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Comparative evaluation of two electronic apex locators in determining working length

Dr. Pragya Jaiswal

Abstract
Electronic apex locators reduce the number of radiographs required and assist where radiographic methods create difficulty. They are also helpful in cases where the apical foramen is some distance from the radiographic apex. In addition to reducing radiographic exposure, Apex Locators can reduce the rate of overestimation of root canal length
Aim: To compare and evaluate the accuracy of two 4th generation electronic apex locators (EAL'S): RAYPEX 5 (VDW, Munich, Germany) and NRG-BLUE (Medic NRG Ltd., Tel Aviv, Israel).
Objective: To determine the reliability of electronic apex locators in detecting the apex and their accuracy in working length determination.
Results: Suggests that electronic root canal measurement can be an objective and acceptably reproducible technique. The outcome of this study indicates that Raypex 5 and Nrg Blue can accurately measure the working length and act as a very helpful aid in the success of endodontic therapy.

Keywords: Working length, apex locators, accuracy

Introduction
The success of endodontic therapy is determined by three factors, proper cleaning and shaping, disinfection and three dimensional obturation of the canal. All should be confined to the root canal system. Both overfilling and underfilling have shown to reduce the success rate of an endodontic treatment. Thus there is importance of working length to limit the extent of the preparation and filling. Various methods which are employed for working length determination are manual methods, radiographic methods and more recently electronic method.
The manual technique depends on the sensitivity of the operator. Thus manual method is not acceptable as it is subjective and scantly reproducible.
In the radiographic approach, calculation of the working length is made with respect to the position of the radiographic apex. The radiographic apex is determined first and then a definite length is substracted i.e 0.524 mm in young patients and 0.659 mm in older patients which is the average distance of the minor constriction (apical constriction) from the root apex, as calculated by Kuttler. Thus in general we are substracting 0.5 - 1mm from the radiographic apex. But this lies true only in cases with apical foramen at the apex of the root which in not present in more than 50% of the cases.[3] If the foramen lies eccentrically above the root apex then extra length should be substracted from the radiographic apex. Radiographic method also depends on a series of factors such as tooth inclination, film position, length of the cone beam, vertical and horizontal cone angulation. Radiographic method cannot determine the exact location of the apical constriction ultimately leading to post-operative pain and failure.
To overcome these problems, electronic methods of working length determination has emerged called as apex locators. They are basically used to locate the apical constriction or the cemento dentinal junction and not the radiographic apex.
The root canal system is surrounded by dentine and cementum that act as insulators to electrical current. At the minor apical foramen, however, there is a small hole in which conductive materials within the canal space (tissue, fluid) are electrically connected to the periodontal ligament that is itself a conductor of electric current. Dentine along with tissue and fluid inside the canal forms a resistor.

The value of this resistance depends on their dimensions and inherent resistivity. When an endodontic file penetrates inside the canal and approaches the minor apical foramen, the resistance between the endodontic file and the foramen decreases, because the effective length of the resistive material decreases. The structure of the tooth root also has capacitive characteristic. Therefore, various electronic methods have been developed that use a variety of other principles to detect the canal terminus. The simplest of apex locator's measures resistance, other devices measure impedance using high frequency, two frequencies, or multiple frequencies. In addition, some systems use low frequency oscillation and/or a voltage gradient method to detect the canal terminus Recently fourth generation electronic apex locators have been developed which measure resistance and capacitance separately rather than the resultant impedance value. Impedenance is the combination of resistance and capacitance There can be different combination of values of capacitance and resistance that provides the same impedence. This can give the same foraminal reading. But by using 4th generation apex locator this can be broken down into primary components and measures separately for better accuracy and thus less chances of occurance of errors.

Very few studies have been documented on the accuracy of these new apex locators so the present study is undertaken to evaluate the accuracy of Raypex 5 and APEX NRG- BLUE apex locators using an alginate model.

