Accuracy of electronic apex locator in relation to the condition of human dental pulp: Histological and histochemical study.

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Abstract: This study was conducted to evaluate the effect of pulp condition on the accuracy of apex locator compared with periapical radiograph. 50 patients were collected for this study. Endodontic treatment was performed with root length measurement with 5th generation apex locator (AL). X-ray was performed while the file in place to verify the working length. The pulp was extirpated for histological and histochemical examination. After histopathological and histochemical examination, the extirpated pulps were classified into 5 groups (10 canals in each group), Group I: normal pulp, Group II: acutely inflammed pulp, Group III: chronically inflammed pulp, Group IV: degenerated pulp, Group V: degenerated pulp with periapical radiolucency. From the radiographic findings and histopathological finding we concluded that presence of pulp tissue inside the canal (normal or inflammed pulp tissue) affects the accuracy of AL during root length determination. As AL gives the most accurate readings in case of degenerated pulp without periapical radiolucency. While in case of degenerated pulp with periapical radiolucency, the AL tends to give over reading in most cases.

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1.Introduction:

Anatomy of the root apex should be considered to obtain accurate working length. This anatomy includes: **Root apex** is the most apical part of the root, **Apical foramen** (major foramen) is located on one side of the anatomical apex. Finally, the **apical constriction** (minor foramen or cementodentinal junction) is that part of the root canal in the apical region with the smallest diameter (**Ricucci and Langeland, 1998**).

The minor diameter is located 0.5–0.75 mm coronal to the major diameter which in turn is located about 0.5 mm coronal to the apical terminus (**Green ,1960, Kuttler, 1995**). As a result, working length (WL) determined from radiographs is generally measured about 1 mm short of the radiographic apex (**Gordon and Chandler, 2004**).

The traditional methods for establishing working length include: Tactile sensation (**Chandler and Bloxham, 1990**), moisture on a paper point (**Ruddle, 2002**) and the use of radiography (**Stein and Corcoran,1992**). Most of these methods have limitations. So, electronic apex locators (EALs) were developed. The principal design and development of the early apex locators dates back to **Suzuki (1942)**. He carried out a research on dogs and discovered that the electrical resistance between the periodontal membrane and the oral mucosa was a constant value. This principle was introduced into clinical practice by **Sunada (1962)** as he measured the electrical resistance between oral mucosa and periodontal ligament by approximately 6.5 kX.

The 1st generation apex locator was discovered by **Sunada (1962)**. It was known as "resistance apex locators". It was supplied by single frequency of direct current. Pain was often felt with this type of apex locator. In addition, these devices gave unreliable measurements in case of wet canals (**Suchde and Talim, 1977**).

The 2nd generation apex locator was supplied by single frequency of alternating current to detect changes in the canal impedance. So, it was called "impedance apex locators" (**Suchde and Talim, 1977**). This generation contains 2 types of apex locator: low frequency and high frequency apex locator. Low frequency AL is based on the assumption that the impedance between the oral mucous membrane and the depth of the gingival sulcus closely resembles the impedance between the canal terminus and the oral mucous membrane (**Inoue, 1973**). While high frequency AL used an insulator to cover most of the surface of the file (**Hasegawa, 1979**). **The 3rd generation apex locator** has been called "frequency dependent" apex locators. This type was supplied by 2 frequencies **to** measure the impedance in the canal. There are 2 types of the

3rd generation ALs: impedance difference type and impedance ratio type. impedance difference AL **measures the impedance value at two different frequencies and calculates the difference between the two values (Yamashita, 1990)** while impedance ratio type measured the position of the file from the ratio between these two impedances (**Kobayashi and Suda, 1994**).

4th generation apex locator measures the impedance characteristics using more than two frequencies (**Welk et al., 2003**). A significant disadvantage of the fourth generation devices is that they need to perform in relatively dry or in partially dried canals (**Vera and Gutierrez, 2004**).

5th generation apex locator was developed in 2003. It measures the capacitance and resistance of the circuit separately. It is supplied by diagnostic table that includes the statistics of the values at different positions to diagnose the position of the file (**Gordon and Chandler, 2004**). Devices employing this method experience considerable difficulties while operating in dry canals (**Slavcho and Dimitur, 2009**).

