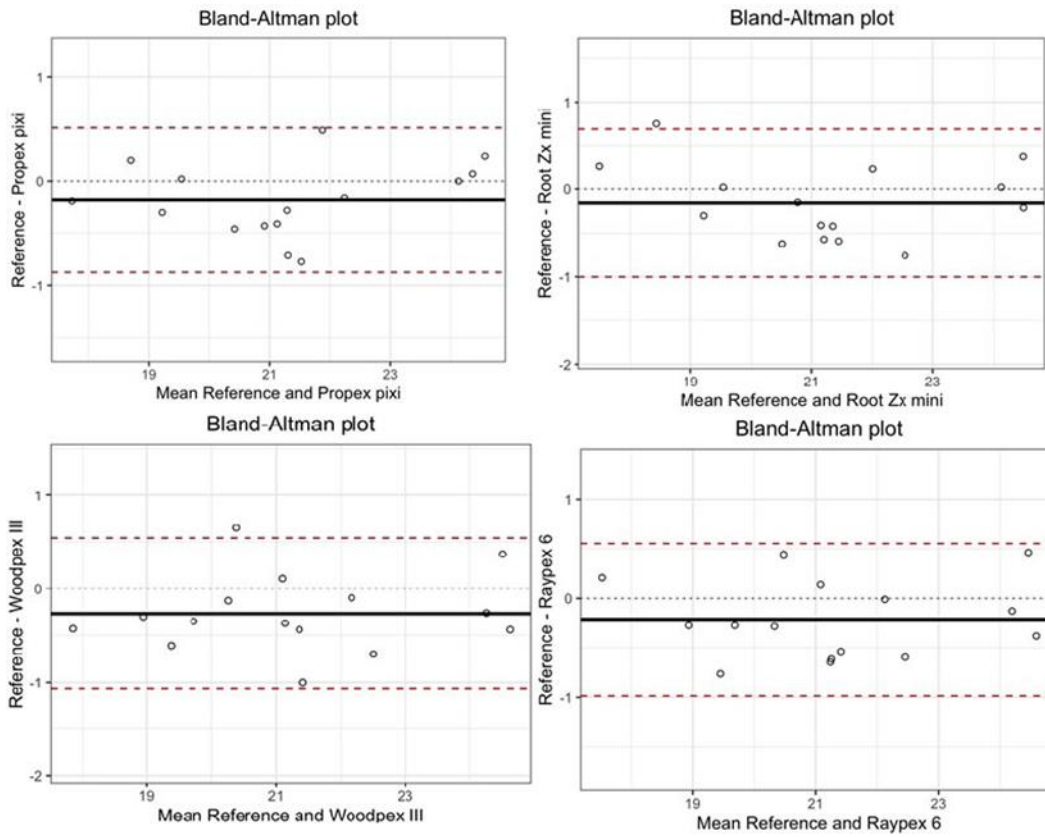


Fig 3. Bland-Altman plot in Internal resorption

Table 1 Comparison of the measurement of the working length using the foramen locators with respect to the real length, in single-rooted teeth with external apical resorption.

	Mean	(SD)	T	p *	ICCs	p**
Propex pixi	19.26	(1.95)	1,93	0.074	0.96	0.00
Root Zx mini	19.25	(2.00)	2,26	0.040	0.97	0.00
Woodpex III	19.88	(1.99)	-5,40	0.000	0.97	0.00
Raypex 6	19.39	(2.08)	0.56	0.583	0.95	0.00
AWL	19.48	(1.92)				

*Statistical Analysis with T-test (p<0.05)

**ICCs Intraclass Correlation Coefficient (p<0.05)

Table 2. Comparison of the measurement of the working length using the foramen locators with respect to the real length, in single-rooted teeth with internal resorption.

Locators	Mean	(DS)	T	p*	ICCs	p**
Propex pixi	21.35	(1.99)	-1,96	0.07	0.98	0.00
Root Zx mini	21.33	(2.14)	-1,40	0.18	0.97	0.00
Woodpex III	21.44	(2.02)	-2,50	0.02	0.97	0.00
Raypex 6	21.38	(2.04)	-2,12	0.05	0.97	0.00
AWL	21.17	(2.06)				

*Statistical Analysis with T-test (p<0.05)

**ICCs Intraclass Correlation Coefficient (p<0.05)

Table 3. Comparison of the accuracy obtained by foramen locators in teeth with external resorption

	Mean	(SD)	F	P
Propex pixi	-0.27	(0.49)		
Root ZX Mini	-0.23	(0.49)	7,32	0.00
Woodpex III	0.46	(0.28)		
Raypex 6	-0.64	(0.61)		

Table 4. Comparison of the accuracy obtained by foramen locators in teeth with internal resorption

	Mean	(SD)	F	P
Propex pixi	0.12	(0.42)		
Root ZX Mini	0.13	(0.44)	0.216	0.885
Woodpex III	0.20	(0.36)		
Raypex 6	0.21	(0.39)		

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10. Versión inicial enviada a publicar

ACCURACY OF FOUR APEX LOCATORS IN PREMOLARS WITH EXTERNAL APICAL REBSORPTION AND INTERNAL REBSORPTION: AN IN VITRO STUDY

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Abstract:

Introduction: The aim of the present in vitro study was to compare the accuracy of the working length measurements of four foramen locators: Root ZX Mini, Raypex 6, Woodpex III and Propex Pixi in uniradicular premolars with simulated external apical resorption and internal resorption. **Materials and methods:** For this study, 30 single-rooted permanent premolars were selected. The samples were divided into two groups: 15 teeth with simulated external root resorption and 15 teeth with internal resorption. Each sample was immersed in containers with alginate covering only the root part. Measurements were acquired from four foramen locators; and compared with the working length measurements that have been previously obtained by the direct visual technique. **Results:** In the teeth with external resorption, there were no statistically significant differences in the measurements obtained with Raypex 6 and Propex pixi foramen locators, but there were statistically significant differences with Root zx mini and Woodpex III. On the other hand, in the samples with

internal root resorption, there were no statistically significant differences in the measurements acquired with Propex mini, Root zx mini and Raypex 6 foramen locators. However, there were significant differences with Woodpex III.

Conclusions: Raypex 6 had the highest accuracy in premolars with simulated external resorption and Root zx mini was the most accurate in teeth with simulated internal resorption. Furthermore, external root resorption affects more the accuracy of foramen locators than internal resorption.

Keywords: Accuracy; Apical foramen; Electronic Apex Locator; Root Resorption.

INTRODUCTION

The determination of the working length is one of the most important factors that contribute to the success of endodontic treatment¹. Thus, determining a correct working length (WL) constitutes an essential step to avoid over- instrumentation, which allows the passage of irritating substances or detritus beyond the apical foramen². In addition, it also avoids sub- instrumentation that prevents total sealing of the root canal up to the apical constriction^{1,2}.

The measurement of working length carried out with the radiographic technique presents many limitations, such as: the difficulty in interpretation because it is a two-dimensional image³; and technical errors made by the operator⁴. This traditional method make it impossible to accurately determine the position of the apical constriction and the apical foramen⁵.

Currently, foramen locators are one of the most reliable tools to obtain a more accurate measurement of the working length¹. This instrument is of vital importance to determine the position of the file in the root canal⁶.

In addition, the use of these devices has become widespread today, proving to be indispensable in endodontic practice due to their high levels of accuracy 97.4% in their measurements⁷; even under conditions in which it would have previously been unthinkable to achieve an accurate measurement, such as in the presence of blood, hypochlorite, even blood or pus⁷.

However, despite its accuracy in locating the apical foramen; there are several pathological variants, that we may find in our clinical practice and might affect the measurement acquired with the foramen locator. Among these pathologies, we find root resorption.

Root resorption is a loss of hard dental tissues as a result of clastic activity^{8,9}. Root resorption can be broadly classified, by the location of the resorption in relation to the root surface, into external and internal resorption^{8,9}.

Also, external root resorption is an irreversible pathological process¹⁰ which can occur in situations as a dental trauma, apical infection, internal bleaching, periodontal treatment, ectopically erupting, and most commonly in the presence of orthodontic movements¹¹.

In addition, another pathology of endodontic interest is internal root resorption, that has been reported as early as 1830⁹. Internal resorption is usually caused by chronic infections, trauma, or inflammatory reactions of the pulp cells. Plus, internal resorption is usually asymptomatic and is detected on routine radiographic examinations⁸. Compared with root external resorption, it has a rare occurrence, and its etiology and pathogenesis has not been completely elucidated⁹.

Additionally, we must take into account the meaning of *accuracy in a measuring instrument* , in order to help us have a clear idea of the objective of this study.

Accuracy in a measuring instrument is the ability of a measuring instrument to give responses close to the true value¹². Furthermore, in the case of foramen locators, it has

been established that the accuracy is greatly influenced by the diameter of the apical foramen¹³.

There is little information of the impact in the accuracy of foramen locators in permanent teeth with external root resorption¹³. Moreover, there are currently no studies on internal resorption.

As previously explained, it is important to study foramen locators in these types of pathology, as these may alter the measurement of the working length in our clinical practice.

For this reason, the purpose of the present study is to compare the accuracy of working length measurements of four foramen locators in single-rooted premolars with simulation of external apical resorption and internal resorption.

Materials and methods:

The present study was approved by the Ethics Committee of Universidad Científica del Sur, Lima, Perú with Evidence N °193-CIEI-SCIENTIFIC-2020. A sample size was determined from the results of the pilot test, after which it was considered to use 30 freshly extracted teeth. Moreover, these had indication for tooth extraction for orthodontic treatment, periodontal or pulp disease reasons and were donated for this study. Plus, periapical radiographs were taken in buccolingual and mesiodistal directions in each tooth, to verify the presence of a single root.

Afterwards, they were subjected to dental calculus removal using an ultrasonic device (UDS-J Woodpecker- China). Then, they were disinfected in 5.25% sodium hypochlorite for two hours to remove traces of organic tissue from the outer surface of the root. Finally, they were stored in a solution of sodium chloride 9% until evaluation¹³.

The sample was divided into two groups: 15 teeth with external resorption and 15 with simulated internal resorption.

Standard endodontic access was performed with a high speed medium round and fissure diamond burs (Micro Diamonds Technology, Israel) with water cooling.

After endodontic access, the cusps edges of the teeth were flattened with a medium round diamond bur (5) (Micro Diamonds Technology, Israel) by approximately one millimeter, to facilitate measurements by means of a stable reference point.

Next, the coronal portion of each canal was flattened⁵ using SX rotary files (Denstply / Maillefer, Ballaigues, Switzerland). Then, a file No. 10 (Maillefer, Ballaigues, Switzerland) was passed into the canal until the tip of the file emerged from the apical foramen, to determine the location of the apical foramen (central or lateral).

Each of the teeth was stored and codified with correlative numbers to identify them.

