IN VIVO ACCURACY AND RELIABILITY OF A NEW APEX LOCATOR IN LOCALIZE THE APICAL FORAMEN

CESAR RENEE VARGAS **RAMOS**[1], KEY FABIANO SOUZA **PEREIRA**[2*], PEDRO GREGOL DA **SILVA**[3], LÍVIA WOLF DOS **SANTOS**[1], ANA CAMILA FERREIRA DA SILVA **QUEIROZ**[1], LUIZ FERNANDO **TOMAZINHO**[4]

1. Master Students, Faculty of Dentistry - Federal University of Mato Grosso do Sul; **2.** Assistant Professor of Endodontics, Faculty of Dentistry - Federal University of Mato Grosso do Sul; **3.** Adjunct Professor, Associate of Discipline of Radiology, School of Dentistry - Federal University of Mato Grosso do Sul; **4.** Titular Professor of Endodontics at the University Paranaense – UNIPAR –Paraná.

* Rua das Garças, 427 - Apto 55, Campo Grande, Mato Grosso do Sul, Brazil. CEP 79010-020
keyendo@hotmail.com

Received: 06/26/2015. **Accepted:** 07/02/2015

ABSTRACT

The objective of this study was evaluated in vivo accuracy and reliability to identify the apical foramen by Quill® Apex Locator. Patients with indication for extraction by orthodontic and periodontal reasons were selected, which resulted in a sample of 21 root canals. Performed the cavity access, the cervical and middle parts of the root canal were prepared and proceeded up the readings at the corresponding point on the display device up to the apical foramen. After that the file was fixed and the tooth extraction was performed. Subsequently we performed a wear on one wall of the apical region, aiming to visualize the tip of the instrument and the continuity up to the apical foramen. The distance between the file tip and the apical ending foramen (FA-I) was measured with the SEM, and were assigned positive values for the instruments that were beyond the apical foramen and negative to the instruments that were before the apical foramen. The sample data showed a mean 0.116 mm (± 0.307 mm) for the variable I-FA, it was close to the apical foramen (zero point). The values did not show any data discrepancy but a certain balance between positive and negative values, with the highest concentration of data in the range of -0.3 to 0.3 mm. In accordance with the t test ($p = 0.097$) it was concluded that there was no significant evidence to reject the average of I-AF is equal to zero (apical foramen). The study demonstrated that the device Quill® was accurate and reliable to identify the apical foramen.

KEYWORDS: Endodontics, odontometry, equipment and supplies.

1. INTRODUCTION

The evolution of endodontic knowledge had its beginnings when it was consolidated that bacteria play a key role as an etiological factor of pulp and periapical changes. Since then, the aim of endodontic treatment became the incessant search for decontamination of the root canal system and its consequent sanitation for later fillings[1].

For the success of these procedures, however, the correct determination of apical limits of endodontic treatment reverses are of particular importance, as evidenced by in vivo studies, in which the most favorable histologic conditions were found when the shutter remained short or apical constriction[2]. Thus, the apical constriction has been recommended as an ideal limit to the working length, since it corresponds to the narrowest portion of the root canal diameter.

Through the decades, various methods have been proposed in order to determine the end of root canals, including mathematicians, radiographic and electronic methods[3].

The radiographic method, when properly executed, can be considered accurate and reliable. However, it is virtually impossible to get X-rays without distortion. The measures highlighted the tip of the instrument to the radiographic vertex are usually larger than the real, which can lead to malpractice. Moreover, the radiographic image provides a two-dimensional view of a three dimensional object, it is often difficult to interpret due to the overlapping anatomical structures[4,5]. Therefore, the search of greater reliability and accuracy in determining the working length appeared to electronic techniques, constant targets of studies and advances in endodontics.

The apical locators, now more properly called electronic locators foraminal, have been proposed and developed nearly a century ago, but only from the 50s began to be employed[6]. However, the reliability of this generation apparatus was not contemplated, especially in channels containing moisture. Other generations of handsets have been launched for decades, but, without satisfactory results on the accuracy and reliability of the

electronic method in evaluating in vitro or in vivo, problem is always linked to moisture in the root canal.

