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## Assessment of the accuracy of a fifth generation apex locator (in vitro study)

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### ABSTRACT

**Background:** The use of electronic apex locators for working length determination eliminates many of the problems associated with the radiographic measurements (interference of anatomical structures, errors in projection such as elongation or shortening, and lack of three-dimensional representation). Its most important advantage over radiography is that it measures the length of the root canal to the apical constriction, not to the radiographic apex. The aim of this study was to assess the accuracy of a new fifth generation apex locator (Joypex 5) in recording the apical constriction and comparing it with a third generation apex locator (Root ZX) in vitro.

**Materials and method:** Twenty four single-rooted sound human premolars, extracted for the purpose of orthodontic treatment and with fully-formed roots, were used in this study. Endodontic access cavity was prepared in each tooth and canal patency up to the apical foramen was checked with a #15 stainless steel K-file. No root canal preparation was performed. Root canal length measurement was done directly and electronically using two apex locators (Joypex 5 and Root ZX). Direct measurement of the root canal length was done by introducing a #15 K-file inside the root canal until its tip was just visible at the apical foramen, then removed from the root canal and its length was measured (in mm) and subtracted by 0.5 mm. For electronic measurement, the teeth were fixed in a sponge soaked in saline and the root canals were also filled with saline. The lip electrode was attached to the sponge and the apex locators were used according to the manufacturers' instructions. The file holder was clipped to the metal shaft of a #15 K-file and the file was then inserted inside the root canal and advanced until the display reading on the LCD of the apex locator was "0.5". The file was then removed from the root canal and its length was measured (in mm). The differences between the readings of each apex locator and the actual length of each canal were computed, and the results were analyzed statistically by paired t-test using SPSS Version 13.

**Results:** The results of this study showed that the Joypex 5 apex locator showed a lower mean difference than the Root ZX apex locator as compared with the actual length, which was statistically significant ( $p < 0.05$ ). Concerning the accuracy of the two apex locators, Joypex 5 apex locator recorded the apical constriction exactly in 67%, while the Root ZX apex locator in only 25%. Within  $\pm 0.5$  mm from the actual length, the accuracy of the Joypex 5 and the Root ZX were 83% and 67%, respectively. Within  $\pm 1$  mm from the actual length, the accuracy of the Joypex 5 and the Root ZX were 100% and 96%, respectively.

**Conclusion:** The Joypex 5 apex locator which is a fifth generation apex locator was more accurate in recording the apical constriction as compared with the Root ZX apex locator which is a third generation apex locator.

**Key words:** Apex locator, fifth generation, accuracy. (J Bagh Coll Dentistry 2011;23(1):12-17)

### INTRODUCTION

The objective of working length determination is to establish the length at which root canal preparation and subsequent obturation are to be terminated <sup>(1)</sup>.

According to the American Association of Endodontists (AAE) (2003), working length is defined as "the distance from a coronal reference point to the point at which canal preparation and filling should terminate"<sup>(2)</sup>. The apical constriction is the recommended end point of instrumentation and obturation since the tooth pulp is narrow at the apical constriction, so the wound is minor, potentially providing optimal healing conditions <sup>(3)</sup>. The location of the apical constriction is considered to be 0.5-1 mm short of the anatomical apex <sup>(4)</sup>.

Radiography is traditionally used to obtain information about root canal anatomy, working length and surrounding apical tissues<sup>(5,6)</sup>. However, the accurate determination of root canal length radiographically is hindered because of anatomical variations, interference of anatomical structures, errors in projection, and lack of three-dimensional representation <sup>(7-10)</sup>.

These factors have stimulated the development of electronic root canal length measuring devices (apex locators) <sup>(11)</sup>. The electronic method eliminates many of the problems associated with the radiographic measurements. Its most important advantage over radiography is that it measures the length of the root canal to the apical constriction, not to the radiographic apex <sup>(12)</sup>.

All apex locators function by using the human body to complete an electrical circuit. One side of the apex locator's circuitry is connected to an endodontic instrument. The other side is connected to the patient's body, either by a contact to the patient's lip or by an electrode held in the patient's hand. The electrical circuit is complete when the endodontic instrument is

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advanced apically inside the root canal until it touches the periodontal tissue. The display on the apex locator indicates that the apical area has been reached<sup>(13)</sup>. Thus, electronic apex locator devices measure the constant resistance or impedance value between the patient's oral mucosa and the periodontal ligament<sup>(14)</sup>.