First, to create the artificial internal resorptions, the roots were horizontally sectioned with a 7.0 / 2.0 thick diamond disc (New Technology Instruments, Germany) at a distance of 7mm from the apex. Then, semicircular cavities were made with No. 016 low speed steel bur (Denstply-Maillefer USA) near the periphery of each sectioned piece. Plus, they were glued with Superglue (Pelikan cyanoacrylate adhesive; Istanbul, Turkey). Finally, the resorption was verified by means of a periapical radiograph¹⁴. (Fig.1)

Furthermore, to simulate external apical resorption, a 45-degree oblique cut was made at the root apex with a thin 7.0 / 2.0-thick diamond disc (New Technology Instruments, Germany), in such a way that the palatal wall is shorter than the vestibular by 3 mm ¹³.

Actual Working Length

All the canals were measured with a 15 file (Maillefer) to have an *actual working length* (AWL) with the direct vision technique:

First, in premolars with external resorption, the file was passively introduced through the canal under direct vision until the tip of the file was visible through the palatal wall¹³. Second, the silicone stop was carefully adjusted to the reference point and proceeded to remove the file from the root canal. Third, it was measured with an Ubermann (Chile) digital vernier caliper from the silicone stop to the tip of the file. From this measurement obtained, 1mm was subtracted manually.

In the case of teeth with internal root resorption, the file was introduced until the tip was visible through the apical foramen. Then, the silicone stop was then adjusted to the reference point and the file was removed from the canal. Next, it was measured with an Ubermann digital caliper (Chile) from the top to the tip of the file. Finally, from this obtained measurement, 1mm was subtracted and measurements were registered.

Subsequently, all the teeth were placed in an alginate mold, in which once the impression material had set, the labial electrode of the locator was inserted in the mold in order to perform the measurements. These measurements are performed within the first 30 minutes of preparing the models to ensure that alginate retains enough moisture¹⁵.

Prior to electronic measurement, training and calibration intra and inter-observer were performed in the pilot study. The inter-observer calibration was carried out with a professor with more than 10 years of Specialist in Endodontics from Universidad Científica del Sur.

Electronic measurement

Before electronic measurement, the canal was irrigated with 0.5 ml of 2.5% sodium hypochlorite to maintain humidity. The excess solution present in the root canal was dried using a number 50 paper cone¹⁶.

For electronic measurement, we used the following foramen locators: Raypex 6 (VDW), Woopex III (Woodpecker), Propex Pixi (Dentsply-Maillefer) and Root zx Mini (Morita) with k-files n° 15 (Dentsply-Maillefer) and the measurement was taken approximately 1mm from the apical foramen.

The foramen locator electrode was attached to the file and carefully inserted into the root canal. The measurements were taken according to the manufacturers' instructions:

In the Root zx Mini (Morita-Japan), which is based on the same functioning method of the Root Zx but has a compact size¹⁶ file No. 15 was carefully inserted into the canal until it passed through the apical foramen; in this case a single sustained beep will sound, and the word “APEX” and the little triangle next to the Flash Bar will start to flash on and off. Then the file is moved back until the LCD screen shows us that the file is in the first green bar, that is, approximately 1mm. of the apical foramen^{16,17}.

In the case of the Propex Pixi (Densply-Maillefer), file No. 15 was carefully inserted into the root canal until it passed the apical foramen, which was showed in the foramen locator with a red “OVER” segment and an audio warning signal (rapid intermittent signal), and then moved the file back to the 0 mark. Next, 0.5mm was manually subtracted from this measurement, this indicates that the file is approximately 1mm from the apical foramen¹⁸.

In the case of Raypex 6 (VDW, Munich-Germany), file n ° 15 was carefully inserted into the canal until it passed through the apical foramen, this was indicated on the screen by the appearance of a red warning point underneath the apical zoom image and brief warning sounds were emitted. The file was moved backward until the locator screen indicated that we were within the first two green bars. In other words, we are approximately 1mm from the apical foramen¹⁹. (Fig .2)

In Woodpex III (Woodpecker, China), a file No. 15 was carefully inserted into the root canal until it passed through the apical foramen. This is indicated when red bars are displayed on the foramen locator, along with a continuous sound “beep” sound. Then the file was retracted until the screen indicated that the file is within the first green bar, which indicates that the file is approximately 1mm from the apical foramen²⁰.

All the measurements were considered valid if the reading remained stable for 5 seconds¹⁶. The file was then removed and measured with an Ubermann (Chile) digital caliper from the silicone stop to the tip of the file.

Statistical Methods

Each sample was evaluated twice: one for measuring the actual working length and then using the four foramen locators. Later, we proceeded to compare both measurements.

All the measurements were recorded on cards and later a database was created in Excel. Then, all the data was recorded in the statistical program STATA version 14 and statistical analysis was performed.

A descriptive analysis was carried out in which the measurements obtained with the different locators were described: means, standard deviation and range were obtained. Subsequently, an inferential analysis was performed, where the working length measurements were compared with the measurements obtained with all foramen locators in both internal resorption and external apical resorption. First, the Shapiro Wilk normality test was applied. Then, as the results were within a normal distribution, the Anova test was performed, and also the T Test for independent samples and the T Test for related samples, in order to analyze the measurements obtained.

Results:

On the one hand, in the comparison of the measurement of the working length obtained with the foramen locators, regarding the actual length in the teeth with external resorption. It was found that there were no statistically significant differences in measurements obtained with Raypex 6 ($p = 0.583$) and Propex Pixi ($p = 0.074$) locators; while there were significant differences in the measurements of the Root ZX MINI ($p=0.040$) and Woodpex III ($p=0.000$) compared to the AWL. The most accurate foramen locator in this group was the Raypex 6. (Table 1)

On the other hand, in the comparison of the measurement of the working length obtained with the foramen locators related to the AWL in the teeth with internal root resorption, it is evident that there were no statistically significant differences in the measurements obtained with the foramen locators Root zx mini ($p = 0.181$), Propex Pixi, ($p = 0.070$), Raypex 6 ($p = 0.052$), but there were significant differences in the measurements obtained with the Woodpex III ($p 0.025$) compared to the actual working length. Root Zx Mini was the most accurate foramen locator in this group. (Table 2)

Furthermore, regarding the accuracy obtained by the foramen locators in teeth with external root resorption, there is a statistically significant difference ($p = 0.000$) between the four foramen locators. (Table 3)

Finally, according to the accuracy obtained by the foramen locators in teeth with internal resorption, there is no statistically significant difference ($p = 0.885$) between the four foramen locators. (Table 4)

Discussion:

The purpose of this study was to determine the accuracy in the measurements of the working length of four foramen locators in unirradiculares premolars with two different pathological variants. Likewise, there is little research on the use of foramen locators in teeth with external resorption and no studies in teeth with internal root resorption in permanent teeth. Therefore, this study is of relevance for being the first to investigate the accuracy of foramen locators in teeth with internal resorption.

The methodology for preparing the teeth with external root resorption in this research is based on the study of Jadhav et al¹³ who performed the simulation of the external resorption through a 45 degrees cut in the apex, and alginate was used as an electroconductive medium. They also obtained the accuracy of Raypex 6, Root zx and Ipex. As a result, it was found that Raypex 6 showed significant accuracy in the measurement of the working length in teeth with simulated external root resorption. Plus, this result matches the result of the present study in which the Raypex 6 show the greatest accuracy in teeth with simulated external root resorption.

Various factors can influence the accuracy of foramen locators such as the diameter of the apical foramen, the irrigation solution, and the electroconductivity of the pulp²¹.

In a study of Herrera et al, artificial enlargement of the diameter of the apical constriction was made in 10 single-rooted teeth. Then, the achievement of the working length was performed with the foramen locator Root Zx, and they concluded that the accuracy of Root ZX varies depending on the diameter of the apical constriction²². This study coincides that of Aydin y cols, which found that the accuracy of Root zx decrease with the increase of the apical diameter²³. Furthermore, according to the manufacturer of the Root zx mini, this locator can show short measurements in the presence of an exceptionally large apical foramen¹⁷.

Plus, according to Pawar et al, the Raypex 6 is the locator with the best performance in teeth with wide apical diameters²⁴. This agrees with our results in which the accuracy of the Raypex 6 was not altered in teeth with external resorption.

Teeth with external root resorption offer difficulties to contemporary methods of determining working length. Moreover, apical constriction, which is considered the most appropriate place to end endodontic therapy, is not present in teeth with root resorption and open apices^{25,26}. Thus, it can be infer that with the increase of the apical foramen, the taper towards the apex disappears and the walls of the root canal become more parallel²³, this may be the reason that the accuracy of the Root ZX mini was altered.

In the studies of Nguyen²⁷ and Saraswathi²⁵ reported that the file size did not affect the accuracy of EALs. In the present investigation, all the measurements were practicable and

reproducible with the inserted instruments. The same file size was used in every case (No. 15 K-file) to have comparable conditions for the in vitro measurements²⁵.

Other factors that can modify the accuracy of these foramen locators are the moisture content of the root canal²⁸ and the device used²⁹.

Root zx mini is a fourth locator generation which measures the impedance of tooth at two different frequencies³⁰; and its disadvantage is that it needs to be in a relatively dry or partially dry canal. In some cases additional drying is required; and it cannot function in a root canal with high exudate and blood^{17,31}.

Raypex 6 is a sixth generation foramen locator³² that overcomes the disadvantages of 4th generation foramen locators. The foramen locator of sixth generation adapts immediately in a dry or wet canal. In this way, it can be used in dry and wet canals, root canals with blood or exudates³³.

All the samples both with internal and external root resorption followed the same irrigation and drying protocols previous to the electronic reading. Root canals with external resorption are more difficult to dry, because the root canals at the apical level are wider than the root canals with internal resorption. In this study, the moisture content in the canal at the apical level possibly modified the results. For this reason, the Raypex 6 locator obtained the best accuracy in teeth with external root resorption.

On the other hand, in regard to teeth with internal root resorption, the Root zx mini was the locator that achieved the highest accuracy. Morita's Root Zx mini, which is considered the gold standard of locators, has obtained excellent results in studies on permanent teeth with mature apices³⁴.

In an in-vivo study by Serna Pena et al ¹⁶ the accuracy of the Root zx mini and Propex Pixi in single rooted teeth was studied. They found that the accuracy of the Root ZX mini in establishing the AWL was 83.33% range of ± 0.5 mm and 100% range of ± 1 mm. Then, the accuracy of Propex Pixi in establishing the AWL was 83.33% of the time to ± 0.5 and 89.99% of the time to ± 1 mm. This result coincides with our study in which the Root zx mini was the most accurate foramen locator, followed by Propex pixi in premolar teeth with internal resorption.

Additionally, in clinical practice we find various morphological variants such as C-shaped canals and root curvatures. The Root zx mini foramen locator has also been shown to have good accuracy against these anatomical variants³⁵⁻³⁷ where the diameter of the apical foramen is not altered.

On the other side, when comparing the accuracy obtained by all the foramen locators in this study, it can be seen that the four foramen locators obtained greater accuracy in teeth with internal resorption ($p = 0.885$) than with teeth with external resorption ($p = 0.000$). In the cases of an incomplete apex, an advanced apical resorption or over instrumentation, the apical constriction may be impaired or absent, and alter the electrical conformation of the root canal.