During clinical work it is noticed that the accuracy of electronic root canal length measurement varies with the pulp and periapical condition (**Kovacevic *et al.*, 2006**). So, pulp condition and periapical diseases should be considered to evaluate the relation between the pulp state and accuracy of electronic apex locators.

Aim of the study:

The aim of this study is to evaluate the accuracy of electronic root length determination (using 5th generation apex locator) in relation to pulp pathosis compared with periapical radiograph .

2.Materials and methods:

This study included 50 patients who were diagnosed for endodontic treatment for different reasons. The procedures were performed in endodontic clinic of Faculty of Oral and Dental Medicine, Nahda University.

Patients with grade 3 mobility or root caries were excluded. Preoperative x-ray was performed to the patient to detect the presence of periapical radiolucency. Access cavity preparation was performed, the file introduced in the canal and root length determination was performed using 5th generation apex locator (i-Root) before any irrigant is used. Another radiograph was taken while the file in place to verify the working length then the pulp was extirpated. The extirpated pulp was stored in 10% buffered formalin for standered histopathological examination and histochemical analysis using Alcian blue (pH 2.5) & PAS for detection of mucopolysaccharides (MPSs).

According to the preoperative x-ray and histological analysis, the pulps were classified into 5 groups (10 canals in each group): Group I: normal pulp, Group II: acutely inflammed pulp, Group III: chronically inflammed pulp, Group IV: degenerated pulp, Group V: degenerated pulp with periapical radiolucency.

The conventional radiographs were converted into digital form by scanner and the images were introduced to Digora soft ware to measure the distance between the file tip and radiographic apex. The apex locator was considered to be accurate if the file tip was located within 0.5 mm of a point 1.0 mm short of the radiographic apex (-1 ± 0.5 mm) (**Oliver *et al.*, 2002, Eduardo Akisue, 2007**).

So, The working length was considered to be: **accurate**: if the distance was ranging from 0.5 to 1.5mm, **over**: if the distance was less than 0.5mm, **under**: if the distance was more than 1.5mm.

3. Results

(A) Histopathological results:

In group V (which had degenerated pulp with periapical radiolucency): the pulp were completely degenerated by liqiufaction necrosis. So there were no histological samples in this group. The histopathological results of the other groups (I, II, III, IV) are Illustrated in figures 1, 2, 3 and 4.

Figure 1A revealed the normal pulp which is surrounded by odontoblastic layer. Figure 1B showed the acutely inflammed pulp which is congested with blood and surrounded by disrupted odontoblastic layer. Figure 1C showed the chronically inflammed pulp with disrupted odontoblastic layer and hyaline degeneration of the connective tissue. Finally, figure 1D showed absence of odontoblastic layer and complete degeneration of connective tissue.

Figure 2A revealed the normal pulp with continuous odontoblastic layer and normal size blood vessels, figure 2B showed acutely inflammed pulp with dilated blood vessels, figure 2C showed the pulp stone in chronically inflammed pulp while figure 2D showed large area of necrosis and decreased cellularity of connective tissue in necrotic pulp.

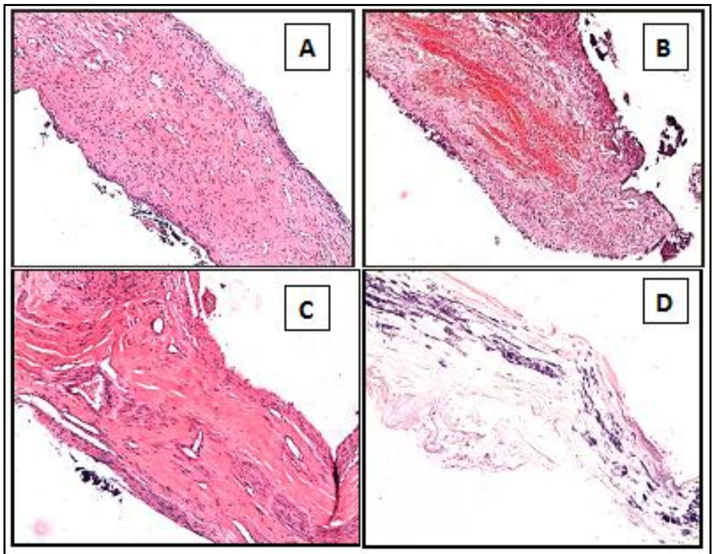

Fig. 1: Difference between the 1st group (A), 2nd group (B), 3rd group(C) and the 4th group (D) with low magnification (H&E x 100).