The development of electronic apex locators begun in 1942, when it was reported that the electrical resistance between the periodontal ligament and the oral mucosa in vivo was a constant value of ~6.5 kilo-ohms (kΩ)<sup>(15)</sup>. Later, Sunada introduced the principle of the 'biological characteristic theory' into clinical practice, stating that electronic apex locators could read the apex by measuring the differences of electrical resistance values between the periodontal ligament and the oral mucosa<sup>(16)</sup>.

Since that discovery, several generations of EALs have been developed to refine their accuracy<sup>(17)</sup>.

These early products were known as first-generation apex locators or resistance apex locators. They measure opposition to the flow of direct current or resistance. When the tip of the reamer reaches the apex in the canal, the resistance value is 6.5 kΩ (current 40 mA)<sup>(13)</sup>.

Problems inherent in using direct current led to the development of electronic apex locators that used alternating current<sup>(18)</sup>. These apex locators were known as second-generation apex locators or impedance apex locators. They measure opposition to the flow of alternating current or impedance. The major disadvantage of second-generation apex locators is that the root canal has to be reasonably free of electro conductive materials to obtain accurate readings<sup>(13)</sup>.

The presence of tissue and electro conductive irrigants in the canal change the electrical characteristics and leads to inaccurate, usually shorter measurements and thus require insulative sheaths over the probe to protect them from conductive fluids<sup>(17)</sup>.

The main shortcoming of these early apex locators (erroneous readings with electrolytes) was overcome by Kobayashi et al. (1991) with the introduction of the ratio method and the subsequent development of the self-calibrating Root ZX (J Morita, Tokyo, Japan) which is considered as a third-generation apex locator. The ratio method works on the principle that two electric currents with different sine wave frequencies will have measurable impedances that can be measured and compared as a ratio regardless of the type of electrolyte in the canal<sup>(19)</sup>.

Kobayashi & Suda<sup>(19)</sup> showed that the ratio of different frequencies has definitive values, and that the ratio rate of change did not change with different electrolytes in the canal. The change in electrical capacitance at the apical constriction is the basis for the operation of the Root ZX and its reported accuracy. Since its introduction the Root ZX has received considerable attention in the literature. It has become the benchmark to which other apex locators are compared.

To further reduce errors and increase accuracy, fourth-generation apex locators were developed, which also use two separate frequencies of 400 Hz and 8 KHz, but unlike the third generation, they use only one frequency at a time<sup>(20)</sup>.

Recently, a fifth generation apex locator has been introduced (Joypex 5) (Denjoy Dental Co., Ltd/ China). This apex locator adopts a fifth generation circuit-T Surge and uses multiple frequencies rather than the dual frequencies of the third and fourth generations of apex locators, so it works in dry or wet canals and requires no calibration as reported by the manufacturer<sup>(21)</sup>.

This study was conducted with the aim of assessing the accuracy of a new fifth generation apex locator (Joypex 5) in locating the apical constriction and comparing it with a third generation apex locator (Root ZX) in vitro.

## MATERIALS AND METHOD

### Materials and Equipment

#### Sample Selection

Twenty four single-rooted sound human premolars, extracted for the purpose of orthodontic treatment and with fully-formed roots, were collected for use in this study. The teeth were cleaned with pumice and carefully rinsed with water to remove the residual debris. The teeth were examined with a magnifying lens and light from a light curing unit for the presence of cracks. Only intact teeth free of defects and of comparable size were selected and stored in distilled water at room temperature.

#### Sample preparation

Endodontic access cavity was prepared in each tooth. Then pulp extirpation was done with a barbed broach and canal patency up to the apex was checked with a #15 stainless steel K-file. Then the root canal was irrigated with normal saline. No root canal preparation was performed<sup>(11)</sup>.

#### Root canal length measurement

##### (1) Direct measurement of the root canal length (Actual length):

A #15 stainless steel K-file with 27 mm length (Dentsply, Maillefer) was used for the direct

measurement of root canal length. The file was introduced inside the root canal until its tip was just visible at the apical foramen. The rubber stopper was adjusted to the reference point and the file was then removed from the root canal and its length from the rubber stopper to the file's tip was measured (in mm) using endoblock millimetric ruler (Dentsply, Maillefer) and subtracted by 0.5 mm assuming that the apical constriction is located 0.5 mm coronal to the apical foramen. The length of each canal with the corresponding reference point was recorded<sup>(11)</sup>.

**(2) Electronic measurement of root canal length:**

The electronic measurement of root canal length was undertaken using two apex locators: Root ZX apex locator (J Morita Corp., Tokyo, Japan), which is a third generation apex locator, and Joypex 5 apex locator (Denjoy Dental Co., Ltd/ China), which is a fifth generation apex locator.