In addition, the thickness of the dentin wall at the level of the apical third is decreased, giving a variation in impedance, indicating apparently short readings. The current flow in this site is modified, promoting voltage gradient values very close to the values of the periodontal ligament³⁸.

All in all, the results of this study will guide the operator in selecting the ideal foramen locator to use in teeth with external root resorption and internal dentin resorption; and in this way, provide the dentist with greater accuracy in determining the working length, which is the key

factor in the success of root canal treatment³⁹. In addition, this study will encourage an increase in the use of foramen locators in the management of various clinical situations such as pathological variants.

Conclusions:

-The most accurate locator in teeth with external resorption is the Raypex 6 and the most accurate foramen locator in teeth with internal resorption is the Root zx mini.

-External root resorption affects more the accuracy of the foramen locators than internal resorption.



Fig 1. Tooth with internal resorption preparation verified by periapical radiography

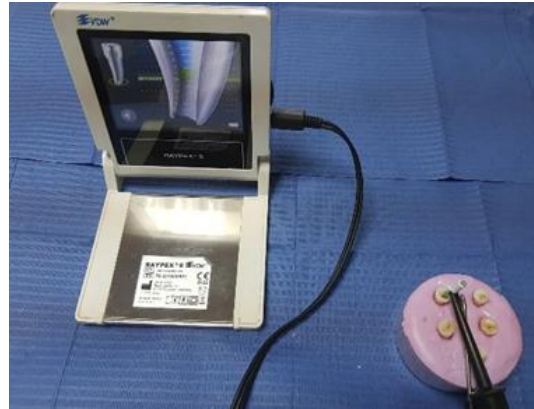


Fig 2. Electronic measurement with the Raypex 6 locator

Table 1 Comparison of the measurement of the working length using the apical locators with respect to the actual working length, in single-rooted teeth with external apical resorption.

Locators	X	DS	T	P
Propex pix	19.26	1.95	1,932	0.074
AWL	19.48	1.92		
Root Zx mini	19.25	2.00	2,266	0.040
AWL	19.48	1.92		
Woodpex III	19.88	1.99	-5,409	0.000
AWL	19.48	1.92		
Raypex 6	19.39	2.08	0.561	0.583
AWL	19.48	1.92		

Table 2. Comparison of the measurement of the working length using the apical locators with respect to the actual working length, in single-rooted teeth with internal resorption.

Locators	X	DS	T	P
Propex pixi	21.35	1.99	-1,963	0.070
AWL	21.17	2.06		
Root Zx mini	21.33	2.14	-1,406	0.181
AWL	21.17	2.06		
Woodpex III	21.44	2.02	-2,503	0.025
AWL	21.17	2.06		
Raypex 6	21.38	2.04	-2,124	0.052
AWL	21.17	2.06		

Table 3. Comparison of the accuracy obtained by foramen locators in teeth with external apical resorption

Locators	X	DS	F	P
Propex pixi	-0.2700	0.49092		
Root ZX Mini	-0.2347	0.49147	7,326	0.000
Woodpex III	0.4633	0.28050		
Raypex 6	-0.647	0.61483		

Table 4. Comparison of the Accuracy obtained by the foramen locators in teeth with internal resorption

Locators	X	DS	F	P
Propex pixi	0.1253	0.42458		
Root ZX Mini	0.1327	0.44637	0.216	0.885
Woodpex III	0.2067	0.36045		
Raypex 6	0.2193	0.39373		

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12. Versión en español

DETERMINACION DE LA EXACTITUD DE CUATRO LOCALIZADORES APICALES EN PREMOLARES UNIRRADICULARES CON REABSORCIÓN RADICULAR: UN ESTUDIO IN VITRO

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Resumen:

Introducción: El objetivo del presente estudio in vitro fue el de comparar la exactitud de las mediciones de la longitud de trabajo de cuatro localizadores de foramen: Root ZX Mini, Raypex 6, Woodpex III y Propex Pixi en premolares unirradiculares con reabsorción radicular simuladas. **Materiales y métodos:** Para este estudio se utilizó 30 premolares permanentes unirradiculares. Las muestras se dividieron en dos grupos: 15 piezas dentarias con reabsorción dentinaria interna y 15 piezas dentarias con reabsorción externa simuladas. Las piezas dentarias fueron posicionadas en envases con alginato, cubriendo únicamente la porción radicular. Se realizaron las mediciones con los cuatro localizadores y los resultados fueron comparados con las medidas de la longitud de trabajo obtenidas previamente con la técnica visual directa y el uso de un Microscópio usb digital 5x, aplicando para estas la prueba de Shapiro-Wilk. Las pruebas de Anova y T de Student para muestras relacionadas fueron ejecutadas para el análisis de las medidas obtenidas **Resultados:** En las piezas dentarias con

reabsorción apical externa no hubo diferencias estadísticamente significativas en las mediciones obtenidas con los localizadores Raypex 6 y Propex pixi, pero si hubo diferencias estadísticamente significativas con los localizadores de foramen Root zx mini ($p=0.04$) y Woodpex III ($p=0.00$). Por otro lado, en la muestra con reabsorción radicular interna no hubo diferencias estadísticamente significativas en las mediciones con los localizadores de foramen Propex pixi, Root zx mini y Raypex 6. Sin embargo, si hubo diferencias significativas con el Woodpex III. **Conclusiones:** Basado en este estudio in vitro, el localizador de foramen Raypex 6 fue el de mayor exactitud en premolares unirradiculares con reabsorción apical externa simulada y el Root zx mini fue el localizador más exacto en premolares con reabsorción dentinaria interna simulada. Adicionalmente, la reabsorción radicular externa afectaría más la exactitud de los localizadores de foramen que la reabsorción dentinaria interna.

Palabras clave: Foramen apical, localizador apical, reabsorción radicular

INTRODUCCION

La determinación de la longitud de trabajo es uno de los factores más importantes que contribuyen al éxito en el tratamiento endodóntico¹. De tal manera, que la determinación de una correcta longitud de trabajo (LT) constituye un paso esencial para evitar una sobre instrumentación, el cual permite el pasaje de sustancias irritantes o detritus más allá del foramen apical². Además, evita también la sub instrumentación que impide el sellado total del conducto hasta la constricción apical.^{1,2}

La determinación de la longitud de trabajo realizada con la técnica radiográfica presenta muchas limitaciones como son: la dificultad en la interpretación por ser una imagen bidimensional³; así como los errores técnicos en angulación y revelado cometidos por el operador⁴. Este método tradicional hace imposible determinar con exactitud posición de la constricción apical y el foramen apical⁵.

En la actualidad, los localizadores de foramen son una de las herramientas más confiables que permiten obtener una medición más exacta de la longitud de trabajo¹. Estos instrumentos reducen el número de radiografías requeridas y minimiza la subjetividad en la interpretación radiográfica⁶

Además, el uso de estos dispositivos se ha masificado hoy en día, demostrando ser indispensables en la práctica endodóntica por sus altos niveles de acierto de un 97.4% en sus mediciones⁷; aún en condiciones en las cuales antes hubiera sido impensable lograr una medición certera, como en presencia de sangre, hipoclorito incluso sangre o pus⁷.

Sin embargo, a pesar de su exactitud en la localización del foramen apical mayor; existen diversas variantes patológicas como los conductos en C, dens invaginatus, dilaceración

radicular^{8,9}; etc. las cuales pueden afectar la medida obtenida con el localizador de foramen.

Entre estas patologías, encontramos las reabsorciones radiculares.

La reabsorción radicular es una pérdida de los tejidos duros dentarios como resultado de una actividad clástica^{10,11}. La reabsorción radicular puede ser ampliamente clasificada en reabsorción externa e interna por la localización de la reabsorción en relación a la superficie radicular^{10,11}.

La reabsorción radicular externa es un proceso patológico irreversible¹² el cual puede ocurrir en diferentes situaciones como en un trauma dental, infección apical, blanqueamiento interno, tratamiento periodontal, erupción ectópica y más comúnmente en la presencia de movimientos ortodónticos¹³.

Por otro lado, otra patología de interés endodóntico es la reabsorción radicular interna, la cual fue reportada por primera vez en el año 1830^{11,14}. Además, la reabsorción interna es usualmente asintomática, y es detectada en exámenes radiográficos de rutina^{10,14}.

Comparado con la reabsorción externa radicular esta es de rara ocurrencia, y su etiología y patogénesis no han sido completamente explicada¹¹.

Adicionalmente, en la literatura hay poca información sobre el impacto en la exactitud en la medición de la longitud de trabajo de los localizadores apicales en piezas permanentes con reabsorción externa¹⁵. Además, no existen estudios en la actualidad en reabsorciones dentinarias internas.

Por lo anteriormente explicado, es importante el estudio de los localizadores de foramen en estos tipos de patologías, ya que estas pueden alterar la medición de la longitud de trabajo en nuestra práctica clínica.

Por tal motivo, el propósito del presente estudio es comparar la exactitud en la medición de la longitud de trabajo de cuatro localizadores de foramen en premolares unirradiculares con simulación de reabsorción apical externa y reabsorción dentinaria interna.

Materiales y Métodos:

El presente estudio fue aprobado por el comité de Ética de la Universidad Científica del Sur, Lima, Perú con Constancia N °193-CIEI-SCIENTIFIC-2020. Se determinó un tamaño de muestra a partir de los resultados de la prueba piloto, luego de lo cual se consideró utilizar 30 piezas dentarias recién extraídas. Estas presentaban indicación para exodoncia por tratamiento de ortodoncia, o a causa de enfermedad periodontal o pulpar y fueron donadas para el estudio. Además, se tomaron radiografías periapicales en sentido vestíbulo-lingual y mesio-distal a cada pieza dentaria para verificar la presencia de un solo conducto.

Después, fueron sometidas a la limpieza del cálculo dentario mediante el uso de un aparato ultrasónico (UDS-J Woodpecker- China). Luego, se desinfectaron en hipoclorito de sodio al 5.25% durante 2 horas para eliminar restos de tejido orgánico de la superficie externa de la raíz. Por último, se almacenaron en una solución salina estéril 0.9% hasta su evaluación.¹⁵

La muestra se dividió en dos grupos: 15 piezas dentarias con reabsorción apical externa y 15 con reabsorción dentinaria interna simuladas (n=15). Se realizó la apertura cameral estándar con una fresa diamantada redonda mediana y de fisura de alta velocidad (Micro Diamonds Technology, Israel) y refrigeración con agua.

Luego de la apertura cameral, se disminuyó la altura de la corona aproximadamente en un milímetro con una fresa diamantada redonda mediana (Micro Diamonds Technology, Israel)

aproximadamente en un milímetro, para facilitar las mediciones por medio de un punto de referencia estable.⁵

La porción coronal de los conductos se amplió⁵ usando limas rotatorias SX (Dentply/Maillefer, Ballaigues, Suiza). Luego, se realizó el pasaje de una lima especial k-#10 (Maillefer, Ballaigues, Suiza) en el conducto hasta que la punta de la lima surja por el foramen apical, para determinar la ubicación del foramen apical mayor (central o lateral).