The previously described problem was solved when a variation of the electronic measurement method of root canals from the determination of the electrical resistance values as a function of two alternating current frequencies was demonstrated, which enabled the reading under humid conditions inside the root canal. From this, many locators were manufactured and the accuracy and reliability of each of these devices have been studied in depth, obtaining excellent results[7,8].

Although the locators indicates the distance between the tip of the file and the apical foramen, the most reliable measure happens when the tip of the file is located on the apical foramen, i.e., the browser reads the apical foramen. Clinically locators when used in reading the apical foramen, as well as better precision, gives the actual length of the tooth and by subtracting this measure is to allow the operator to set the working length below 0.5 mm or 1 mm to ensure that all endodontic treatment phases are limited to root canal [9].

Many studies have shown good results with the use of electronic odontometry, revealing that accurate measurements are obtained with various types of locators foraminal currently[10-12]. However, with the emergence of new devices in the dental market, it is important that further research be conducted, particularly in methodologies to assess the functioning of these devices *in vivo* in order to check and compare the efficiency in measuring the root canal accurately and reliably.

2. MATERIAL AND METHODS

This study, in vivo, held odontometry readings in 21 human teeth (04 maxillary central incisors, upper lateral incisors 03, 01 lower central incisor, lateral incisor 01, 05 upper canines, canine lower 01, 01 first premolar, 02 upper second premolars, 02 lower first premolars, 01 seconds premolar), with prior indication of extraction for orthodontic or periodontal reasons. Patients were submitted to anamnesis and clinical examination by a trained operator for the experiment. The study was approved by the Ethics Committee of the participating institution (CAAE: 07102412.5.0000.0021). Initial radiographic examinations were performed in order to detect situations that would throttle the experiment. The apparent length of the tooth was measured on the radiograph using a millimeter ruler endodontic, and obtaining the length of interim work.

After antisepsis of the operative field, the teeth were anesthetized by infiltration of local anesthetic articaine 4% with epinephrine 1: 100,000 (DFL®, Brazil). The teeth were absolute isolation, and any metal restore this removed during coronary opening procedure in order to avoid interference in the readings of the electronic finder.

After the location of the channel entrance, the initial catheterization K file 10 or 15 (Dentsply Maillefer®, Switzerland) was performed, to approximately 4 mm below the provisional working length established by measuring the tooth length in the original image radiography. Abundant irrigation of sodium hypochlorite solution at 2.5% was made the pulp cavity during this procedure. In all cases, prior to the measurement electronics, the preparation was carried out of the cervical and middle thirds with drills Gates Glidden figures 2 and 3 (Dentsply Maillefer®, Switzerland) and the root canal at the mouth end enlargement was done with the drill CPdrill (Helsen®, Brazil).

Aiming to exploring the path again initially recognized, the instruments were positioned again for 4 mm exploratory provisional length. In cases of dead or necrotic pulp, the excess bleeding or sodium hypochlorite at the level of the pulp chamber was drawn into the realization of the measure.

In order to measure electronically, a file type K (Dentsply Maillefer®, Switzerland) that best adjust to the anatomical diameter of the root canal was introduced toward the apex until the green light to stay lit, as described below sequence (modus operandi according to the manufacturer):

- Insert the tool into the root canal, making sure that it fits the walls of the canal to the provisional working length;
- Turn on the apparatus;
- Connect the electrode (colgante pole) in the corner of the mouth of the patient;
- Connect the other electrode to file (lime port);
- The instrument should be introduced apical turning it gently clockwise or oscillatory movements. As the file approaching the foramen, the device LEDs will be illuminated by the green light and remain stable, which means that it has reached the apical foramen "position FO" (foraminal output).

When the file get to the point "0.0" (green light), it was fixed with cyanoacrylate (Henkel®, Brazil) and light-cured composite resin (Evolu-x Dentsply®, Brazil) was inserted around the file to fill all crown opening.