Materials and Method

A total of 40 root canals from extracted human permanent teeth were used for the study. Teeth were inspected for root fracture and evidence of incomplete root formation and doubtful teeth were discarded. Teeth were stored in formalin solution (10%). Access opening was prepared using Cavity access set (Densply Maillefer, Ballaigues, Switzerland). In each multirooted tooth one canal (distal for mandibular and mesial for maxillary) was chosen for the study.

Awl Measurement

The actual root canal length is defined as the distance from the coronal reference point to the apical constriction.

It was established individually by advancing #10 K file until the tip of the instrument was just visible at the apical foramen with a magnifying glass. The silicone stop was adjusted to the level chosen as reference for root canal measurement and an Endoblock (Dentsply) was used to measure the distance from the silicone stop to the file tip to 0.5 mm precision. Each measurement was repeated 3 times and the mean value calculated and computed (Table 2). This measurement was recorded as the reference (or control) length, and regarded as actual working length (AWL), which was compared with the working length subsequently determined with the apex locators.

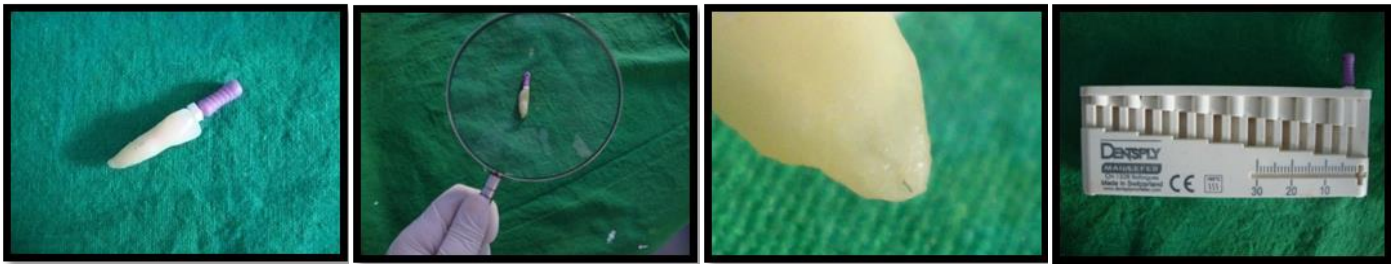


Fig 4: Actual working length determination EWL MEASUREMENT (Electronic working length)

Electronic working length was taken in all the tooth using Raypex 5 and NRG Blue tooth alternately in the in-vitro alginate model.

In- vitro model chosen for this research project was based on the model designed by Kaufman and Katz. The teeth were embedded in the alginate, while setting. A metal rod was also inserted at one end of the model to attach the lip clip of the apex locator for completion of the circuit. When not in use the model was wrapped with a wet paper and refrigerated to keep it in a moist environment throughout the experiment.

Both devices were operated according to manufacturer's instructions.

Apex NRG blue (Medic NRG Ltd,Tel Aviv, Israel) is a novel miniature apex locator which is a multifrequency 3rd generation apex locator with a blue tooth attachment. The technology of this apex locator is based on digital processing (DSP) and uses square multi-frequency currents. This can be used both in dry and wet conditions. Nrg blue contains two colour LED light signals orange and blue. The acoustic signal (alarm) gives the indication of reaching the apex. The markings present on the apex locator are Apex,.25,.5, 1.0, 1.5. When the file goes beyond the apex the device gives orange LED signal and when the file is just at the apex it gives a blue LED signal. The reading 0.5 on the device is recorded as the electronic working length. Each measurement for both the devices were repeated 3 times and the mean value calculated and computed (Table 2 and 3). This measurement was recorded as the electronic working length (EWL).

For each canal, the differenc AWL and EWL was calculated

AWL is substracted from the electronic working length.

1) Positive values: file in position past the apical constriction.
- Measurement exceeding the AWL
2) Negative values: file tip short of apical foramen.
- Measurement short of AWL

Data were statistically analysed using SPSS software for non parametric correlation.