Cada una de las piezas dentarias se colocó en un depósito de plástico y se codificó con números correlativos, para identificarlas.

Primeramente, para crear las reabsorciones internas artificiales, las raíces se seccionaron horizontalmente con disco diamantado fino de 7.0/2.0 de grosor (New Technology Instruments, Germany) a una distancia de 7mm del ápice. Luego, se realizaron cavidades semicirculares con fresas de baja velocidad de acero Nro.# 016 (Dentply-Maillefer USA) cerca de la periferia de cada pieza seccionada. Además, se pegaron con Superglue (Pelikan cyanoacrylate adhesive; Estambul, Turkey). Finalmente, la reabsorción se verificó por medio de una radiografía periapical¹⁶. (Figura1)

Adicionalmente, para simular la reabsorción apical externa, un corte oblicuo de 45 grados se realizó en el ápice radicular con un disco diamantado fino de 7.0/2.0 de grosor (New Technology Instruments, Germany), de tal manera que la pared palatina sea más corta que la vestibular por 3 mm¹⁵.

Longitud real de Trabajo (LRT)

Todos los conductos se midieron con una lima k-#15 (Maillefer) para tener una Longitud real de Trabajo (LRT) con la técnica de visión directa y con el uso de un microscopio USB digital USB con una magnificación de 50X (Fuzhou conic industrial Co, LTD Fujian, China):

Primero, en las premolares con reabsorción apical externa, a visión directa se introdujo la lima pasivamente por el conducto hasta que la punta de la lima sea visible por la pared palatina¹⁵. Segundo, se ajustó el tope cuidadosamente al punto de referencia y se procedió a retirar la lima del conducto. Tercero, se midió con un calibrador de vernier digital (Ubermann®, Chile) desde el tope hasta la punta de la lima. De esta medida obtenida se restó 1mm y la medida fue anotada.

En el caso de piezas dentarias con reabsorción radicular interna, se introdujo la lima hasta que la punta fue visible por el foramen apical. Luego se ajustó el tope al punto de referencia y se procedió a retirar la lima del conducto. Se midió con un calibrador digital Ubermann (Chile) desde el tope hasta la punta de la lima. De esta medida obtenida se restó 1mm y se apuntó la medida.

Posteriormente todos los dientes se colocaron en un molde de alginato, en el cual una vez fraguado el material de impresión, se insertó el electrodo labial del localizador para poder realizar las mediciones. Estas mediciones se realizaron dentro de los primeros 30 minutos desde que se prepararon los modelos para asegurarse que el alginato mantenga la suficiente humedad¹⁷.

Previo a la medición electrónica, se realizó una capacitación y calibración intra e inter observador esto se realizó en la prueba piloto.

La calibración inter-observador se realizó con un Docente con más de 10 años de Especialidad en Endodoncia de la Universidad Científica del Sur.

Medición electrónica

Antes de la medición electrónica, el conducto se irrigó con 0.5 ml de hipoclorito de sodio al 2.5% para mantener la humedad. El exceso de solución presente en el conducto se secó por medio de un cono de papel número 50¹⁸.

Para la medición electrónica se utilizó los localizadores Raypex 6(VDW), Woodpex III (Woodpecker), Propex Pixi (Dentsply-Maillefer) y el Root zx Mini (Morita) con limas-K #15 (Dentsply-Maillefer). Todos los localizadores de foramen fueron calibrados de acuerdo a las instrucciones de los fabricantes antes de tomar las mediciones.

El electrodo del localizador se adjuntó a la lima y se introdujo cuidadosamente en el interior del conducto. Las medidas se tomaron según instrucciones de los fabricantes:

En el Root zx Mini (Morita-Japón), el cual está basado en el mismo método de funcionamiento del Root Zx pero tiene un tamaño compacto¹⁸, la lima se introdujo cuidadosamente en el interior del conducto hasta pasar el foramen apical, esto se indica por una barra “APEX” tintineante. Luego retrocedimos la lima hasta que la pantalla LCD nos muestre que estamos en la primera barra verde (la barra de color cambia a verde indicando que se ha llegado a un área crítica), lo cual indica que la punta de la lima llegó a una posición cerca del ápice¹⁹.

En el caso del Propex Pixi (Densply-Maillefer), la lima n° 15 se introdujo cuidadosamente en el interior del conducto hasta pasar el foramen apical, el cual se indicó cuando la barra de color rojo “OVER” aparezca junto con una señal auditiva de precaución (señal rápida e intermitente) y luego se retrocedió hasta que el localizador indique ‘0.0’. Luego, la lima se colocó en una regla endodóntica y la longitud de trabajo fue medida. Finalmente, de esta medida se resta manualmente 0.5mm. Esta es una precaución de seguridad sugerida por el fabricante para evitar la sobre-instrumentación y nos permite estar seguros que estamos en la zona apical.²⁰

En el caso del Raypex 6 (VDW, Munich-Alemania), la lima se introdujo cuidadosamente en el interior del conducto hasta pasar el foramen apical, esto se indicó en la pantalla por la aparición un punto rojo de advertencia debajo de la imagen de zoom apical y se emitieron breves sonidos de advertencia. Luego, se procedió a retroceder la lima hasta que la pantalla del localizador nos indicó que estamos dentro de las dos primeras barras de color verde. Esto corresponde a una sección de la constricción apical hasta el foramen apical, la cual es una zona relevante para determinar la longitud de trabajo.²¹

En el Woodpex III (Woodpecker, China), la lima n°15 se introdujo cuidadosamente en el interior del conducto hasta pasar el foramen apical. Esto se indica cuando las barras en rojo se muestran en la pantalla del localizador, acompañado de un continuo sonido “beep”. Luego se retrocedió la lima hasta que la pantalla del localizador nos indicó que estamos dentro de la primera barra verde, lo cual nos indica que estamos en una posición cerca del foramen apical.²²

Todas las medidas se consideraron válidas si la lectura permaneció estable por 5 segundos¹⁸.

Se retiró la lima y se midió con un calibrador digital Ubermann (Chile) desde el tope hasta la punta de la lima.

Métodos Estadísticos

Las muestras fueron evaluadas dos veces: una para obtener la medida de la longitud real y la otra utilizando los cuatro localizadores apicales, luego, se procedió a contrastar ambas medidas.

Todas las medidas se recolectaron en una base de datos en Excel. Luego, se registraron los datos en el programa estadístico STATA (STATA versión 14; STATA, Texas, USA) y se realizó su posterior análisis estadístico.

Se realizó un análisis descriptivo en el cual se describió las medidas obtenidas con los diferentes localizadores, se obtuvieron medias, desviación estándar y rango. Posteriormente, se realizó un análisis inferencial donde se comparó las medidas de referencia con las medidas obtenidas con los localizadores en ambos tipos de reabsorción. En primer lugar se aplicó la prueba de normalidad de Shapiro-Wilk. Luego, como los resultados estaban dentro de una distribución normal, se utilizaron las pruebas de Anova, y la Prueba T para muestras relacionadas para analizar las medidas obtenidas.

En la comparación de la medición de la longitud de trabajo obtenida con los localizadores de foramen, respecto a la longitud real en las piezas dentarias que tenían reabsorción radicular externa, se encontró que no hubo diferencias estadísticamente significativas en las mediciones obtenidas con los localizadores Raypex 6 ($p=0.58$) y Propex Pixi ($p=0.07$); mientras que si hubo diferencias significativas en las mediciones del Root ZX MINI ($p=0.04$)

y Woodpex III ($p=0.00$) en comparación a la longitud real. El localizador con mayor exactitud en este grupo fue el Raypex 6.

En la Correlación Intraclase todos los valores obtenidos con todos los localizadores de foramen fueron más de 0.90 ($p=0.00$), lo cual significa que hay una buena correlación entre los localizadores de foramen. (Tabla 1). El gráfico de Bland-Altman demuestra la exactitud de los localizadores de foramen en relación a la longitud de trabajo real, demostrando ser un buen estimador del valor real de la variable. (Figura 2)

Por otro lado, en la comparación de la medición de la longitud de trabajo obtenida con los localizadores de foramen respecto a la longitud real de trabajo en las piezas dentarias que tenían reabsorción radicular interna se evidencia que no hubo diferencias estadísticamente significativa en las mediciones obtenidas con los localizadores Root zx mini ($p=0.18$), Propex Pixi, ($p=0.07$), Raypex 6 ($p=0.18$), pero si hubo diferencias significativas en las medidas obtenidas con el Woodpex III ($p=0.02$) en comparación con la longitud real. En este grupo, el Root Zx Mini es el que se acercó más a la longitud real de las piezas dentarias. En la Correlación Intraclase todos los valores obtenidos con todos los localizadores de foramen fueron más de 0.90 ($p=0.00$), lo cual significa que hay una buena correlación entre los localizadores de foramen. (Tabla 2). El gráfico de Bland-Altman demuestra la exactitud de los localizadores de foramen en relación a la longitud de trabajo real, demostrando ser un buen estimador del valor real de la variable. (Figura 3)

Por último, respecto a la exactitud obtenida por los localizadores de foramen frente a las piezas dentarias con reabsorción radicular externa, si existe diferencia estadísticamente significativa ($p= 0.00$) entre los cuatro localizadores. (Tabla 3)

Además, respecto a la exactitud obtenida por los localizadores de foramen en piezas dentarias con reabsorción dentinaria interna, no existe diferencia estadísticamente significativa ($p=0.88$) entre los cuatro localizadores. (Tabla 4)

Discusión

El objetivo del presente estudio fue determinar la exactitud en las mediciones de la longitud de trabajo de cuatro localizadores de foramen en premolares unirradiculares con dos diferentes variantes patológicas. Asimismo, hay pocas investigaciones en cuanto al uso de localizadores en piezas dentarias con reabsorción externa y ningún estudio en piezas dentarias con reabsorción radicular interna en piezas dentarias permanentes. Por tal motivo, este estudio es de relevancia por ser el pionero en investigar la exactitud de los localizadores de foramen en piezas dentarias con reabsorción radicular interna.

La metodología de la preparación de las piezas dentarias con reabsorción radicular externa en esta investigación se basó en el estudio de Jadhav y cols¹⁵, quien realizó la simulación de la reabsorción externa por medio de un corte con una angulación de 45 grados y se usó el alginato como un medio electroconductor. Además, obtuvo la exactitud del Raypex 6, Root zx y el Ipex (NSK, Nakanishi Inc., Tochigi, Japan). Como resultado, encontró que el Raypex 6 demostró una exactitud estadísticamente significativa en la medición de la longitud de trabajo en piezas dentarias con reabsorción radicular externa simulada. También, estos resultados coinciden con el presente estudio en el cual el Raypex 6 fue el localizador que obtuvo la mayor exactitud en piezas dentarias con reabsorción radicular externa simuladas.

Hay diversos factores que pueden influenciar en la exactitud de los localizadores de foramen como el diámetro del foramen apical²³, el localizador de foramen usado²⁴ y la humedad del canal radicular²⁵.