In sequence, the total isolation was removed and the tooth extracted as the surgical technique indicated. The obtained teeth were cleaned with sodium hypochlorite at 2.5% for 10 minutes and stored in saline solution.

Before subjecting the sample measurements, the same were prepared as described below. The output of the apical foramen was visually identified by inserting the tip of a K file 08 or 10 (Dentsply Maillefer®, Switzerland) on its external portion, towards apex/ Crown only to facilitate its location. This maneuver aimed properly choose which face could be worn. The last 4 mm dentin wall of the outer faces of the root were gently removed by wear with carborundum disk (Komet®, Bra-

zil).

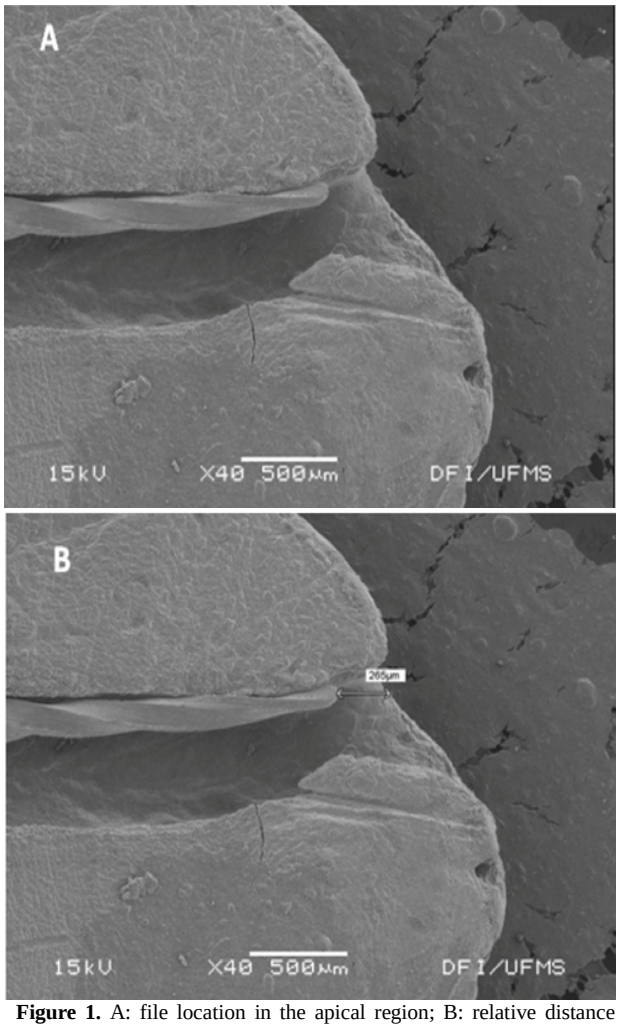

Figure 1. A: file location in the apical region; B: relative distance from the tip of the file - foraminal real output (I-FA).

We used the scanning electron microscope (SEM) JSM - 6380LV (JEOL®, Japan), increasing 40 or 50 times and photographs were taken to measure relative distances the tip of the file – via actual output foraminal WITHOUT User Control software interface Version 7.6 Copyright © 2004 (JEOL Technics LTD., Japan) (Figures 1 and 2).

Data analysis was performed using statistical analysis under the Anderson-Darling test and Student's t test.

3. RESULTS

The study consisted of a sample of 21 elements, which was measured the distance from the tip of the instrument to the apical foramen of the analyzed teeth (variable I-FA) in millimeters, with positive values for instruments that have passed the apical foramen and negative (-) for instruments that fell short of the foramen.