Fig 5: Alginate model

Fig 6: electronic working length determination

Table 2: Measurement of Actual Working Length, AWL (reference or Control Length)

S. No.	1st Reading	2nd Reading	3rd Reading	Mean
1	22.500	22.000	22.500	22.333
2	23.000	22.500	23.000	22.833
3	21.000	21.500	21.000	21.167
4	24.500	24.500	24.500	24.500
5	20.500	20.000	20.000	20.167
6	19.500	19.000	19.000	19.167
7	22.000	22.000	22.000	22.000
8	21.000	20.500	20.500	20.667
9	23.000	22.500	22.500	22.667
10	21.500	21.500	21.500	21.500
11	22.500	22.500	22.500	22.500
12	23.000	22.500	23.000	22.833
13	24.500	24.000	24.000	24.167
14	23.000	22.500	22.500	22.667
15	21.000	21.000	21.000	21.000
16	19.000	18.500	18.500	18.667
17	18.000	18.000	18.000	18.000
18	17.500	17.000	17.000	17.167
19	19.500	19.000	19.000	19.167
20	21.500	21.000	21.500	21.333
21	22.000	22.000	22.000	22.000
22	23.500	23.500	23.500	23.500
23	19.000	19.500	19.000	19.167
24	19.500	19.000	19.500	19.333
25	20.000	20.500	19.500	20.000
26	23.000	23.000	23.000	23.000
27	22.000	21.500	22.000	21.833
28	21.000	21.500	21.000	21.167
29	20.500	21.000	20.000	20.500
30	19.000	19.500	18.500	19.000
31	18.000	17.500	18.500	18.000
32	19.500	19.000	19.000	19.167
33	22.000	21.500	21.500	21.667
34	19.000	18.500	18.500	18.667
35	23.000	22.500	22.500	22.667
36	22.500	22.000	22.000	22.167
37	21.000	20.500	20.500	20.667
38	19.000	18.500	18.500	18.667
39	20.000	19.500	19.500	19.667
40	19.000	18.500	19.500	19.000

Table 3: Electronic Working Length determination with RAPEX 5, (EWL)

S. No.	1st Reading	2nd Reading	3rd Reading	Mean
1	22.000	22.000	22.000	22.000
2	22.500	22.000	22.500	22.333
3	21.000	21.000	21.000	21.000
4	24.000	24.000	24.000	24.000
5	20.500	20.500	20.000	20.333
6	19.000	19.000	19.000	19.000
7	21.500	22.000	22.000	21.833
8	20.500	20.500	21.000	20.667
9	22.500	22.500	22.500	22.500
10	21.500	21.500	21.500	21.500
11	22.500	22.500	22.500	22.500
12	23.000	22.500	23.000	22.833
13	24.500	24.500	24.000	24.333
14	23.000	23.000	23.500	23.167
15	21.000	21.000	21.000	21.000
16	18.500	18.500	18.500	18.500
17	18.000	18.000	17.500	17.833
18	17.500	17.000	17.000	17.000
19	19.000	19.000	19.000	19.000
20	21.500	21.000	21.000	21.167
21	22.000	21.500	21.500	21.667
22	23.500	23.500	23.000	23.333
23	19.000	19.000	19.000	19.000
24	19.500	19.500	19.500	19.500
25	20.000	20.000	20.000	20.000
26	22.500	23.000	22.500	22.667
27	22.000	21.500	22.000	21.833
28	21.000	21.000	21.000	21.000
29	20.500	20.000	20.000	20.167
30	19.500	19.500	19.500	19.500
31	17.500	17.500	18.000	17.667
32	19.000	19.000	19.000	19.000
33	21.500	21.500	21.500	21.500
34	19.000	19.000	19.000	19.000
35	22.500	22.500	22.500	22.500
36	22.000	22.000	22.000	22.000
37	20.500	20.000	20.500	20.333
38	18.500	18.500	18.500	18.500
39	19.500	19.500	19.500	19.500
40	19.000	19.000	19.000	19.000