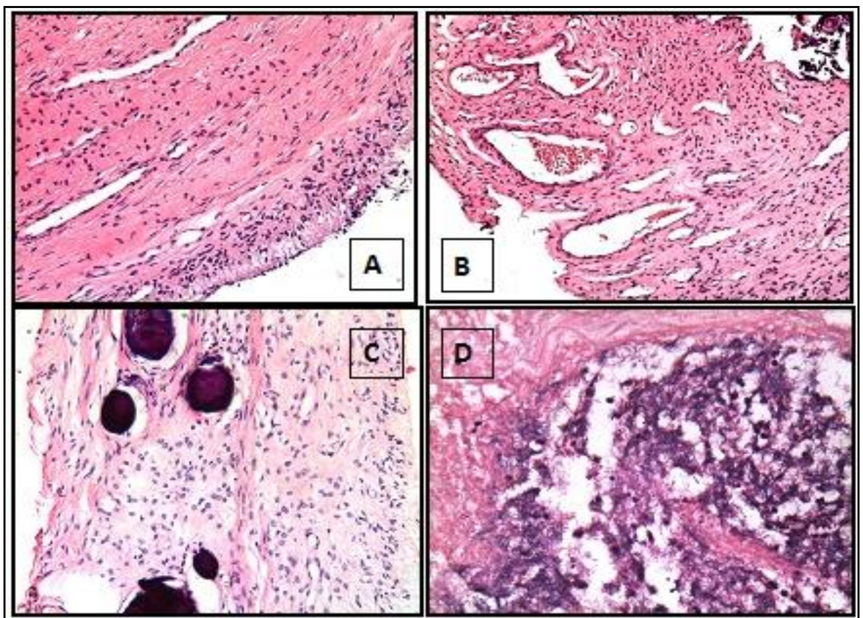

Fig.2: Difference between the 1st group (A), 2nd group (B), 3rd group(C) and the 4th group (D) with higher magnification (H&E x 200).

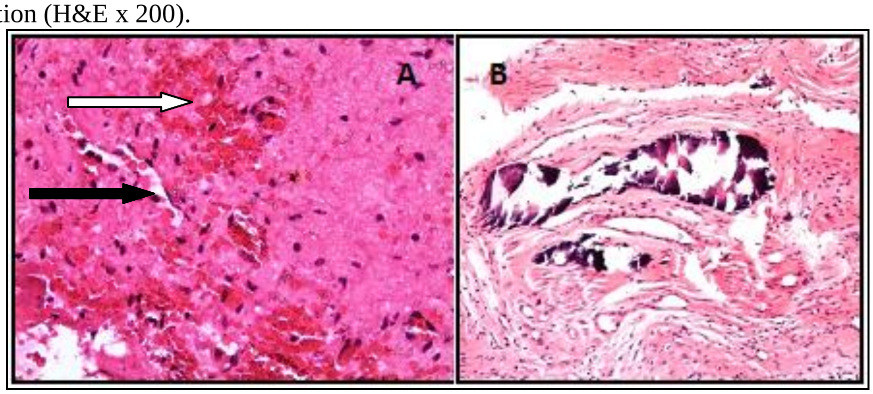

Fig.3: Comparison between blood vessels in groupII (A) and group III(B)

Figure 3A demonstrates dilated blood vessels while its endothelial lining is interrupted (black arrow) and extravasated RBCs present in the connective tissue (white arrow) while figure 3B demonstrates dilated blood vessels engorged with coagulated blood.