En un estudio referido por Herrera y cols²³, se realizó de manera artificial la ampliación del diámetro de la constricción apical en 10 piezas dentarias uniradiculares y se realizó la obtención de la longitud de trabajo con el localizador de foramen Root Zx, concluyeron que la exactitud del localizador Root ZX varía en función al diámetro de la constricción apical. Este estudio coincide con el de Aydin y cols²⁶ los cuales encontraron que el Root zx disminuye su exactitud de acuerdo con el aumento del diámetro apical. Además, de acuerdo al fabricante del Root zx mini este puede presentar mediciones cortas en presencia de un foramen apical excepcionalmente grande¹⁹.

Por otra parte, según Pawar y cols, el Raypex 6 es el localizador con mejor performance en piezas dentarias con diámetros apicales anchos²⁷. Esto coincide con nuestros resultados en el cual la exactitud del Raypex 6 no fue alterado en piezas dentarias con reabsorción externa.

Las piezas dentarias con reabsorción radicular externa ofrecen dificultades a los métodos contemporáneos de determinación de la longitud de trabajo. Además, La constricción apical que es considerada el lugar más apropiado de terminación de la terapia endodóntica no está presente en piezas dentarias con reabsorción radicular y ápices abiertos^{28,29}. Se puede deducir que con el incremento del foramen apical, la conicidad hacia el ápice desaparece y las paredes del canal radicular se vuelven más paralelas²⁶, pudiendo ser esta la razón que la exactitud del Root ZX mini se ve alterada.

Otro factor que puede influenciar en la medición del localizador de foramen es el dispositivo usado. Root zx mini es un localizador de cuarta generación la cual mide la impedancia de las piezas dentarias a dos diferentes frecuencias ³⁰ ; y su desventaja es que necesita de un canal radicular relativa o parciamente seco. En muchos casos, un secado adicional es requerido; y no puede funcionar en un conducto radicular con mucho exudado y sangre^{19,31} .

Raypex 6 es un localizador de sexta generación ³² el cual supera las desventajas de los localizadores de cuarta generación. Los localizadores de sexta generación se adapta inmediatamente a canales radiculares secos y húmedos. Por lo tanto, puede ser usados en canales radiculares secos y húmedos, canales radiculares con sangre y exudados.³³

Todas las muestras con reabsorción radicular interna y externa siguieron el mismo protocolo de irrigación y secado antes de la lectura electrónica. Las piezas dentarias con reabsorción radicular externa con más difíciles de secar, porque a nivel apical son más anchos que los conductos con reabsorción interna. En este estudio, la humedad en el conducto radicular posiblemente modificó los resultados. Por esta razón el Raypex 6 obtuvo la mayor exactitud en piezas dentarias con reabsorción radicular externa.

Por otra parte, respecto a las piezas dentarias con reabsorción radicular interna, fue el Root zx mini el localizador que alcanzó una mayor exactitud. El Root Zx mini de Morita el cual es considerado el gold estándar de los localizadores obteniendo excelentes resultados en estudios en piezas dentarias permanentes con ápices maduros³⁴.

En un estudio en vivo de Serna Peña y cols ¹⁸ la exactitud del Root zx mini and Propex Pixi en piezas dentarias unirradiculares fue estudiada. Ellos encontraron que la exactitud del Root ZX mini en establecer la longitud real de trabajo fue de 100% en un rango de ± 1 mm. También la exactitud del Propex Pixi en establecer la longitud de trabajo fue de 89.99% en un rango

de ± 1 mm. Este resultado coincide con nuestro estudio en el cual el localizador de foramen Root zx mini fue el más exacto, seguido del Propex Pixi en piezas dentarias con reabsorción interna.

Adicionalmente, en la práctica clínica encontramos diversas variantes morfológicas como los conductos en C y las curvaturas radiculares. El localizador de foramen Root zx mini también ha demostrado tener una buena exactitud frente a estas variantes anatómicas³⁵⁻³⁷

Aunque hay pérdida de dentina circundante y este tejido es más delgado en el sitio de la reabsorción, la reabsorción interna no afectó la precisión de los localizadores de foramen. La razón es la presencia de dentina. Los conductos radiculares están rodeados de dentina y cemento que son aislantes de la corriente eléctrica. Además, los aislantes no pueden conducir corrientes eléctricas porque todos sus electrones están fuertemente unidos a sus átomos³⁸. En el presente estudio, la reabsorción interna no tiene comunicación con el ligamento periodontal que es conductor de corriente eléctrica. Son necesarios más estudios con reabsorción radicular interna perforante, en estos casos donde existe comunicación con el ligamento periodontal.

Por otro lado, al comparar la exactitud obtenida por todos los localizadores de foramen en este estudio, se puede observar que los cuatro localizadores de foramen obtuvieron mayor exactitud en dientes con reabsorción interna que en dientes con reabsorción externa.

La medición corta de la longitud por el localizador de foramen puede explicarse por el hecho de que el dispositivo emite una alarma cuando la punta de la lima entra en contacto con el tejido periapical. En muchos casos, el tejido periapical penetra hasta cierto punto en el canal. Esta penetración es mayor en los dientes con ápice abierto y aquellos con ápice ancho y, por

lo tanto, la punta de la lima entra en contacto con el tejido penetrado en el canal antes de alcanzar el agujero apical, lo que resulta en una lectura corta de la longitud³⁹.

Finalmente, los resultados de este estudio guiarán al operador en la selección del localizador de foramen ideal para usar en piezas dentarias con reabsorción radicular externa y reabsorción dentinaria interna; y de esta manera, brindarle al dentista una mayor exactitud en la determinación de la longitud de trabajo, que es el factor clave en el éxito del tratamiento de conducto⁴⁰. Además, este estudio fomentará un aumento en el uso de localizadores de foramen en el manejo de diversas situaciones clínicas como las variantes patológicas.

Conclusiones

-Basado en este estudio en vitro, el localizador con más exactitud en dientes con reabsorción externa es el Raypex 6 y el localizador de foramen más exacto en dientes con reabsorción interna es el Root zx mini.

-La reabsorción radicular externa afecta más la exactitud de los localizadores de foramen que la reabsorción interna.

Reconocimiento

Los autores desean agradecer al Mg. Esp. Ronald Gonzáles, Ph.D. Esp. Jorge Álamo, C.d. Esp. Bruno Luján y C.d. Edwin Espinoza por su gran ayuda académica. Queremos agradecer a nuestra familia por su apoyo. Sobre todo, queremos agradecer a Dios por todas sus bendiciones.

Conflicto de intereses: "Ninguno declarado"



Fig 1. Pieza dentaria con preparación reabsorción interna verificada por una radiografía