Table 4: Electronic Working Length determination with APEX NRG-BLUE (EWL)

S. No.	1st Reading	2nd Reading	3rd Reading	Mean
1	21.500	21.500	21.500	21.500
2	22.500	22.000	22.500	22.333
3	20.500	20.500	20.500	20.500
4	23.500	24.000	23.500	23.667
5	20.500	20.000	20.000	20.167
6	18.500	19.000	19.000	18.833
7	21.500	21.500	22.000	21.667
8	20.700	20.700	20.700	20.700
9	22.000	22.000	22.000	22.000
10	21.500	21.000	21.000	21.167
11	22.000	22.000	22.500	22.167
12	23.000	23.000	22.500	22.833
13	24.000	24.000	24.500	24.167
14	23.000	23.000	23.000	23.000
15	20.500	21.000	21.000	20.833
16	18.500	18.000	18.000	18.167
17	18.000	18.500	18.000	18.167
18	17.000	16.500	17.000	16.833
19	19.000	19.000	19.000	19.000
20	21.000	21.500	21.000	21.167
21	22.000	22.000	22.000	22.000
22	23.000	22.500	22.500	22.667
23	18.500	18.000	18.000	18.167
24	19.500	19.000	19.000	19.167
25	19.500	20.000	20.000	19.833
26	22.500	22.000	22.000	22.167
27	21.500	21.000	21.000	21.167
28	21.000	21.000	21.000	21.000
29	20.000	19.500	20.000	19.833
30	19.500	19.000	19.000	19.167
31	17.000	17.000	17.500	17.167
32	19.000	18.500	19.000	18.833
33	21.500	21.000	21.000	21.167
34	19.000	18.500	18.500	18.667
35	22.500	22.500	22.500	22.500
36	22.000	22.000	21.500	21.833
37	20.500	20.500	20.000	20.333
38	18.500	18.500	18.500	18.500
39	19.500	19.000	19.000	19.167
40	19.000	18.500	18.500	18.667

Result

The recorded AL was compared with the values obtained with EALs. In each case, AL was substracted from the electronically determined distance, recording the result in tabular form (Table 4 and 5). Positive values indicated measurements exceeding the AL (long), negative values indicated measurements short of AL. For each EAL the mean value of the difference between the values obtained with EAL and AL were calculated (Table 6).

Percentages were determined and statistical evaluation was completed using the Friedman test and Tukey multiple range test for non-parametric correlation among groups. Statistical significance was considered when $P<0.05$.

Measurents obtained using Raypex5 were consistently closer to the actual length (AL) (± 0.5).The mean difference between the actual length(AL) and length measured by the Raypex 5 was -0.100 mm (SD 0.222) and NRG blue -0.34mm (SD 0.341). A positive co-relation of 0.667 (P=0.00) existed between the two devices.

An exact measurement to physiological foramen (AWL or control length) was made with Raypex5 22.5% of the time. If the tollerence of ± 0.5 mm was allowed the accuracy reached was 97.50%, if the tollerence of ± 1mm was allowed the accuracy reached was 100% (Table 7). where as, the NRG blue Apex locator was, exact12.5% of time, accurate 87.50% of the time to ± 0.5 mm and 100% of the time to ± 1mm(Table 8).

Comparing the differences between measurents obtained with the electronic apex locator and the actual working length of the tooth as obtained using the magnifying glass, the % of measurements within ± 0.5 mm of the actual length was 97.5% for Raypex 5,87.5% for NRG blue.

Under the invitro condition of the study, the Raypex 5 is a device which is more accurate in determining the working length when compared with apex NRG- blue.