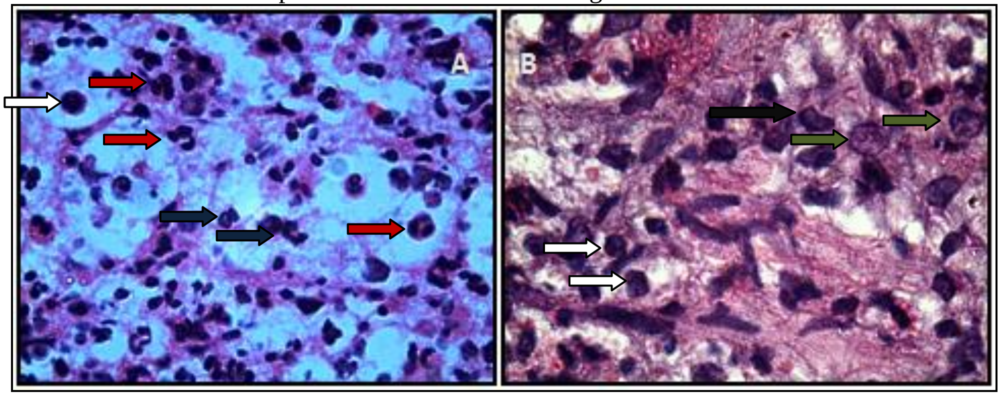

Fig.4: Types of cells present in groupII (A) and group III(B) by oil immersion lenses

Figure 4A revealed that the acutely inflammed contains neutrophils (red arrows), eosinophils (blue arrows) in addition to lymphocytes (white arrows). While figure 4B demonstrated small lymphocytes (white arrows), large lymphocytes (black arrows) and macrophage (green arrows) in chronically inflammed pulp.

(B) Histochemical results:

The histochemical results are illustrated in figure 5:

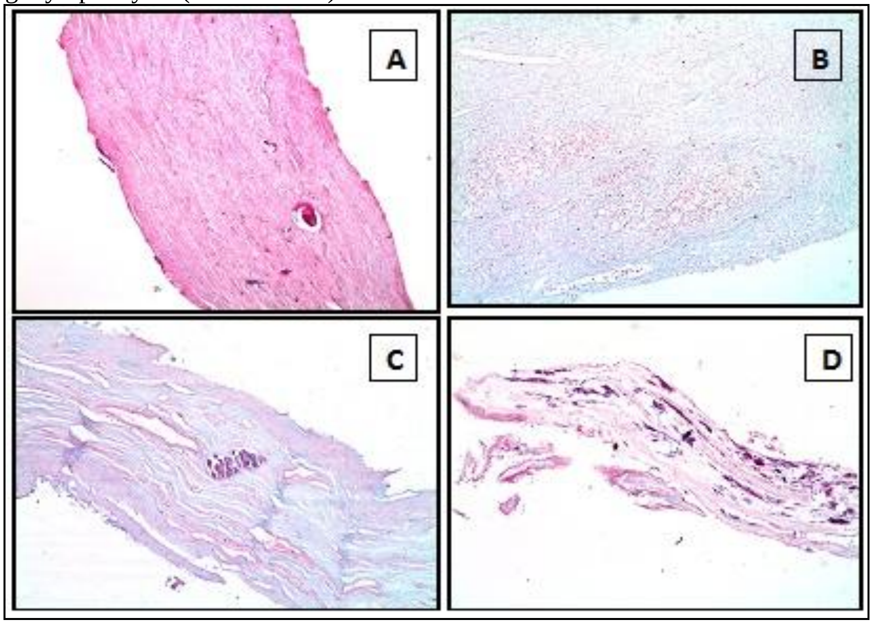

Figure 5: 5A showed the normal pulp with +ve PAS reaction for neutral MPSs, figure 5B showed the acutely inflammed pulp with strong +ve alcianophilic reaction for acidic MPSs, figure 5C showed the chronically inflammed pulp with +ve alcianophilic reaction in some areas and +ve PAS reaction in other areas, .
While figure 5D showed the necrotic pulp with PAS +ve alcinophilic reaction for acidic and neutral MPSs

(C) Radiographic results:

The x-rays taken (while the file in place during electronic root length measurement) were introduced to Digora soft ware to measure the exact distance between the file tip and the radiographic apex. This was illustrated in figure 4:

Figure 6A showed x-ray of upper central incisor while the file fixed in place after root length measurement. Figure 6B showed the measured distance between the file tip and the radiographic apex which indicated over reading by 1.1 mm.