Through the scatter plot (Figure 3), one can get an idea of behavior and how the data is distributed. It is

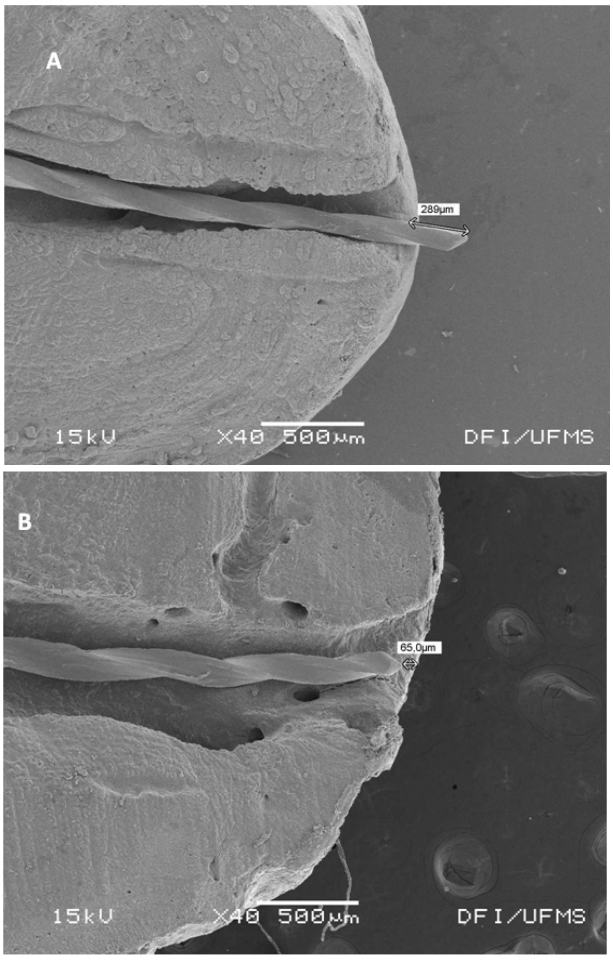

Figure 2. A: file position exceeding the apical region; B: relative distance from the tip of the file - real foraminal exit.

noticed that 9 values were negative and 12 positive, moreover, much of the data is between - 0.3 and 0.3 mm.

To verify the normality of the I-FA sample variable data made up the Anderson-Darling test. It was found that the sample showed normal distribution p-value (0.240) under significance level of 5% ($\alpha = 5\%$). After, we proceeded with the t-test in a single sample to verify, under the null hypothesis, the average assumption of variable I-FA equal to 0 (zero), the test statistic value and p-value (0.097) and significance level $\alpha = 5\%$, the average does not reject the hypothesis of 0 (zero) of the variable I-AF.

The sample data showed an average of 0.116 mm for the variable I-FA, reasonably close to zero. Presented right balance between positive and negative values, with the highest data concentration between - 0.3 to 0.3 mm.

For inferential analysis ($\alpha = 5\%$) it was found that, statistically by Anderson-Darling method, the data are normally distributed, using t test, it is concluded that there is significant evidence for rejection average R-FA is equal to zero (apical foramen).

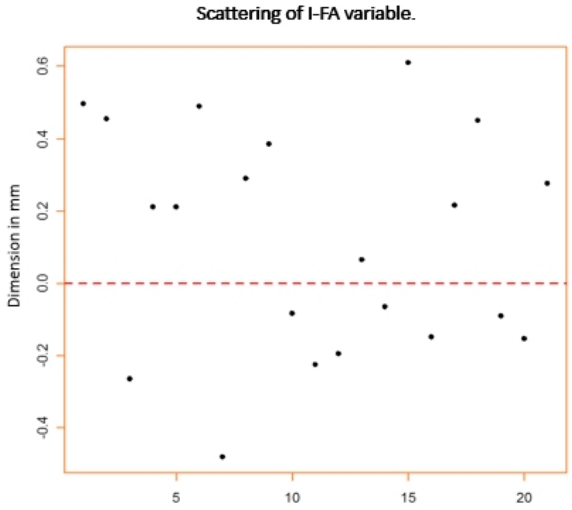

Figure 3. Scatter plot of the variable I-FA.

4. DISCUSSION

Mechanical preparation and endodontic filling, should be limited to dentin canal, histologically area occupied by pulp tissue[2]. The big challenge is to define the working length in function of the apical limit of instrumentation and filling mainly because evidence shows that the correct location is a crucial factor for the success of endodontic treatment[13].