Table 5: Mean Difference Between RAYPEX 5 (EWL) And Actual Working Length (AWL)

S. No.	Mean Ewl	Mean Awl	Difference	DWL(+/-)
1	22.000	22.333	-0.333	-
2	22.333	22.833	-0.500	-
3	21.000	21.167	-0.167	-
4	24.000	24.500	-0.500	-
5	20.333	20.167	0.167	+
6	19.000	19.167	-0.167	-
7	21.833	22.000	-0.167	-
8	20.667	20.667	0.000	0
9	22.500	22.667	-0.167	-
10	21.500	21.500	0.000	0
11	22.500	22.500	0.000	0
12	22.833	22.833	0.000	0
13	24.333	24.167	0.167	+
14	23.167	22.667	0.500	+
15	21.000	21.000	0.000	0
16	18.500	18.667	-0.167	-
17	17.833	18.000	-0.167	-
18	17.167	17.167	0.000	0
19	19.000	19.167	-0.167	-
20	21.167	21.333	-0.167	-
21	21.667	22.000	-0.333	-
22	23.333	23.500	-0.167	-
23	19.000	19.167	-0.167	-
24	19.500	19.333	0.167	+
25	20.000	20.000	0.000	0
26	22.667	23.000	-0.333	-
27	21.833	21.833	0.000	0
28	21.000	21.167	-0.167	-
29	20.167	20.500	-0.333	-
30	19.500	19.000	0.500	+
31	17.667	18.000	-0.333	-
32	19.000	19.167	-0.167	-
33	21.500	21.667	-0.167	-
34	19.000	18.667	0.333	+
35	22.500	22.667	-0.167	-
36	22.000	22.167	-0.167	-
37	20.333	20.667	-0.333	-
38	18.500	18.667	-0.167	-
39	19.500	19.667	-0.167	-
40	19.000	19.000	0.000	0

Table 6: Mean Difference between APEX NRG-BLUE (EWL) and Actual Working Length (AWL)

S. No.	Mean Ewl	Mean Awl	Difference	Dwl(+/-)
1	21.500	22.333	-0.833	-
2	22.333	22.833	-0.500	-
3	20.500	21.167	-0.667	-
4	23.667	24.500	-0.833	-
5	20.167	20.167	0.000	0
6	18.833	19.167	-0.333	-
7	21.667	22.000	-0.333	-
8	20.700	20.667	0.167	+
9	22.000	22.667	-0.667	-
10	21.167	21.500	-0.333	-
11	22.167	22.500	-0.333	-
12	22.833	22.833	0.000	0
13	24.167	24.167	0.000	0
14	23.000	22.667	0.333	+
15	20.833	21.000	-0.167	-
16	18.167	18.667	-0.500	-
17	18.167	18.000	0.167	+
18	16.833	17.167	-0.333	-
19	19.000	19.167	-0.167	-
20	21.167	21.333	-0.167	-
21	22.000	22.000	0.000	0
22	22.667	23.500	-0.833	-
23	18.167	19.167	-1.000	-
24	19.167	19.333	-0.167	-
25	19.833	20.000	-0.167	-
26	22.167	23.000	-0.833	-
27	21.167	21.833	-0.667	-
28	21.000	21.167	-0.167	-
29	19.833	20.500	-0.667	-
30	19.167	19.000	0.167	+
31	17.167	18.000	-0.833	-
32	18.833	19.167	-0.333	-
33	21.167	21.667	-0.500	-
34	18.667	18.667	0.000	0
35	22.500	22.667	-0.167	-
36	21.833	22.167	-0.333	-
37	20.333	20.667	-0.333	-
38	18.500	18.667	-0.167	-
39	19.167	19.667	-0.500	-
40	18.667	19.000	-0.333	-

Table 7: Mean difference between the values obtained with each electronic apex locator (EAL) and the actual length (AL)

Apex locator	Mean*	SD
Apex Nrg Blue	-.34mm	.341
Raypex 5	-.100 mm	.222

*Minus sign indicates measurements short of actual length.