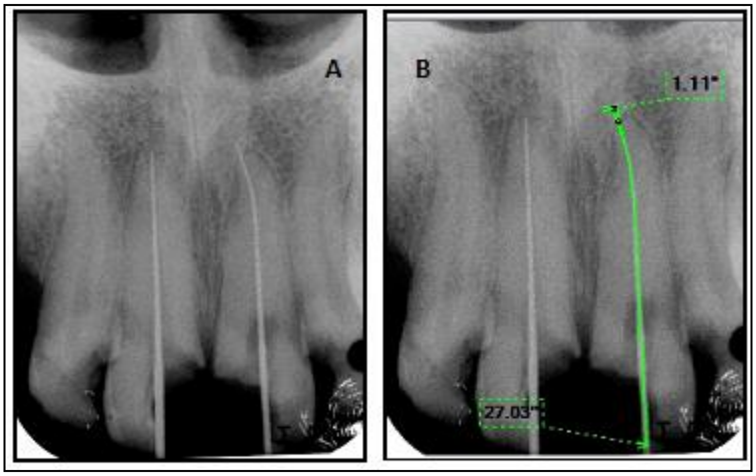

Figure 6: The radiographic results are summarized in table (1)

Table (1): Accuracy of apex locator compared with periapical radiograph in each group.

The condition of the pulp	Accurate reading of A.L.	short reading of A.L.	long reading of A.L
Normal pulp	4	5	1
Acute pulpitis	5	3	2
Chronic pulpitis	5	4	1
Degenerated pulp (deg.p.)	7	1	2
Degenerated pulp with periapical radiolucency	1	2	7

(D) Statistical results:

The statistical analysis was carried out using SPSS program (SPSS, 2008). Cross-tabulation and Chi square test (SPSS, analysis, descriptive statistics, crosstabs). This statistic (illustrated in diagram 1) revealed that there was no statistical significant difference between 1st , 2nd , 3rd and 4th group in the prevalence of accurate working length using apex locator while there was a statistical significant difference between the last group (degenerated pulp with periapical redulucency(deg. P.(PR)) and all other groups.

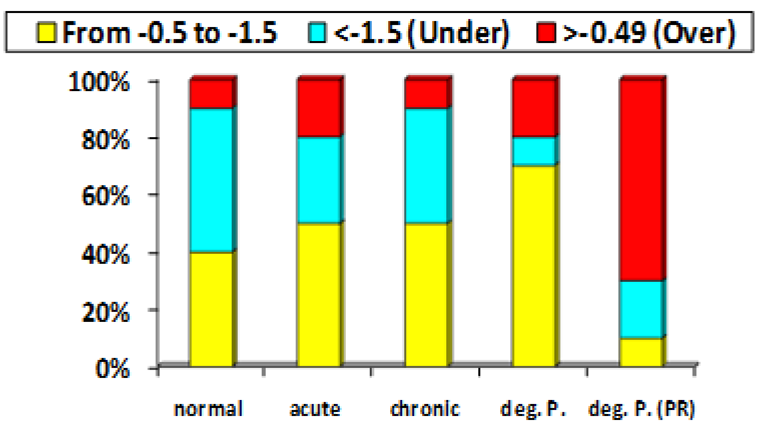

Diagram 1

4. Discussion:

We performed the present study on 50 canals. Regardless the condition of the dental pulp, we found that: generally the apex locator was accurate in only 22 cases (44%). This result is in agreement with many studies such as **Rahul *et al.*, 1995** (43% for 2nd generation AL and 71.7% for 3rd generation difference impedence AL), **Welk *et al.*, 2003** (34.4% for 5th generation multi frequency AL) and **Siu *et al.*, 2009** who used 4 types of AL and found that AL could find apical constriction in only 50% or less.

In the 1st group, AL tends to under record the root length (with statistical mean of -1.3± 0.9mm from the radiographic apex). This result may be due the healthy connection between the periodontal ligament and the pulp tissue. This connection shortens the electrical circuit of apex locator leading to short reading. This is in agreement with **Nekofar *et al.*, 2002** who reported that 1st generation AL polarize the tissue inside the canal leading to reading as if the file reached the foramen.

In the 2nd group, this group shows longer reading than the 1st group (with statistical mean of -1.1± 0.9 mm from the radiographic apex) due to presence of high electroconductive media (as blood and exudates) in the pulp tissue which is in agreement with **Lee *et al.* (2002).**

During endodonic treatment, dryness of pulp chamber was very difficult due to excessive bleeding that can't be controlled at the time of root length measurement. This excessive blood in the pulp chamber may be the cause of inaccurate reading in the other 5 cases.