Radiographic of odontometry methods are still the most used and disseminated to clinicians in helping endodontic therapy. However, it is difficult to obtain radiographs without distortion[5,14]. The location of the apical foramen does not coincide in over 60% of cases with the root apex and the distance between these structures varies from 0 to 3 mm[15,16]. Thus, we find that it is virtually impossible to pinpoint the location of the apical foramen, based on the radiographic apex.

The shift of the foramen should be considered during endodontic treatment, for the radiography does not detect the deviation[17]. This data is most critical when evaluating teeth with pulp necrosis carriers of periapical lesions visible radiographically as conventional radiographs are not adequate resources in the diagnosis of apical root resorption in the early stages and this problem is accentuated when the root lysis is present in the face buccal or palatal root involved[18]. Thus, faced with a treatment that requires precision so that success is achieved, radiography should not be isolated and conclusive factor in determining the limit instrumentation and filling of root canals.

The use of electronic devices in odontometry is increasingly common in endodontic practice. Electronic locators foraminal (LFE) does not have the same limitations of radiographic methods and the benefits achieved with their use are well known. The third generation apparatus can be regarded as the most reliable method to determine the working length in endodontic therapy[10,12,19]. They were executed in vivo studies in order to attest to the accuracy and reliability of the electronic method[10,20]. These studies selected patients with teeth extractions indicated for periodontal, orthodontic or prosthetic reasons. This methodology is often used because it offers closer to what happens clinically results as it provides direct visualization of the apical limit of the property determined by the electronic method for the actual position of the largest foramen.

This study used a methodology similar to most in vivo studies evaluating the accuracy of LFEs, differing in diversification of morphological groups of teeth, instrument fixation type in the channel and especially the visualization method and measurement of the actual position end of the instrument and the actual output of the apical foramen.

The preparation of the cervical and middle thirds was carried out with drills Gates-Glidden[10], prior to measurement, since according to the results found in the study[21], who evaluated the Root ZX locator, the values obtained by the device with progressive instrumentation technique found them much closer to the real working length. This fact is probably due to the instrument could play more wall in the apical region causing more effectively read the impedance region[22].

This research used as irrigating solution sodium hypochlorite to 2.5%, which has no influence in the process of electronic measurement[23,24]. It was not taken care to remove the excess liquid from the pulp chamber, which prevents the irrigating solution contact with the external environment the pulp cavity, promoting a shift in the passage of electric current, leading to device read error[10,20].

The methodology option by measuring the Scanning Electron Microscope (SEM) was adopted because this equipment has great magnification power with high image quality, providing high sharpness, depth of focus (image three-dimensional appearance) and has specific software accuracy for measuring measurement units. Aiming to verify the accuracy of a machine working in tenths of millimeters, a tool that is accurate in measuring quality should be the choice for evaluation, because we have to get reliable measures, which do not compromise the search result[10,25].

The measurements were performed under conditions and clinical variables belonging to the own endodontic treatment and gathering the group investigated morphologically different types of teeth, thus achieving a greater diversification of possible anatomical situations during the experiment[10,19,25].

Measurements of the apical foramen were performed using the demarcation of the corresponding device to "0.0" (green LED), which corresponds to the location of the apical foramen in QUILL® locator. The location of

the apical foramen through electronic odontometry is currently considered the most correct way of using LFEs[22]. The accuracy of performing the measurement reading with anatomically as the apical foramen is explained in a study[9] which evaluated in vivo, a modified version of QUILL® device designed especially for the experiment. For this, a total of 21 root canals were analyzed and the results demonstrated the ability of the foramen locator based on ray method in locating the apical foramen. The results also demonstrated and explained because the impedance locators based on the radius of the method are not able to determine the end of the file into the root canal with accuracy. According to the authors, the reason why this happens is because the impedance distance (or range) will not change significantly in this region. These points, in the case of QUILL®, corresponding numeric markings between 3 and 0.5 from the apical foramen and can only be used by dentists as a reference to find the file that the tip is near the apical foramen.

The diameter of the file connected to the electrode must be compatible with the diameter of the canal in the apical area, favoring the accuracy of LFEs[26,27]. Thus, in teeth with complete root formation, electronic measurement should be performed gauge compatible files. To read the samples in this study, files were used 10, 15 and 20, as were those best adapted for reading, after cervical and middle preparation of root canals[11].