Root ZX apex locator (J Morita Corp., Tokyo, Japan) is a third-generation apex locator that uses dual frequency and comparative impedance principles. The electronic method employed was the "ratio method" or "division method." The Root ZX simultaneously measures the two impedances at two frequencies (8 and 0.4 kHz) inside the canal. A microprocessor in the device calculates the ratio of the two impedances. The quotient of the impedances is displayed on LCD meter panel and represents the position of the instrument tip inside the canal<sup>(19)</sup>. It is used as a control.

Joypex 5 apex locator adopts a fifth generation circuit-T Surge and uses multiple frequencies and works in dry or wet canals and requires no calibration as claimed by the manufacturer (Denjoy Dental Co., Ltd/ China). It comes with adjustable five different settings for the apical constriction (0.1, 0.2, 0.3, 0.4, or 0.5 mm from the apex) which can be adjusted by the operator<sup>(21)</sup>. In this study, it was adjusted to 0.5 assuming that the apical constriction is 0.5 mm from the apical foramen.

For electronic measurement, the teeth were fixed in a sponge soaked in saline and the root canals were also filled with saline. Cotton pellets were used to remove excess saline from the pulp chamber. The lip electrode was attached to the sponge and the apex locators were used according to the manufacturers' instructions<sup>(21,22)</sup>.

The file holder was clipped to the metal shaft of #15 K-file (27mm in length) above the rubber stopper. The file was then inserted inside the root canal and advanced until the display reading on the LCD of the apex locator was "0.5". The rubber stopper was then adjusted to the same reference

point that was used in the direct measurement of the root canal length and the file was removed and its length from the rubber stopper to the file's tip was then measured (in mm) using endoblock millimetric ruler<sup>(11)</sup>.

In order to compare between the readings of the two apex locators, the differences between the readings of each apex locator and the actual length of each canal were computed. Then the results were analyzed statistically using SPSS Version 13.

**RESULTS**

The descriptive statistics (mean, standard deviation, minimum and maximum and standard error) for the differences between the readings of each apex locator and the actual length of each canal (in mm) are shown in Table 1.

**Table 1: descriptive statistics of differences between the readings of each apex locator and the actual length**

Groups	Mean	N	Standard Deviation	Standard Error Mean
Joypex 5	.1667	24	.43406	.08860
Root ZX	.4375	24	.55780	.11386

From this table it can be seen that the Joypex 5 apex locator showed a lower mean difference than the Root ZX apex locator.

Paired t-test comparison of differences between the readings of the two apex locators is shown in Table 2, which showed a statistically significant difference between the two apex locators (p<0.05).

**Table 2: Paired t-test comparison of differences between the readings of the two apex locators**

Groups	T	df	Sig. (2-tailed)
Joypex 5 & Root ZX	-2.325	23	.029

**Table 3: Distribution of the readings according to the difference from the actual length**

	Number of readings*	
	Joypex 5	Root ZX
within ±1 mm	24	23
within ±0.5 mm	20	16
=actual length	16	6

Concerning the accuracy of the two apex locators, the number of readings that were equal to the actual length, the readings within ±0.5 mm,

and the readings within  $\pm 1$  mm from the actual length were computed relative to the total number of readings as shown in Table 3 and 4.

**Table 4: Accuracy of the two apex locators according to the difference from the actual length**

	Accuracy	
	Joypex 5	Root ZX
within $\pm 1$ mm	100%	96%
within $\pm 0.5$ mm	83%	67%
=actual length	67%	25%

From Table 4, it can be seen that the Joypex 5 apex locator recorded the actual length exactly in 67%, while the Root ZX apex locator in only 25%. Within  $\pm 0.5$  mm from the actual length, the accuracy of the joypex 5 apex locator was 83%, while the accuracy of the Root ZX apex locator was 67%. Within  $\pm 1$  mm from the actual length, the accuracy of the Joypex 5 apex locator was 100%, while the accuracy of the Root ZX apex locator was 96%.

## DISCUSSION

The experimental model used in this study was adopted from the study of Leonardo et al. <sup>(11)</sup>, who conducted a study on the accuracy of the Root ZX apex locator and Mini Apex Locator during root canal determination in primary teeth with different stages of root resorption. They fixed the teeth in a sponge soaked in saline.

In vitro models in which extracted teeth are immersed in media with similar electrical resistance to the periodontium can provide valuable information <sup>(23)</sup>. Usually extracted teeth are placed in a conductive environment made of agar-agar <sup>(24)</sup>, alginate <sup>(25)</sup>, gelatin <sup>(26)</sup>, or saline <sup>(27)</sup> for laboratory studies. The use of saline solution has been shown to produce reliable measurement data <sup>(28,29)</sup>.