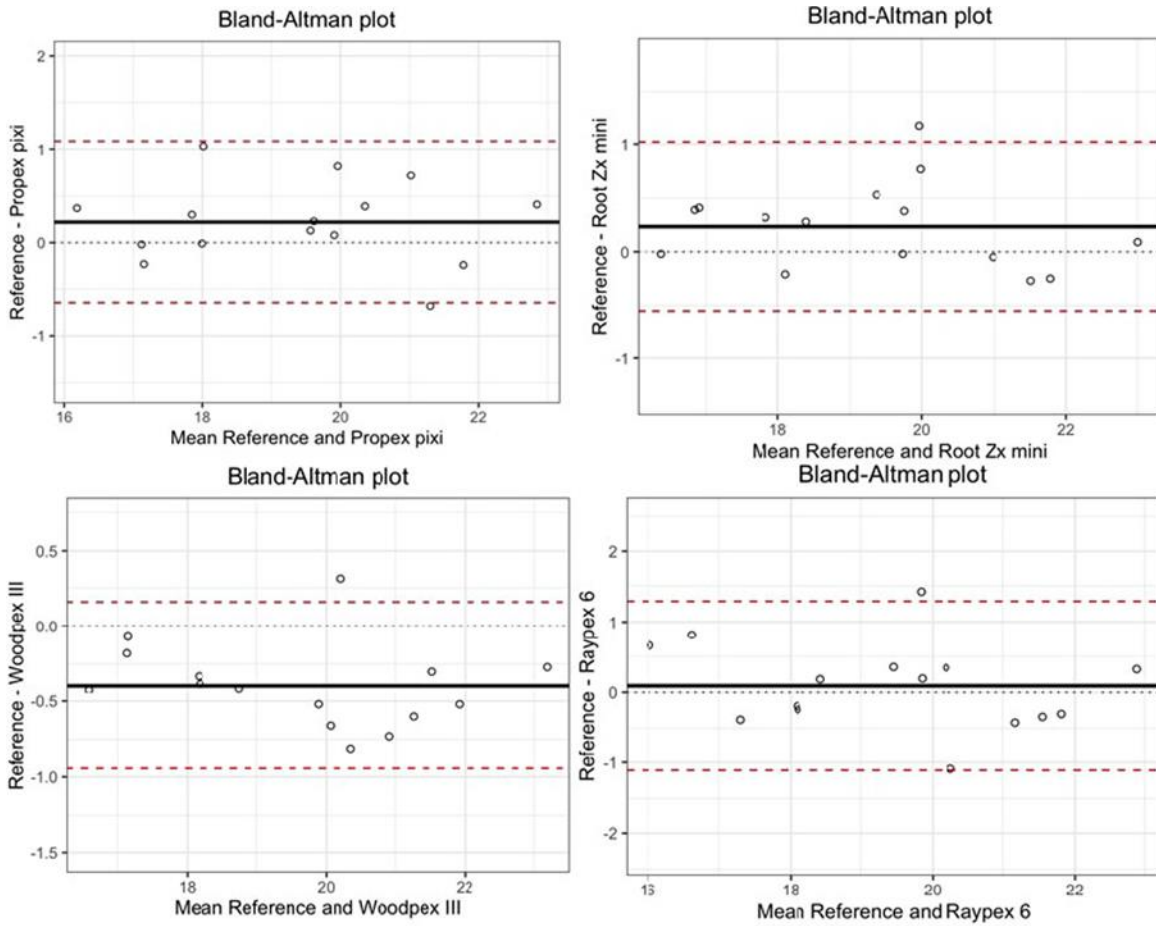


Fig 2. Gráfico Bland-Altman en Reabsorción Externa

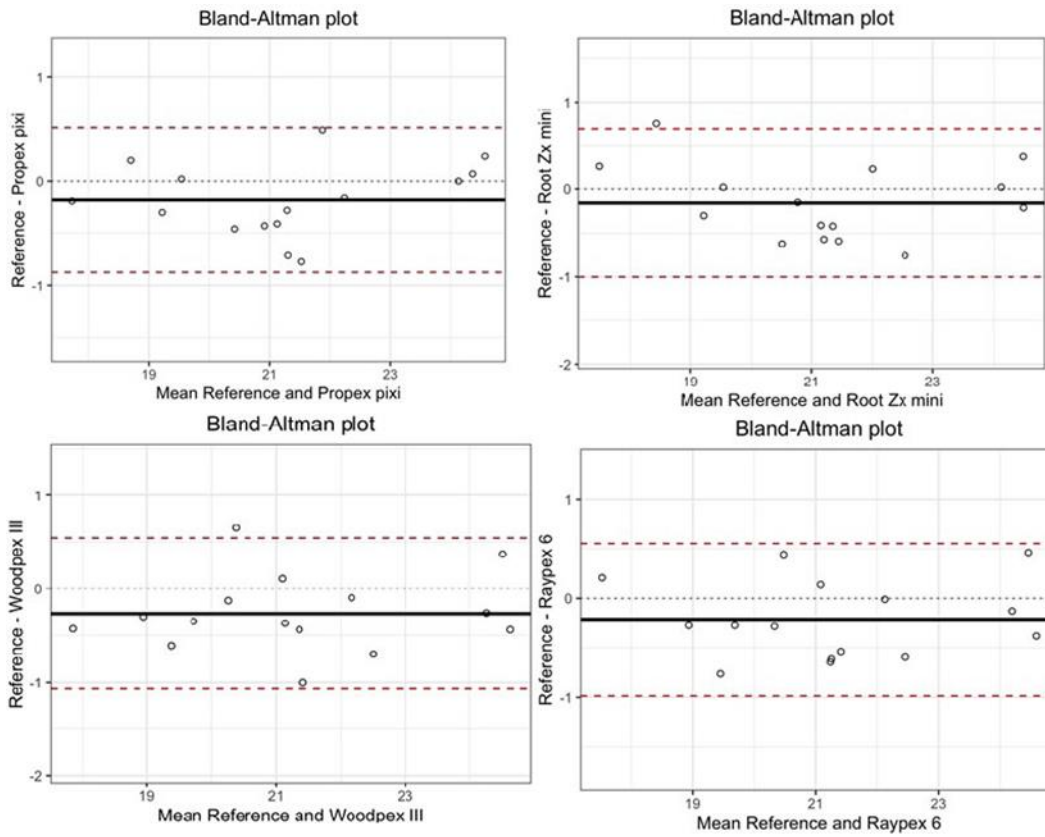


Fig 3. Gráfico Bland-Altman en Reabsorción Interna

Tabla 1 Comparación de la medición de la longitud de trabajo utilizando los localizadores apicales respecto a la longitud real, en los dientes unirradiculares con reabsorción apical externa.

Localizadores	X	(DS)	T	p *	ICCs	p**
Propex pixi	19.26	(1.95)	1,93	0.074	0.96	0.00
Root Zx mini	19.25	(2.00)	2,26	0.040	0.97	0.00
Woodpex III	19.88	(1.99)	-5,40	0.000	0.97	0.00
Raypex 6	19.39	(2.08)	0.56	0.583	0.95	0.00
LRT	19.48	(1.92)				

*Análisis estadístico con T-Student ($p < 0.05$)

**Coeficiente Correlación Intraclase (ICC) ($p < 0.05$)

Tabla 2 Comparación de la medición de la longitud de trabajo utilizando los localizadores apicales respecto a la longitud real, en los dientes unirradiculares con reabsorción apical interna.

Localizadores	X	(DS)	T	p*	ICCs	p**
Propex pixi	21.35	(1.99)	-1,96	0.07	0.98	0.00
Root Zx mini	21.33	(2.14)	-1,40	0.18	0.97	0.00
Woodpex III	21.44	(2.02)	-2,50	0.02	0.97	0.00
Raypex 6	21.38	(2.04)	-2,12	0.05	0.97	0.00
LRT	21.17	(2.06)				

*Análisis estadístico con T-Student ($p < 0.05$)

**Coeficiente Correlación Intraclase (ICC) ($p < 0.05$)

Tabla 3. Comparación de la Exactitud obtenida por los localizadores de foramen en piezas dentarias con Reabsorción Apical Externa

Localizadores	X	(DS)	F	P
Propex pixi	-0.27	(0.49)		
Root ZX Mini	-0.23	(0.49)	7.32	0.000
Woodpex III	0.46	(0.28)		
Raypex 6	-0.64	(0.61)		

Tabla 4. Comparación de la Exactitud obtenida por los localizadores de foramen en piezas dentarias con Reabsorción Interna

Localizadores	X	(DS)	F	P
Propex pixi	0.12	(0.42)		
Root ZX Mini	0.13	(0.44)	0.216	0.885
Woodpex III	0.20	(0.36)		
Raypex 6	0.21	(0.39)		

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13. Abreviaturas.-

1. Working length (WL)
2. Actual working length (AWL)
3. Longitud de trabajo (LT)
4. Longitud real de Trabajo (LRT)

14. ANEXOS

ANEXO 1

CARTA ACEPTACION 1

[IEJ] Editor Decision



Mohammad Jafa... 12:28 a. m.
para mí ^



De	Mohammad Jafar Eghbal via Journals Portal, Shahid Beheshti University of Medical Sciences • journalsserver@sbmu.ac.ir
Responder a	Mohammad Jafar Eghbal • iranendo@gmail.com
Para	Astrid lopez • astrid_vlm@hotmail.com
Fecha	20 de diciembre de 2021 12:28 a. m.

Dear Dr. Astrid lopez:

We have reached a decision regarding your submission to Iranian Endodontic Journal, "ACCURACY OF FOUR FORAMEN LOCATORS IN PREMOLARS WITH EXTERNAL APICAL REBSORPTION AND INTERNAL REBSORPTION: AN IN VITRO STUDY".

Our decision is: Accept Submission

Mohammad Jafar Eghbal
Editor-in-Chief
iranendo@gmail.com

ANEXO 2

PRUEBA IMPRENTA DEL ARTICULO



Accuracy of Four Apex Locators in Premolars with Root Resorption: An *In vitro* Study

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ARTICLE INFO	ABSTRACT
<p>Article Type: Original Article</p> <p>Received: 13 Sep 2021</p> <p>Revised: 18 Nov 2021</p> <p>Accepted: 11 Dec 2021</p> <p>Doi: 10.22037/iej.v17i1.35498</p> <p>*Corresponding author: Astrid López-Maekawa, Endodontics Specialist, Master Program in Stomatology, School of Stomatology, Universidad Científica del Sur, Lima, Peru</p> <p>E-mail: astrid_vlm@hotmail.com</p>	<p>Introduction: The aim of the present <i>in vitro</i> study was to compare the accuracy of the working length measurements of four foramen locators: Root ZX mini, Raypex 6, Woodpex III and Propex Pixi in uniradicular premolars with simulated root resorption. Materials and Methods: For this study, 30 single-rooted permanent premolars were selected. The samples were divided into two groups: 15 teeth with simulated external root resorption and 15 teeth with internal resorption. Each sample was immersed in containers with alginate covering only the root part. Measurements were acquired from the four foramen locators and compared with the working length measurements that have been previously obtained with the direct visual technique and the use of a Digital USB Microscope under 5x. Next, the Shapiro-Wilk normality test was applied. The ANOVA test and <i>t</i>-test for related samples were performed, in order to analyze the measurements obtained. Results: In the teeth with external resorption, no statistically significant differences in the measurements were obtained with Raypex 6 and Propex Pixi foramen locators, but there were statistically significant differences with Root ZX mini and Woodpex III Root Zx mini [Root Zx mini ($P=0.040$) and Woodpex III ($P=0.000$)]. On the other hand, in the samples with internal root resorption, there were no statistically significant differences in measurements with the Root ZX mini, Propex Pixi and Raypex 6 foramen locators. However, there were significant differences with Woodpex III. Conclusions: Based on this <i>in vitro</i> study, Raypex 6 had the highest accuracy in premolars with simulated external resorption and Root ZX mini was the most accurate in teeth with simulated internal resorption. Furthermore, external root resorption affects the accuracy of foramen locators more than internal resorption.</p> <p>Keywords: Apical Foramen; Electronic Apex Locator; Root Resorption</p>

Introduction

The determination of the working length is one of the most important factors that contribute to the success of endodontic treatment [1]. Thus, determining a correct working length (WL) constitutes an essential step to avoid over-instrumentation, which allows the passage of irritating substances beyond the apical foramen [2]. In addition, it also avoids under instrumentation that prevents total sealing of the root canal up to the apical constriction [1, 2].

The determination of the working length carried out with the radiographic technique presents many limitations, such as: the

difficulty in interpretation because it is a two-dimensional image [3]; and technical errors in angulation and developing made by the operator [4]. This traditional method makes it impossible to accurately determine the position of the apical constriction and the apical foramen [5].

Currently, Foramen locators are one of the most reliable tools to obtain a more accurate measurement of the working length [1]. These instruments reduce the number of required radiographies and minimize the subjectivity involved in radiographic interpretation [6].

In addition, the use of these devices has become widespread today, proving to be indispensable in endodontic practice due to

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Figure 1. Tooth with internal resorption preparation verified by periapical radiography

their high levels of accuracy 97.4% [7]; even under conditions in which it would have previously been unthinkable to achieve an accurate measurement, such as in the presence of blood, hypochlorite or pus [7].

However, despite its accuracy in locating the apical foramen; there are several anatomical variations such as C-shaped canals, dens invagination, root dilaceration, etc. [8, 9] which may affect the measurement obtained with the foramen locator. Among these pathologies, we find root resorption.

Root resorption is a loss of hard dental tissues as a result of clastic activity [10, 11]. Root resorption can be broadly classified into external and internal resorption by the location of the resorption in relation to the root surface [10, 11].

Also, external root resorption is an irreversible pathological process [12] which can occur in situations as a dental trauma, apical infection, internal bleaching, periodontal treatment, ectopically erupting and most commonly in the presence of orthodontic movements [13].

In addition, another pathology of endodontic interest is internal root resorption that was reported as early as 1830 [11, 14]. Internal resorption is usually caused by chronic infections, trauma, or inflammatory reactions of the pulp cells. Plus, internal resorption is usually asymptomatic, and is detected on routine radiographic examinations [10, 14]. Compared with root external resorption, it has a rare occurrence, and its etiology and pathogenesis have not been completely elucidated [11].

Furthermore, there is little information of the impact in the accuracy of foramen locators in permanent teeth with external root resorption [15]. Moreover, there are currently no studies on internal resorption.

As previously explained, it is important to study foramen locators in these types of pathology, as these may alter the determination of the working length in our clinical practice.

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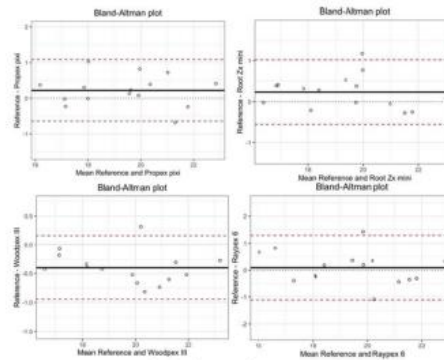


Figure 2. Bland-Altman plot in external resorption

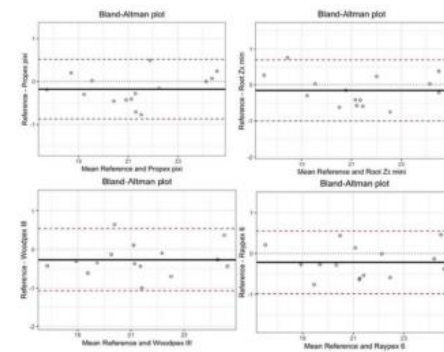


Figure 3. Bland-Altman plot in internal resorption

For this reason, the purpose of the present study is to compare the accuracy of the working length measurements of four foramen locators in single-rooted premolars with simulation of external and internal resorption.