When analyzing the results of the experiment, we note that the statistical tests, relating to data supplied by the readings QUILL® device in relation to point 0.0, did not represent statistically significant differences [10,19,23,25,28].

The sample data showed a mean of 0.116 mm to variable filling I-FA, reasonably close to zero. It did not present any data discrepancy and yes right balance between positive and negative values, with the highest concentration data in the range of - 0.3 to 0.3 mm. Similar data were found[19], which investigated the accuracy of the gold standard unit of accuracy and reliability in the scientific literature, Root ZX® in locating the apical foramen. The authors found 96.2% accuracy within a range of 0.5 mm.

According to the biological pulp conditions the QUILL® behaved within an acceptable clinical limit of determination of the working length; as from the location of the apical foramen the endodontist can do decrease of 0.5 mm or 1 to start the preparation root canal and in accordance with the values of the measures found. Always procedures instrumentation and filling would be contained within the root canal, close to the desired limit for the endodontic therapy, the CDC limit.

The variation of the measures in specimens values can be clarified by the complex anatomy of the root canal in its apical third. In cases where there is the presence of large lateral canals, the measures may be influenced, marking a shorter working length[23]. This statement is in line with the results of[29], which investigated the relationship between impedance and root apical anatomy human teeth and demonstrated that the impedance values found in root canal with a single foramen were significantly higher when compared to complex anatomy (several foramen). Thus, the apparatus described played increasing the apical third of the canal capacitance generating shorter readings.

Considering: the importance of establishing a correct apical limit of instrumentation and filling that respect the biological space delimited by the apical tissues, and the limitations of the radiographic method in the precise location of this limit, the QUILL® device was capable and reliable in locating the apical foramen, as from the identification of this anatomical structure. We can back 1 mm to stay close to the average of the desired limit by professionals, ie the apical constriction and CDC also limit.

5. CONCLUSION

According to the results the QUIL® apex locator (Ultradent, USA) was accurate and reliable in locating the apical foramen *in vivo*.

REFERENCES

[1]. Kakehashi S, Stanley HR, Fitzgerald RJ. The effects of surgical exposures of dental pulps in germ-free and conventional laboratory rats. Oral Surg Oral Med Oral Pathol. 1965; 20(9):340-49.

[2]. Ricucci D, Langeland K. Apical limit of root canal instrumentation and obturation: part 2. A histologic study. IntEndod J.1998; 31(6):394-409.

[3]. Nekoofar MH, Ghandi MM, Hayes SJ, Dummer PMH. The fundamental operating principles of electronic root canal length measurement devices. Int Endod J. 2006; 39(8):595-609.

[4]. Bramante CM, Berbet A. A critical evaluation of some methods of determining tooth length. Oral Surg Oral Med Oral Pathol. 1974; 37:463-73.

[5]. Olson DG, Roberts S, Joyce AP, Collins DE, McPherson JC. Unevenness of the Apical Constriction in Human Maxillary Central Incisors. J Endod. 2008; 34(2):157-9.

[6]. Sunada I. New method for measuring the lenght of the root canal. J Dent Res. 1958; 41(2):375-87.

[7]. Vajrabhaya L, Tepmongkol P. Accuracy of apex locator. End Dental Traumatol. 1997; 13:180-2.

[8]. Yamaoka M, Yamashita Y, Saito T. Electrical root canal measuring instrument based on a new principle – makes measurements possible in a wet root canals. Japão: Osada Product Information; 1989: 12 p.

[9]. Rambo MVH, Gamba HR, Borba GB, Maia JM, Ramos CAS. In vivo assessment of the impedance ratio method used in electronic foramen locators. Bio Medical Engineering OnLine 2010, 9:46 doi:10.1186/1475-925X-9-46.