The results of **the 3rd group** resembles group II but it give more tendency to record under reading than group II (with statistical mean of -1.4±1.35mm from the radiographic apex). **Nekoofar *et al.*(2006)** reported the factors affecting capacitance and resistance of the canal by equation 1 and 2.

The **capacitance** of the canal is affected by equation 1:

Equation 1 $$C \propto \frac{E \times Ac}{d}$$

C: the capacitance of the canal
E: the dielectric constant of the pulp tissue
Ac: the outer area of the file
d: the thickness of dentinal wall

It was found that **Rush *et al.*, 1963** measured the electrical resistance of human tissues and he found that bone and fats have greeter electrical resistance than blood and muscle fiber . So, Presence of areas of high resistance to the electric current in the pulp (as pulp stones and fatty degeneration) leads to change in E value which is supposed to be constant through the canal. This leads to irregular change in capacitance from area to another which leads to irregular readings.

In addition, if the tissue with high resistivity in the pulp is attached to the dentin surface, this leads to irregular increase in thickness of dentinal wall (d) which by turn decreases the capacitance at this areas .

In group IV: AL gives the most accurate reading compared with the other groups (with statistical mean of -0.79± 0.74mm from the radiographic apex). This tendency to accurate results is in agreement with **Kovacevic *et al.* (2006)** but he regarded the accurate reading to formation of transitional ions concentration zone at the apex. These results are also in agreement with other authors as **Stein and Corcoran (1990) and Wu *et al.*(1992)** as they found that the necrotic pulp gives more accurate reading than vital pulp.

Histochemical examination revealed that in groups II and III the pulp tissue gave strong Alcian +ve reaction that indicates presence of acidic media in the canal. This acidic electroconducive media may decrease the accuracy of apex locator even with the most recent devices. This is confirmed by **Fan *et al.*(2006)** who found that when the canal is filled with strong electrolytes such as ethylenediamine tetraacetic acid (EDTA), the accuracy of AL decreased. The results also coincide with **Jung *et al.* (2008)** who found that SmarPex (5th generation) demonstrated the greatest tendency to under-record the canal length on using EDTA as the irrigant. While, The histochemical examination of the 4th group revealed presence of weak +ve alcianophilic reaction. So, the effect of the pulp acidity which may be the cause of inaccurate reading in group II and III was decreased

In **group V**: We found that the apex locator tends to give over reading in most of the cases (with statistical mean of -0.56 ±1.38mm from the radiographic apex). Presence of periapical radiolucency in this group indicates that alteration of the size of apical constriction may be found due to inflammatory root resorption (**Lee *et al.*, 2002 and Oliver *et al.*, 2002**). In case of present device: it calculates capacitance and resistance of the canal separately according to equation2:

equation2 $$R \propto \frac{p \times 1}{Ar}$$

R: resistance
P: resistivity of the material inside the canal
Ar: cross section of the canal

So, increase diameter of apical constriction (Ar) by inflammatory resorption leads to decrease the resistance of the canal (which supposed to increase to its maximum value at the apical constriction only).

Conclusion:

Electronic root length determination is affected by presence of pulp tissue in the canal and periapical radiolucency as AL give short reading compared with x-ray in case of presence of normal or inflamed pulp tissue in the canal. While it gives over reading compared with x-ray in case of presence of periapical radiolucency.

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5. References:

1-Chandler N.P. and Bloxham G.P. (1990): Effect of gloves on tactile discrimination using an endodontic model. International Endodontic Journal, 23:97–99.

2-Eduardo A., Giulio G., Jose A. P. (2007): Influence of pulp vitality on length determination by using the elements diagnostic unit and apex locator**.** Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod., 104, (4):129-132.

3-Fan W., Fan B. and Gutmann J.L. (2006): Evaluation of the accuracy of three electronic apex locators using glass tubules. International Endodontic Journal, 39:127-135.

4-Gordon M. and Chandler N. (2004): Electronic apex locators. International Endodontic Journal, 37: 425 – 437.

5-Green D. (1960): Stereomicroscopic study of 700 root apices of maxillary and mandibular posterior teeth. Oral Surg. Oral Med. Oral Pathol., 13:728–33.

