Comparative study of three electronic apex locators in the determination of working length

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ABSTRACT

Introduction: Tooth length measure is important to endodontic treatment success. **Objective:** This in vitro study was conducted to compare the ability of three electronic devices when measuring foramen and apical contrition. **Methods:** One hundred human single-rooted teeth were used to have direct measurement (tooth length) performed by inserting the file into the root canal until its tip was visualized in the apical foramen. Measurement by apex locators (Neosono Ultima EZ, Foramatron IV e Tri Auto ZX) was performed twice to establish measurement of the apical foramen and constriction. Results were considered acceptable when coinciding with direct measurements, or different from ± 0.5 mm. One-way ANOVA, Tukey-Kramer and Student t-tests were performed. **Results:** Tri Auto ZX was more accurate in locating the foramen (86.3%) and apical constriction (84.2%). There was no difference between Tri Auto ZX and Foramatron IV when locating the constriction ($p = 0.19$). As far as the apical foramen measurement, Tri Auto ZX and Neosono Ultima EZ were similar in precision ($p = 0.13$). **Conclusions:** Tri Auto ZX was more accurate in locating the apical foramen than Foramatron IV and was also more effective in measuring a point close to and below the foramen when compared to Neosono Ultima EZ.

Keywords: Endodontics. Root canal preparation. Tooth apex.

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Introduction

Correctly determining the working length of root canals is fundamental for endodontic treatment success. Studies indicate that its ideal measurement is defined when the apical constriction is located.[1-3] In order to achieve a precise measure, it is necessary to use instruments with adequate accuracy.

Many dentists perform radiographic imaging examination to define the apical limit, but the resulting image is 2D and often does not allow for anatomical and pathological variations when present in dental elements.[4,5] As a result, apex locators were developed to supply the endodontic technique with precision and quality.

The first generation of devices worked with direct current (resistance type).[6] The second generation uses alternating current and evaluates impedance, such as in Foramatron IV and Neosono D.[7] In the 90's, devices assessing the difference or relation of impedance variations to electrical currents of different frequencies, providing reliable measurements,[7-9] were developed. Some examples include te Neosono Ultima EZ and Root Zx (also incorporated in Tri Auto ZX).

Efficacy of apex locators as an alternative to radiographic examination in determining the working length has already been proven.[7,9-11] However, due to the various options of equipment available on the market, verifying their accuracy is fundamental to assist professionals in choosing those with adequate accuracy to measure the apical constriction. Thus, the purpose of the present in vitro study was to evaluate the ability of three different electronic apex locators to find the apical foramen, as well as a point lying close to it.

Material and methods:

The study was approved by the Ethics Committee of Human Research (process #693/10).

One hundred single-rooted human teeth with completely formed roots were selected, extracted for reasons unrelated to the present research, and stored in 10% formaldehyde solution. The teeth were washed in water for 24 hours. After endodontic access, root canal patency and foramen were verified with a #15 K-file (Maillefer, Ballaigues, Switzerland) introduced into the canal until it reached 1 mm from the apical foramen. When necessary, the incisal edges were planned with a carborundum disc to create sharp reference edges in order to facilitate future measurements. After being duly numbered, teeth were measured by means of direct and electronic methods, as described below.

Direct method

A 31-mm # 15 K-file was inserted into the canal until its tip, visualized with the aid of a magnifying glass (under 2.5 X magnification), reached the most cervical edge of the apical foramen. In this position, the file was seized with a needle holder placed tangent to the reference edge and removed from the canal. The distance from the tip of the file to the point of apprehension by the needle holder was measured using an electronic pachymeter (Starret, 727-6 / 150, Brazil) with 0.01-mm resolution. The obtained measurements, denominated as tooth length (TL), were duly recorded for comparison with measurements provided by the electronic devices.

Electronic method

When measuring by the electronic method, teeth were secured at the cement-enamel junction height to the perforated cap of a plastic bottle so that the root was submerged in saline solution contained inside the bottle.[12,13] The labial clip of the employed apparatus was adapted to another perforation made into the cap. The former also remained in contact with saline solution. The root canal was filled with saline solution up to its cervical third, leaving the pulp chamber free of solution. Electronic devices evaluated were: Neosono Ultima EZ (Amadent, USA), Foramatron IV (Parkell, USA) and Tri Auto ZX (J. Morita Corp., Japan). For each tooth, two electronic measurements were obtained with the three different apex locators. The first one was made to locate the foramen, whereas the second aimed to locate the apical constriction.