Materials and Methods

The present study was approved by the Ethics Committee of Universidad Científica del Sur University in the City of Lima, Perú with Evidence N 193-CIEI-SCIENTIFIC-2020. A sample size was determined from the results of the pilot test, after which it was considered to use 30 freshly extracted teeth. Moreover, these had indication for tooth extraction for orthodontic, periodontal or pulp disease reasons and were donated for this study. Plus, periapical radiographs were taken

in buccolingual and mesiodistal directions in each tooth to verify the presence of a single root.

Afterwards, they were subjected to dental calculus removal using an ultrasonic device (UDS-J; Woodpecker, Guangzhou, China). Then, they were disinfected in 5.25% sodium hypochlorite for 2 h to remove traces of organic tissue from the outer surface of the root. Finally, they were stored in a sterile 0.9% saline solution until evaluation. [15]

The samples were divided into two groups: 15 teeth with external resorption and 15 with simulated internal resorption (n=15). Standard endodontic access was performed with a high speed medium round and fissure diamond burs (Micro Diamonds Technology, Israel) with water cooling.

After endodontic access, the cusps edges of the teeth were flattened with a medium round diamond bur (Micro Diamonds Technology, Israel) by approximately one millimeter, to facilitate measurements by means of a stable reference point [5].

Next, the coronal portion of each canal was flattened [5] using SX rotary files (Dentstply Maillefer, Ballaigues, Switzerland). Then, a # 10 k-file (Dentsply Maillefer, Ballaigues, Switzerland) was passed into the canal until the tip of the file emerged from the apical foramen, to determine the location of the apical foramen (central or lateral).

Each of the teeth was stored and codified with correlative numbers to identify them.

Table 1. Comparison of the measurement of the working length using the apical locators with respect to the real length, in single-rooted teeth with external apical resorption

Locators	Mean (SD)	T	P *	ICCs**	P
Propex pixi	19.26 (1.95)	1.93	0.074	0.96	0.00
Root ZX mini	19.25 (2.00)	2.26	0.040	0.97	0.00
Woodpex III	19.88 (1.99)	-5.40	0.000	0.97	0.00
Raypex 6	19.39 (2.08)	0.56	0.583	0.95	0.00
AWL	19.48 (1.92)				

* Statistical Analysis with ANOVA test (P<0.05); ** ICCs: Interclass correlation coefficient (P<0.05)

Table 2. Comparison of the measurement of the working length using the apical locators with respect to the real length, in single-rooted teeth with internal resorption

Locators	Mean (SD)	T	P*	ICCs**	P
Propex pixi	21.35 (1.99)	-1.96	0.07	0.98	0.00
Root ZX mini	21.33 (2.14)	-1.40	0.18	0.97	0.00
Woodpex III	21.44 (2.02)	-2.50	0.02	0.97	0.00
Raypex 6	21.38 (2.04)	-2.12	0.05	0.97	0.00
AWL	21.17 (2.06)				

* Statistical Analysis with ANOVA test (P<0.05); ** ICCs: Interclass correlation coefficient (P<0.05)

First, to create the artificial internal resorptions, the roots were horizontally sectioned with a 7.0/2.0 thick diamond disc (New Technology Instruments, Germany) at a distance of 7 mm from the apex. Then, semicircular cavities were made with No. 016 low speed steel bur (Dentstply-Maillefer, Tulsa, Okla, USA) near the periphery of each sectioned piece. Plus, they were glued with Superglue (Pelikan cyanoacrylate adhesive; Istanbul, Turkey). Finally, the resorption was verified by means of a periapical radiograph [16] (Figure 1).

Furthermore, to simulate external apical resorption, a 45-degree oblique cut was made at the root apex with a thin 7.0/2.0-thick diamond disc (New Technology Instruments, Germany), in such a way that the palatal wall is shorter than the vestibular by 3 mm [15].

Actual working length

All the canals were measured with a # 10 k-file (Maillefer) to have an *actual working length* (AWL) with the direct vision technique and the use of a digital USB microscope with a magnification of 50x (Fuzhou Conic Industrial Co., Fuzhou, Fujian, China):

First, in premolars with external resorption, the file was passively introduced through the canal until the tip of the file was visible through the palatal wall [15]. Second, the silicone stop was carefully adjusted to the reference point and proceeded to remove the file from the root canal. Third, it was measured with an Ubermann digital vernier caliper a digital vernier caliper (Ubermann®, Chile) from the silicone stop to the tip of the file. From this measurement obtained, 1 mm was subtracted manually and the measurement was registered.

In the case of teeth with internal root resorption, the file was introduced until the tip was visible through the apical foramen. Then, the silicone stop was then adjusted to the reference point and the file was removed from the canal. Next, it was measured with an Ubermann digital caliper (China) from the top to the tip of the file. Finally, from this measurement, 1 mm was subtracted.

Subsequently, all the teeth were placed in an alginate mold, in which once the impression material had set, the labial electrode of the locator was inserted in the mold in order to perform the measurements. These measurements are performed within the first 30 min of preparing the models to ensure that alginate retains enough moisture. [17]

Prior to electronic measurement, training and calibration intra and inter-observer were performed in the pilot study. The inter-observer calibration was carried out with a professor of endodontics with more than 10 years of experience from Universidad Científica del Sur.

Electronic measurement

Before electronic measurement, the canal was irrigated with 0.5 mL of 2.5% sodium hypochlorite to maintain humidity. The excess solution present in the root canal was dried using a #50 paper cone [18].

For electronic measurement, we used the following foramen locators: Raypex 6 (VDW, Munich, Germany), Woodpex III (Guilin Woodpecker Medical Instrument Co., Guilin, Guangxi, China), Propex Pixi (Dentsply Maillefer, Ballaigues, Switzerland) and Root ZX mini (J Morita Corp, Tokyo, Japan) with K-files #15 (Dentsply Maillefer, Ballaigues, Switzerland). All foramen locators were calibrated according to the manufacturers' instructions before measurements.

The foramen locator electrode was attached to a file and carefully inserted into the root canal. The measurements were taken according to the manufacturers' instructions:

In the Root ZX mini, which is based on the same functioning method of the Root ZX mini but has a compact size [18], the file was carefully inserted into the canal until it passed through the apical foramen; in this case a single sustained beep will sound, and the word "APEX" and the little triangle next to the Flash Bar will start to flash on and off. Then the file is moved back until the LCD screen shows us that the file is in the first green bar (the bar color changes to green to indicate you have reached a critical area), that indicates the file tip reaches a position near the apex [19].

In the case of the Propex Pixi, the file was carefully inserted into the root canal until it passed the apical foramen, which was showed in the foramen locator with a red "OVER" segment and an audio warning signal (rapid intermittent signal), and the file was moved back where the Propex Pixi indicates '0.0'. Then the file was placed onto an endodontic ruler and the apical length was measured. Finally, a minimum of 0.5 mm was subtracted from the measured file length. This is a safety precaution suggested by the manufacturer to avoid over-instrumentation and allowed us to make sure that we are in the apical zone [20].

In the case of Raypex 6, the file was carefully inserted into the canal until it passed through the apical foramen, this was indicated on the screen by the appearance of a red warning point underneath the apical zoom image and brief warning sounds. Then, the file was moved backward until the locator screen indicated that we were within the first two green bars.

Table 3. Comparison of the accuracy obtained by foramen locators in teeth with external resorption

Locators	Mean (SD)	F	P
Propex pixi	-0.27 (0.49)	7.32	0.00
Root ZX mini	-0.23 (0.49)		
Woodpex III	0.46 (0.28)		
Raypex 6	-0.64 (0.61)		

This corresponds to the section of the apical constriction up to the apical foramen, that is the relevant region for determining the working length [21].

In Woodpex III, the file was carefully inserted into the root canal until it passed through the apical foramen. This is indicated when red bars are displayed on the foramen locator, along with a continuous sound "beep" sound. The file was retracted until the screen indicated that the file is within the first green bar, which indicates the file has gone the position near by the apical foramen [22].

All the measurements were considered valid if the reading remained stable for 5 sec [18]. The file was then removed and measured with an Ubermann digital caliper (China) from the silicone stop to the tip of the file.

Statistical methods

Each sample was evaluated twice: one for measuring the actual working length and then using the four foramen locators. Later, we proceeded to compare both measurements.

All the measurements were collected in a database in Excel. Then, all the data was recorded in the STATA statistical program (STATA version 14; STATA, Texas, USA) and statistical analysis was performed.

A descriptive analysis was carried out in which the measurements obtained with the different locators were described: means, standard deviation and range were obtained. Subsequently, an inferential analysis was performed, where the working length measurements were compared with the measurements obtained with all the foramen locators in both types of resorption. First, the Shapiro-Wilk normality test was applied. Then, as the results were within a normal distribution, the ANOVA test was performed, and *t*-test for related samples, in order to analyze the measurements obtained.

Results

In the comparison of the measurement of the working length obtained with the foramen locators, regarding the actual length in the teeth with external resorption. It was found that there were no statistically significant differences in measurements obtained with Raypex 6 (*P*=0.58) and Propex Pixi (*P*=0.07) locators; while there were significant differences in the measurements of the Root

Table 4. Comparison of the accuracy obtained by the foramen locators in teeth with internal resorption

Locators	Mean (SD)	F	P
Propex pixi	0.12 (0.42)	0.216	0.885
Root ZX mini	0.13 (0.44)		
Woodpex III	0.20 (0.36)		
Raypex 6	0.21 (0.39)		



ZX mini ($P=0.04$) and Woodpex III ($P=0.00$) compared to the AWL. The most accurate foramen locator in this group was the Raypex 6. In the Interclass correlation coefficient all the values obtained with all the foramen locators were more than 0.90 ($P=0.00$), that means that there is a good correlation between the foramen locators (Table 1). Bland and Altman plots show the accuracy of the foramen locators in relation to the actual working length, proving to be a good estimator of the real value of the variable (Figure 2).

On the other hand, in the comparison of the measurement of the working length obtained with the foramen locators related to the actual working length in teeth with internal root resorption, it is evident that there were no statistically significant differences in the measurements obtained with the foramen locators Root ZX mini ($P=0.18$), Propex Pixi, ($P=0.07$), Raypex 6 ($P=0.05$), but there were significant differences in the measurements obtained with the Woodpex III ($P=0.02$) compared to the actual working length in this group. Root ZX mini was the most accurate foramen locator in this group. In the interclass correlation coefficient all the foramen locators obtained values more than 0.90 ($P=0.00$), that means that there is a good correlation between the foramen locators (Table 2). Bland and Altman plots show the accuracy of the foramen locators in relation to the reference measurements, proving to be a good estimator of the real value of the variable (Figure 3).