In this study, the Root ZX apex locator was used as a control since it has received considerable attention in the literature and has become the benchmark to which other apex locators are compared <sup>(17)</sup>.

In the direct measurement of the root canal length, 0.5 mm was subtracted from the total length of each tooth assuming that the apical constriction (minor foramen) is located 0.5 mm from the apical foramen (major foramen). This assumption is based on that the apical constriction varies between 0.5 mm and 0.8 mm depending on the age of the tooth (0.5 mm in the younger age group and 0.8 mm in the older age group for all tooth types) as reported by Kuttler <sup>(30)</sup>, Dummer et al. <sup>(31)</sup> and Stein & Corcoran <sup>(32)</sup>. In this study, the

teeth were obtained from young patients undergoing orthodontic treatment, and hence a 0.5 mm apical constriction seems more logical.

Many studies used an error range of  $\pm 0.5$  mm to assess the accuracy of the electronic apex locators as compared with the actual length. Measurements attained within this tolerance are considered highly accurate. Other studies relied on a more lax clinical range of  $\pm 1$  mm from the foramen. One reason cited for accepting a  $\pm 1$  mm margin of error is the wide range seen in the shape of the apical zone. Root canals do not always end with an apical constriction, a well-delineated minor or major apical diameter, or an apical foramen within the base of cemental cone. With a lack of such demarcations, an error tolerance of  $\pm 1$  mm is deemed clinically acceptable as reported by Shabahang et al. <sup>(33)</sup>. Moreover, another source of error that may arise in the direct determination of the working length might be the difficulty in the visual control of the relation between the rubber stopper/reference point, rubber stopper/ruler, and file tip/ruler. In addition, sometimes it is challenging to visualize the exact point where the tip of the file reached the cervical border of the foramen, even with magnification <sup>(34)</sup>. Therefore, in this study, the accuracy of both apex locators was computed with an error range of both  $\pm 0.5$  mm and  $\pm 1$  mm from the actual length.

The statistically significant difference between the Joypex 5 apex locator and the Root ZX apex locator in recording the apical constriction could be attributed to the advanced electronic T-surge circuit adopted in the fifth generation Joypex 5 apex locator which uses multiple frequencies alternating current rather than the dual frequency alternating current incorporated in the third generation Root ZX apex locator <sup>(21)</sup>. The use of a single frequency signal at a time eliminates the need for filters that separate the different frequencies which helps prevent the noise inherent in such filters, and increases the accuracy. In addition, the calculations of the position of the file tip are based on measurements of root mean square (RMS) values of the signals, which expresses the energy of the measured signal and is more immune to various noises or signal distortions than other parameters of the signal, such as amplitude or phase which are used in other devices. The combination of these two techniques is claimed to increase the measurement accuracy and the reliability of the device as reported by the manufacturer <sup>(20)</sup>.

The results of this study concerning the accuracy of the Root ZX apex locator within  $\pm 0.5$  mm are in agreement with the findings of

Vajrabhaya and Tepmongkol<sup>(35)</sup> and Ounsi and Naaman<sup>(36)</sup> who reported that the accuracy of the Root ZX apex locator within  $\pm 0.5$  mm varied greatly from 50% to 100%, and with the findings of Goldberg et al. (2002)<sup>(37)</sup> who evaluated the accuracy of the Root ZX apex locator in single-rooted teeth with apical root resorption that were inserted into a sponge soaked with normal saline and found that the accuracy of the Root ZX apex locator was 63%. In contrary, the findings of this study disagree with the findings of Shabahang et al.<sup>(33)</sup> who reported that the in vivo accuracy of the Root ZX apex locator within 0.5 mm from the minor foramen was 96% of the time. The difference in results could be attributed to the differences in the test conditions (clinical versus laboratory as reported by Tosun et al.<sup>(38)</sup>).

On the other hand, the results of this study concerning the accuracy of the Root ZX apex locator within  $\pm 1$  mm are in agreement with the findings of Weiger et al.<sup>(39)</sup> who reported that the accuracy of the Root ZX apex locator within  $\pm 1$  mm ranges from 64%-100%. Moreover, the accuracy of the Root ZX in this study was better than that reported by Kielbassa et al.<sup>(40)</sup> who found that, in the measurements of primary teeth, the Root ZX apex locator was accurate within 1 mm in 64% of the cases.

The discrepancy in measurements between studies may be due to the type and age of teeth selected, the presence or absence of apical pathology and the variability in the location and anatomy of the apical constriction<sup>(41)</sup>.

Concerning the Joypex 5 apex locator, there is no available research to compare our results with it since it is a new generation and introduced recently.

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