Neosono Ultima EZ and Foramatron IV

In order to obtain tooth length by the electronic method, from the reference border to the apical foramen (CEF), a K-file attached to the file holder was inserted slowly into the canal until the locator tip reached the apical foramen (0.0 in the display). At this point, the sound emitted by Neosono is extinguished and the sound emitted by Foramatron becomes re-

petitive. The instrument, seized with the needle holder and removed from the canal, was measured with the pachymeter as aforementioned described for the direct measurement. With a view to locating the constriction or a point near and below the foramen (CEC), the instrument was seized and removed from the canal when the tips of these devices reached the 0.5 level, also visible by the viewfinder.

Tri Auto ZX

At first measurement (CEF), the file was seized and removed from the canal when all lights on the display up to the apex level were on and the sound became continuous. In second measurement (CEC), file apprehension and removal occurred when all display lights, up to level 0.5, were on and the sound became more repetitive.

Data analysis

To evaluate the reliability of devices and their clinical suitability, measurements provided by both direct (CD) and electronic (CEF and ECC) methods were displayed in tables in SPSS Statistics™ (version 20.0; SPSS Inc., Chicago, IL, USA) software, subsequently compared and submitted to one-way ANOVA, Tukey-Kramer and the paired Student t-tests. Regarding the ability to locate the foramen, electronic measurements (CEF) were considered acceptable when they coincided with direct measurements or differed from ± 0.5 mm (tolerance limit). Considering that the apical constriction is situated on average 0.5 mm and 0.7 mm from the apical foramen,[1,2] and applying the same tolerance limit (± 0.5 mm) to evaluate the ability of devices to locate a point near and below the apical foramen (constriction), electronic measurements were considered acceptable when they coincided with the CD or ≤ 1.2 mm.

Results

Five teeth were excluded from the experiment due to file fracture (one tooth) and root canal obstruction (four teeth).

Table 1 and 2 present analyses of variance comparing direct measurement of both the apical foramen and a point near, as well as below the foramen with the apex locator measurements, respectively. Table 3 shows the comparison between the apex locator proportions of the apical foramen measurements, and Table 4 shows values referring to the length below the apical foramen.

Comparison between direct (CD) and electronic (CEF) methods revealed Neosono Ultima EZ device provided 74 acceptable measurements (77.9%); in other words, 74 measurements were coinciding with CD or different from ± 0.5 mm. Of the 21 measurements considered unacceptable, one remained beyond and 20 fell short of the apical foramen.

Table 1. Analysis of variance test and individual comparisons by Tukey--Kramer test of CD X CEF relationship.

APPARATUS	MEANS	DEVIATION	F	p
FORAMATRON IV	-0,50[b]	0,81	6,377	0,001
NEOSONO ULTIMA EZ	-0,27[a]	0,38		
TRI AUTO ZX	-0,21[a]	0,48		

Note: * one-way ANOVA; Tukey-Kramer p < 0.05;

Table 2. Analysis of variance test and individual comparisons by Tukey--Kramer test of CD X CEC relationship.

APPARATUS	MEANS	DEVIATION	F	p
NEOSONO ULTIMA EZ	-1,29[a]	0,62	33,38	<0,001
FORAMATRON IV	-0,91[b]	1,11		
TRI AUTO ZX	-0,37[c]	0,48		

Note: * one-way ANOVA; Tukey-Kramer p < 0.05.

Table 3. Testing of proportions for the CDI X CEF ratio.

COMPARISON	PERCENTAGES	p*
Neosono X Foramatron	77,9 X 62,1	0,0176
Neosono X Tri Auto	77,9 X 86,3	0,1300
Foramatron X Tri Auto	62,1 X 86,3	0,0001

Note:*Paired Student t -test.

Table 4. Test of proportions for the CDI X CEC relationship.

COMPARISON	PERCENTAGES	p*
Neosono X Foramatron	52,6 X 76,8	0,0005
Neosono X Tri Auto	52,6 X 84,2	0,0001
Foramatron X Tri Auto	76,8 X 84,2	0,1997

Note:*Paired Student t -test.

When using Foramatron IV, 59 measurements were considered acceptable (62.1%). Of the 36 unacceptable ones, two were beyond the apical foramen and 34 fell short of the apical foramen.

Tri Auto ZX provided 82 acceptable measurements (86.3%). Of the 13 unacceptable measurements, two were beyond while 11 were below the apical foramen.