Furthermore, regarding the accuracy obtained by the foramen locators in teeth with external root resorption, there is a statistically significant difference ($P=0.00$) between the four foramen locators (Table 3).

Finally, according to the accuracy obtained by the foramen locators in teeth with internal resorption, there is no statistically significant difference ($P=0.88$) between the four foramen locators (Table 4).

Discussion

The purpose of this study was to determine the accuracy in the measurements of the working length of four foramen locators in premolars with two different pathological variants. Likewise, there is little research in the use of foramen locators in teeth with external resorption and no studies in teeth with internal root resorption. Therefore, this study is of relevance for being the first to investigate the accuracy of foramen locators in teeth with internal resorption.

The methodology for preparing the teeth with external root resorption in this research is based on the study of Jadhav *et al.* [15] who performed the simulation of the external resorption through a 45 degrees cut in the apex, and alginate was used as an electro conductive medium. Moreover, they obtained the

accuracy of Raypex 6, Root ZX and iPex (NSK, Nakanishi Inc., Tochigi, Japan). As a result, it was found that Raypex 6 showed significant accuracy in teeth with simulated external root resorption. Plus, this finding matches the results of the present study in which the Raypex 6 show the greatest accuracy in teeth with simulated external root resorption.

Various factors may influence the accuracy of foramen locators such as the diameter of the apical foramen [23], the foramen locator used [24] and the moisture content of the root canal [25].

In a study of Herrera *et al.* [23], artificial enlargement of the diameter of the apical constriction was made in 10 single-rooted teeth. They found that the accuracy of Root ZX varies depending on the diameter of the apical constriction. This study coincides that of Aydin *et al.* [26], which found that the accuracy of Root ZX decrease with the increase of the apical diameter. Furthermore, according to the manufacturer of the Root ZX mini, this locator can show short measurements in the presence of an exceptionally large apical foramen [19].

Plus, according to Pawar *et al.* [27] the Raypex 6 is the locator with the best performance in teeth with wide apical diameters. This agrees with our results in which the accuracy of the Raypex 6 was not altered in teeth with external resorption.

Teeth with external root resorption offer difficulties to contemporary methods of determining working length. Moreover, apical constriction, which is considered the most appropriate place to end endodontic therapy, is not present in teeth with root resorption and open apices [28, 29]. Thus, it can be infer that with the increase of the apical foramen, the taper towards the apex disappears and the walls of the root canal become more parallel [26], this may be the reason that the accuracy of the Root ZX mini was altered.

Other factor that influence the measurement of the foramen locator is the device used. Root ZX mini is a fourth locator generation which measures the impedance of tooth at two different frequencies [30]; and its disadvantage is that it need to be in a relatively dry or partially dry canal. In some cases additional drying is required; and it cannot function in a root canal with high exudate and blood [19, 31].

Raypex 6 is a sixth generation foramen locator [32] that overcome the disadvantages of 4th generation foramen locators. The foramen locator sixth generation adapts immediately in a dry or wet canal. In this way, it can be used in dry and wet canals, root canals with blood or exudates [33].

All the samples both with internal and external root resorption followed the same irrigation and drying protocols previous to the electronic reading. Root canals with external resorption are more difficult to dry, because the roots canals at the apical level are wider than the root canals with internal

resorption. In this study, the moisture content in the canal at the apical level possibly modified the results. For this reason, the Raypex 6 locator obtained the best accuracy in teeth with external root resorption.

On the other hand, in regard to teeth with internal root resorption, the Root ZX mini was the locator that achieved the highest accuracy. Morita's Root ZX mini, which is considered the gold standard of locators, has obtained excellent results in studies on permanent teeth with mature apices [34].

In an *in vivo* study by Serna-Pena et al. [18] the accuracy of the Root ZX mini and Propex Pixi in single rooted teeth was studied. They found that the accuracy of the Root ZX mini in establishing the AWL was 100% range of ± 1 mm. Then, the accuracy of Propex Pixi in establishing the AWL was 89.99% range of ± 1 mm. This result coincides with our study in which the Root ZX mini was the most accurate foramen locator, followed by Propex Pixi in teeth with internal resorption.

Additionally, in clinical practice we find various morphological variants such as C-shaped canals and root curvatures. The Root ZX mini foramen locator has also been shown to have good accuracy against these anatomical variants [35-37] where the diameter of the apical foramen was not altered.

Even though there is loss of surrounding dentine and this tissue is thinner in the site of the resorption, internal resorption did not affect the accuracy of the foramen locators. The reason is the presence of dentin. Root canals are surrounded by dentine and cementum that are insulators to electric current. Plus, insulators cannot conduct electric currents because all their electrons are tightly bound to their atoms [38]. In the present study, internal resorption has no communication with the periodontal ligament that is a conductor of electric current. Further studies with perforating internal root resorption are necessary, in these cases where there is communication with the periodontal ligament.

On the other side, when comparing the accuracy obtained by all the foramen locators in this study, it can be seen that the four foramen locators obtained greater accuracy in teeth with internal resorption than with teeth with external resorption.

Underestimation of length by apex locator may be explained by the fact that the device alarms when the file tip contacts the periapical tissue. In many cases, the periapical tissue penetrates into the canal to some extent. This penetration is greater in open apex teeth and those with a wide apex and thus file tip contacts the tissue penetrated into the canal before reaching the apical foramen resulting in underestimation of the length [39].

All in all, the results of this study will guide the operator in selecting the ideal foramen locator to use in teeth with external root resorption and internal dentin resorption; and in this way,

provide the dentist with greater accuracy in determining the working length, which is the key factor in the success of root canal treatment [40]. In addition, this study will encourage an increase in the use of foramen locators in the management of various clinical situations such as pathological variants.

Conclusions

Based on this *in vitro* study, the most accurate locator in teeth with external resorption is the Raypex 6 and the most accurate foramen locator in teeth with internal resorption is the Root ZX mini. External root resorption affects more the accuracy of the foramen locators than internal resorption.

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Conflict of Interest: 'None declared'.

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ANEXO 3

CONSTANCIA DE APROBACIÓN DEL COMITÉ DE ÉTICA

COMITÉ INSTITUCIONAL DE ÉTICA EN INVESTIGACIÓN 

CONSTANCIA N° 193-CIEI-CIENTÍFICA-2020

El presidente del Comité Institucional de Ética en Investigación de la Universidad Científica del Sur (CIEI-CIENTÍFICA) da constancia que el proyecto de investigación, cuyos datos se registran a continuación, ha sido **aprobado** por el CIEI-CIENTÍFICA.

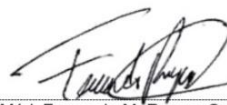
Código de registro: **056-2020-POS8**
 Título: **Comparación de la exactitud de cuatro localizadores apicales en premolares unirradiculares con simulación de reabsorción apical y reabsorción dentinaria interna**
 Investigador(a): **Astrid Vanessa Lopez Maekawa**

La aprobación del proyecto de investigación implica que el documento presentado a evaluación cumple con los lineamientos de Universidad en materia de investigación y ética, los cuales se sustentan en la normativa internacional vigente. Adicionalmente, en el contexto de la pandemia de enfermedad por COVID-19, le recomendamos cumplir con las normas publicadas por el estado peruano.

En tal sentido, esta aprobación carecerá de valor si es que el proyecto de investigación arriba indicado es modificado de cualquier forma. Toda enmienda, añadido, eliminación o eventualidad (eventos adversos, etc.) posterior a la fecha de aprobación debe ser reportado al CIEI-CIENTÍFICA.

La vigencia de la aprobación de este documento es de dieciocho (18) meses (**hasta el 22 de enero del 2022**), periodo en el que puede desarrollarse el proyecto. Cualquier trámite para su renovación deberá ser enviado antes del término de la vigencia de este documento, debiendo suspenderse todo desarrollo hasta que la renovación sea aprobada.

Villa El Salvador, 23 de julio de 2020




Méd. Fernando M. Runzer Colmenares
 Presidente
 Comité Institucional de Ética en Investigación

Asesoría al postulante
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ANEXO 4

RESOLUCIÓN DE APROBACIÓN DEL PROYECTO DE TESIS



RESOLUCIÓN DIRECTORAL DE ACEPTACIÓN DEL PROYECTO DE TESIS Y NOMBRAMIENTO DEL ASESOR

RESOLUCIÓN DIRECTORAL DE LA CARRERA DE ESTOMATOLOGÍA N° 050-DACE-DAFCS-U. CIENTÍFICA-2021

Lima, 14 de setiembre del 2021

VISTO:

El informe técnico del Comité Institucional de Ética en Investigación de la Universidad Científica del Sur con código N° 056-2020-POS8, se aprueba el proyecto de Tesis Titulado: “COMPARACIÓN DE LA EXACTITUD DE CUATRO LOCALIZADORES APICALES EN PREMOLARES UNIRRADICULARES CON SIMULACIÓN DE REABSORCIÓN APICAL Y REABSORCIÓN DENTINARIA INTERNA” presentado por ASTRID VANESSA LÓPEZ MAEKAWA.

CONSIDERANDO:

Que, de acuerdo al Reglamento General de la Universidad Científica del Sur y los reglamentos de pre/posgrado para obtener el Grado Académico de MAESTRO EN ESTOMATOLOGÍA en la Carrera de Estomatología de la Universidad Científica del Sur, se debe desarrollar un trabajo de investigación.

Que, de acuerdo con la normativa vigente de la Universidad Científica del Sur, en uso de las atribuciones conferidas al Director Académico de Carrera.

SE RESUELVE:

ART. 1º: APROBAR E INSCRIBIR el Proyecto de Tesis titulado: “COMPARACIÓN DE LA EXACTITUD DE CUATRO LOCALIZADORES APICALES EN PREMOLARES UNIRRADICULARES CON SIMULACIÓN DE REABSORCIÓN APICAL Y REABSORCIÓN DENTINARIA INTERNA” de el/la Bach. ASTRID VANESSA LÓPEZ MAEKAWA, con registro: N° 056-2020-POS8 y establecer el inicio de periodo de ejecución del mencionado proyecto el pasado 23 de julio del 2020 hasta el 22 de enero del 2022 como indica la constancia del Comité de Ética..

ART. 2º: NOMBRAR Asesor/a del trabajo de tesis señalado, a al/la Mg. Esp. Carmen Rosa García Rupaya.

Regístrese, comuníquese y archívese.



Dr. Claudio Peña Soto
Director Académico de la Carrera de Estomatología



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ANEXO 6

INSTRUMENTOS USADOS EN LA INVESTIGACION

- Localizador de Foramen Root Zx mini
- Localizador de Foramen Raypex 6
- Localizador de Foramen Propex Pixi
- Localizador de Foramen Woodpex III
- Calibrador vernier digital (Ubberman@Chile)
- Microscopico USB Digital (Fuzhou conic industrial Co, LTD Fujian, China)



Localizador Root Zx mini



Localizador Raypex 6



Localizador Propex Pixi



Localizador Woodpex III



Calibrador Digital



Microscopio usb Digital