Table 8: Measurement percentage distribution for Raypex 5

Measurement (Raypex 5)	No. of Teeth	Accuracy Percentage
EXACT (0)	9	22.50%
(+/-) 0.5mm	39	97.50%
(+/-) 1mm	40	100%

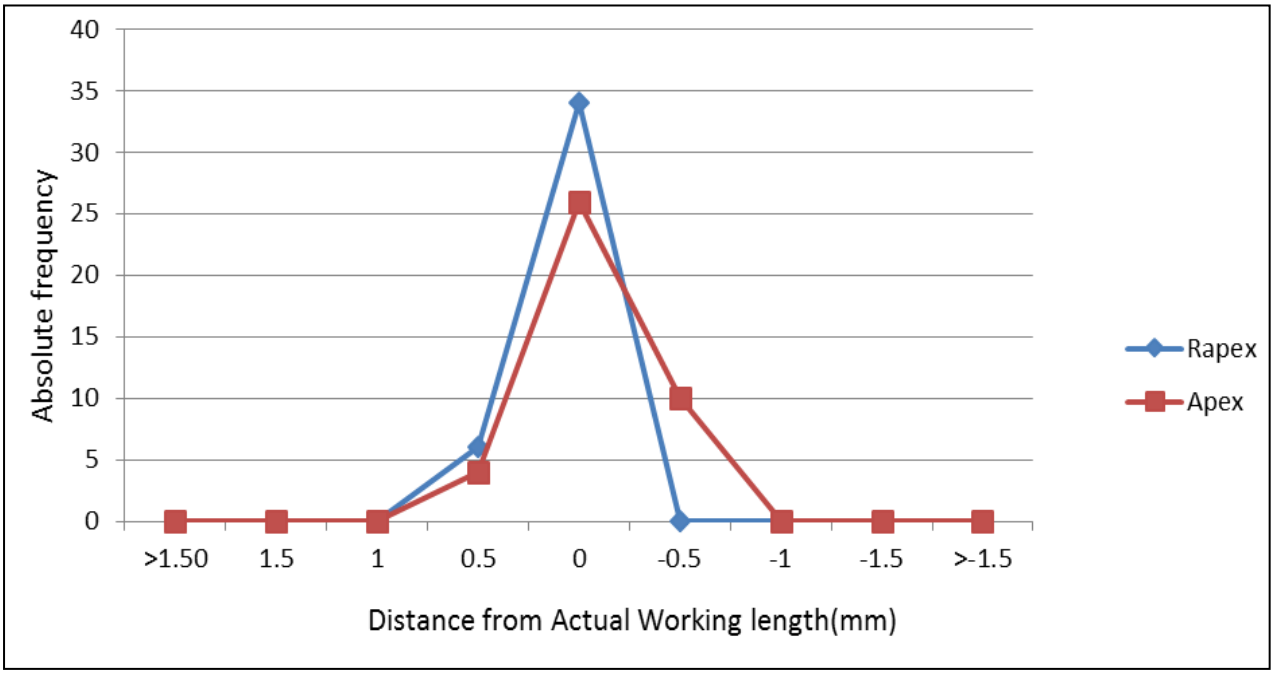
Table 9: Measurement percentage distribution for NRG- BLUE

Measurement (Nrg Blue)	No. of Teeth	Accuracy Percentage
EXACT (0)	5	12.50%
(+/-) 0.5mm	35	87.50%
(+/-) 1mm	40	100%

Table 10: Percentage distribution of the electronic length measurement with two apex locators

	Raypex 5		Apex Nrg Blue	
Distance from actual length (mm)	N=40	Percentage (%)	N=40	Percentage (%)
-1.0 to -0.5mm	0	0%	10	25%
-0.5 to 0.0mm	34	85%	26	65%
0.01 to 0.5mm	6	15%	4	10%
0.5 to 1.0mm	0	0%	0	0%

*Negative value indicates measurements short of AL.



Graph 1: Measurement Distribution Graph for Raypex 5 and NRG Blue

Discussion

All EALs function by using the human body to complete an electrical circuit. One side of the apex locator's circuit subsequently is connected to the oral mucosa through a lip clip and the other side to a file. When the file is placed into the root canal and advanced apically until it is tip touches periodontal tissue at the apex, the electrical circuit is completed. The electrical resistance of the EAL and the resistance between the file and oral mucosa are now equal, which results in the device indicating that the apex has been reached.