[10]. Chita JJ, Silva PG, Pereira KFS, Onoda HK, Borba JC, Ramos CAS. Precisão e Confiabilidade de um Novo Localizador Foraminal Eletrônico. Pesq Bras Odontoped Clin Integr. 2012; 12(4):457-63.
[11]. D'Assunção FL, Albuquerque DS, Ferreira LC. The ability of two apex locators to locate the apical forame: in vitro study. J Endod. 2006; 32(6):560-2.
[12]. Vardasca De Oliveira PT, Chita JJ, Silva PG, De Vicente FS, Pereira KFS. Análise da precisão de dois localizadores foraminais de fabricação chinesa e o Root ZX II. Pesq Bras Odontoped Clin Integr, João Pessoa. 2010; 10(1):83-8.
[13]. Schaeffer MA, White RR, Walton RE. Determining the optimal obturation length: a meta-analysis of literature. J Endod. 2005; 31(4):271-4.
[14]. Gonçalves Real D, Davidowicz H, Moura-Netto C, Zenkner CLL, Pagliarin CML, Barletta FB, Moura AAM. Accuracy of working lenght determination using 3 electronic apex locators and direct digital radiography. Oral Surg Oral Med Oral Pathol Oral Radiol Oral Endod. 2011; 111:44-9.
[15]. Dummer PMH, Mcginn JH, ReeS DG. The position and topography of the apical constriction and apical foramen. IntEndod J. 1984; 17:192-8.
[16]. Kutler Y. Microscopic investigation of root apexes. J Americ Dent Ass. 1955; 50:544-52.
[17]. Blaskovic-Subat V, Marici B, Sutalo J. Asymmetry of the root canal foramen. Int Endod J. 1992; 3:158-64
[18]. Ferlini Filho. Estudo radiográfico e microscópico das reabsorções radiculares na presença de periodontites apicais crônicas (microscopia óptica e de varredura). [Tese]. Bauru: Faculdade de Odontologia de Bauru, Universidade de São Paulo; 1999.
[19]. Shabahang S, Goon WWY, Gluskin AH. An "in vivo" evaluation of Root ZX electronic apex locator. J Endod. 1996; 22(11):616-8.
[20]. Dunlap C, Remeikis NA, Be Gole EA, Rauschenberger CR. An in vivo evaluation of an electronic apex locator that uses the ratio method in vital and necrotic canals. J Endod. 1998; 24(1):48-50
[21]. Ibarrola JL, Chapman BL, Howard JH, Knowles KI, Ludlow MO. Effect of preflaring on Root ZX apex locators. J Endod. 1999; 25:625–6.
[22]. Pereira KFS, Da Silva PG, De Vicente FS, Arashiro FN, Coldebella CR, Ramos CAS. An in vivo study of working length determination with a new apex locator. Braz Dent J. 2014; 25(1):17-21.
[23]. Kobayashi C, Suda H. New electronic canal measuring device based on the ratio method. J Endod. 1994; 20(3):111-4.
[24]. Meares WA, Steiman HR. The influence of Sodium Hipochlorite Irrigation on the Accuracy of the Root ZX electronic apex locator. J Endod. 2002; 28(8):595-8.
[25]. Pagavino G, Pace R, Baccetti T. A sem study of "in vitro" accuracy of the Root ZX electronic apex locator. J Endod. 1998; 24(6):438-41.
[26]. Ebrahim AK, Wadachi R, Suda H. Ex vivo evaluation of the ability of four different electronic apex locators to determine the working lenhth in teeth with various foramen diameters. Aust Endod J. 2006; 51(3):258-62.
[27]. Herrera M, Ábalos C, Planas AJ, Llamas R. Infuence of apical constricton diameter on Root ZX apex locator precision. J Endod. 2007; 33:995-8.
[28]. Wrbas KT, Ziegler AA, Altenburger MJ, Schirrmeister JF. In vivo comparison of working length determination with two electronic apex locators. I Endod J. 2007; 40:133-8.
[29]. Ardeshna SM, Flanagan M, Ng YL. Gulabivala K. An investigation into the relationship between apical root Impedance and canal anatomy [abstracts British Endodontic Society Spring Scientific Meeting 2008]. Int Endod J. 2008.