Comparison among lengths obtained by direct (CD) and electronic (CEC) methods revealed Neosono Ultima EZ provided 50 acceptable measurements; in other words, 50 measurements were coinciding with CD or ≤ 1.2 mm (52.6%). All 45 measurements considered unacceptable fell short of the apical foramen.

When using Foramatron IV, 73 measurements were considered acceptable (76.8%). Of the 22 unacceptable ones, four were beyond the apical foramen while 18 were below.

Tri Auto ZX provided 80 acceptable measurements (84.2%). Of the 15 unacceptable ones, 13 were beyond while two were below the apical foramen.

Discussion

Accuracy of apex locators is determinant for high-quality endodontic treatment.[9-11] Thus, based on the results of the present research, Tri Auto ZX was more accurate in the location of the foramen and constriction and lower accuracy when compared to Foramatron IV and Neosono Ultima EZ. Other studies performed with Tri Auto ZX consider it reliable to measure not only a point located near and below the apical foramen, but also to locate adequate working length in cases of endodontic retreatment, root fractures, and also in apical limit control during biomechanical preparation of root canals.[12,14-17]

Alves et al[12] conducted an ex vivo study and measured the length of 62 single-rooted canines. Three measurements were obtained for each tooth. In the first one, the file was inserted until visualized at the root apex; for the second one, electronic apex locators were used; and the third measurement taking procedure occurred with the same locators after biomechanical preparation, filling and removal of filling material of root canals. The first measurement coincided in 76% of the cases, with the second measurement performed by Tri Auto ZX. After removal of filling material from the roots, the accuracy of this locator increased to 81%. Other authors found that after in vitro biomechanical preparation of 20 roots in the group in which Tri Auto ZX located the working length at 1 mm distance from the root foramen, accuracy was higher than the one located at 2 mm, when compared with the actual tooth length at 1 and 2 mm from the apical limit.[18]

According to measurements obtained with Tri Auto ZX, which were unacceptable in locating a point below the foramen, 13 teeth had measurement beyond while two were below acceptable length. Some studies have shown that the irrigating solution used in root canals may influence apical localization.[8,19] However, for the present laboratory-based study, saline solution was used based on other applicable methodologies.[12,13] Additionally, it was neutral, aiming to hydrate extracted teeth.

Erdemir et al[19] used Tri Auto ZX to measure 140 teeth in vivo in the presence of irrigating solutions such as: 0.9% saline solution, 2.5% sodium hypochlorite, 3% hydrogen peroxide, 0.2% chlorhexidine, 17% EDTA, and Ultracaine DS. Based on the results, the group of teeth irrigated with saline solution had the lowest accuracy (35%) in the location of apical constriction, which was longer compared to the other groups (85%).

In the present study, Neosono Ultima EZ accuracy for the measurement up to the apical foramen did not present significant difference in comparison with Tri Auto ZX. But it was less than a point below the foramen. Some studies involving Neosono Ultima EZ have verified its measurement changes according to the experimental conditions to which it is exposed.[20,21] Researchers measured the length of glass tubules containing different solutions with Neosono Ultima EZ and two other locators. According to data analysis, it was observed that Neosono Ultma EZ was more reliable in measurements with a ± 1 mm margin of the final real distance, and it varied according to the solutions present inside the tubules.[21] In contrast, Lucena-Martín et al[22] detected in vitro the accuracy of 100% of 20 single-rooted teeth measured with Neosono Ultima EZ with a margin of ± 0.5 mm from direct measurement of the apical foramen.

The accuracy of the measurements performed by the Foramatron IV in this study was lower when compared to another study.[23] The authors observed

that Foramatron IV coincided in 80% of cases with the actual working length, and this was more accurate than the radiographic method (76.6%).[23] The lower precision of this device that was obtained in the present research can be justified because it belongs to the second generation of apex locators whose reading can suffer interference from ionized liquids, blood and exudate.[7] In addition, studies present different methods and may interfere with results.

Growing technological innovation has given rise to new apex locators, aiming to increase precision due to adversities found in endodontic treatment. However, exact measurement of working length can still vary according not only to the type of device used, but also to anatomical differences and irrigating solutions.[8,9] But even in face of drawbacks, the most recent apex locators present high precision and are equal or superior[24,25] when compared to those belonging to previous generations and that were used in the present research.[26,27]

Conclusions

Based on this study results, it can be concluded that there was a difference in the behavior of the three electronic apex locators tested. Tri Auto ZX was the most effective in locating the apical foramen and in measuring a point short and near the apical foramen.

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