6-Inoue N. (1973): An audiometric method for determining the length of root canals. Journal of the Canadian Dental Association, 39: 630–636.

7-Jung A. K., and Sung K.K., (2008): Accuracies of seven different apex locators under various conditions. Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod., 106(4) :57-62.

8-Kobayshi C.h. and Suda H.,(1994): A new engine –driven canal preparation system with electronic canal measuring capability. Journal of Endodontics, 23: 751 – 756.

9-Kuttler Y. (1955): Microscopic investigation of root apices. Journal of the American Dental Association, 50: 44–52.

10-Lee S.J., Nam K.C., Kim Y.J. and Kim D.W. (2002): Clinical accuracy of a new apex locator with and automatic compensation circuit. Journal of Endodontics, 28:706–709.

11- Kovacevic M. , Tomislav T. , Snjezˇana G. , Nives J. , Sanja Z. and Dragica B. (2006): Electronic root canal length measurement before and after experimentally induced pulpitis and apical periodontitis in dogs. Med. Bio. Eng. Comput., 44:695–701.

12- Nekoofar M. H., Ghandi M. M., Hayes S. J. and Dummer P. M. (2006): The fundamental operating principles of electronic root canal length measurement devices. International Endodontic Journal, 39: 595–609.

13-Oliver P., Oliver S., and Thomas A. (2002): Influence of the canal contents on the electrical assisted determination of the length of root canals. Journal of endodontics, 28:83-85.

14-Olson A.K., Goerig A.C., Cavataio R.E. and Luciano J. (1991): The ability of the radiograph to determine the location of the apical foramen. International Endodontic Journal, 24:28–35.

15-Rahul K. A. and Kishor G. (1995): An in vivo evaluation of the ENDEX and RCM Mark lit electronic apex locators in root canals with different contents Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod., 79:497-503.

16-Ricucci D. and Langeland K., (1998): Apical limit of root canal instrumentation and obturation, part 2. A histological study. International Endodontic Journal, 31: 394–409.

17-Ruddle C.J. (2002): Cleaning and shaping root canal systems. In: Cohen S., Burns R.C., Pathways of the Pulp, 8th edn. St Louis, MO: Mosby, 231–91.

18-Rush S., Abildskov J.A. and McFee R. (1963): Resistivity of body tissues at low frequencies. Circulation Research, 12: 40–50.

19-Siu C., Marshall J.G. and Baumgartner J.C. (2009): An in vivo comparison of the Root ZX II, the Apex NRG XFR, and Mini Apex Locator by using rotary nickel-titanium files**.** Journal of Endodontics, 35(7):962-965.

20-Slavcho D. and Dimitur R. (2009): Sixth generation adaptive apex locator. Journal of IMAB - Annual Proceeding (Scientific Papers), book 2:75-87.

21-Stein T.J.,Corcoran J.F. and Zillich R.M. (1990): The influence of the major and minor foramen diameters on apical electronic probe measurements. Journal of Endodontics, 16:520–522.

22-Stein T.J. and Corcoran J.F. (1992): Radiographic 'working length' revisited. Oral Surg. Oral Med. Oral Path., 74:796–800.

23-Suchde R.V. and Talim S.D. (1977): Electronic ohmmeter: an electronic device for the determination of the root canal length. Oral Surg., Oral Med., and Oral Pathol. 43, 141–149.

24-Sunada I. (1962): New method for measuring the length of the root canal. J. Dent. Res., 41:375–387.

25-Suzuki K. (1942): Experimental study on iontophoresis. Journal of Japanese Stomatology, 16: 411–417.

26-Tamarut T.,Cindric N. and Medugorac G. (1988): Qualitative changes of the pulp and multiple electric measurement of the canal. Acta Stomatol Croat, 22:45–53.

27-Vera J and Gutierrez M (2004): Accurate working-length determination using a Fourth-generation apex locator. Contemporary Endodontics, 1: 4–8.

28-Welk A.R., Baumgartner J.C. and Marshall J.G. (2003) :An in vivo comparison of two frequency-based electronic apex locators. Journal of Endodontics, 29: 497–500.

29-Wu M.K., R'oris A., Barkis D. and Wesselink P. (2000): Prevalence and extent of long oval canals in the apical third. Oral Surg. Oral Med. Oral Path. Oral Radiol. Endod., 89:739–743.

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