In the present study we used 15 no. k file for electronic working length determination as the precision of measurement also depend on the file size and the dimensions of root canal and foramen. Reported that the apex locator precision varied as a function of apical constriction diameter. It was reported that with increasing diameter of the root canal, the electronically measured length became shorter with small files, depending on the fluid inside the canal. Normally, small-diameter files of size 10 are used to determine the initial working length to prevent the distortion of the apical constriction. But Small files are likely to leave space within the canal exposing more metallic surface to the surrounding electrolyte, whereas files of large diameter will fit more tightly, a smaller surface exposed to electrolytes and hence different electrochemical properties.

This study is focused on the comparison of the apex locators Rapex 5 and NRG-Blue under defined experiment conditions. It is stated that both instruments operate in the presence of pulp tissue and conductive or nonconductive fluids that can change the electrical characteristics within the root canal.

Raypex-5 claims to be a fourth-generation device (according to manufacturer), and the unit uses 2 separate frequencies 400 hz and 8 khz. The manufacturer claim that the combination of using only one frequency at a time and basing measurements on he root mean square values of the signals increases the measurement accuracy and the reliability of the device. The device uses the same 2 alternating current frequencies (400 to 8 khz) and determine the working length via impedence ratio. the main difference lies in their display and that the Root ZX passes 2 currents simultaneously where as Raypex 5 does so successively.

Raypex 5, which is an impedence –ratio apex locator shows a blinking red alarm when the file tip has just passed the apical foramen. The file tip is just withdrawn just to the point that the blinking apex indicator goes away indicating that the file is between major and minor foramen. As the meter scale of Raypex 5 has colour coded areas for different apical regions, a conversion table was set up based on the interpretation of the different zones in the user manual (VDW 2005). (Table 1)

Apex NRG blue (Medic NRG Ltd, Tel Aviv, Israel) is a novel miniature apex locator which is a multifrequency 3rd generation apex locator with a blue tooth attachment. The technology of this apex locator is based on digital processing (DSP) and uses square multi-frequency currents. This can be used both in dry and wet conditions. Nrg blue contains two colour LED light signals orange and blue. The acoustic signal (alarm) gives the indication of reaching the apex. The markings present on the apex locator are Apex, .25, .5, 1.0, 1.5. When the file goes beyond the apex the device gives orange LED signal and when the file is just at the apex it gives a blue LED signal. The reading 0.5 on the device is recorded as the electronic working length. This reading corresponds to the apical constriction. The results were interpreted with care due to experimental short comings, particularly when instrumenting narrow root canals with files having a diameter of 0.15mm (#15 K file). The apical constriction might be unintentionally displaces or destroyed which leads to erroneous results. To avoid this problem #10 K file was used to determine the actual root canal length before electronic working length measurement.

Measurents obtained using Raypex5 were consistently closer to the actual length (AL) (± 0.5).The mean difference between the actual length(AL) and length measured by the Raypex 5 was -0.100 mm (SD 0.222) and NRG blue -0.34mm (SD 0.341). A positive co-relation of 0.667 (P=0.00) existed between the two devices.

Comparing the differences between measurents obtained with the electronic apex locator and the actual working length of the tooth as obtained using the magnifying glass, the % accuracy within ± 0.5 mm of the actual length was 97.5% for Raypex 5, 87.5% for NRG blue.

The measurement beyond the apical foramen is 15% for Raypex 5 which is according to the results obtained by Eva katia stober (15%) and Shobreb (9%).The results of our study can be more aptly supported by the results of the study done by who found that accuracy of Raypex 5 to determine the apical foramen was 75% and 94%; taking ± 0.5 in to account. They also showed that the EAL determined the canal length within ± 0.5 from the reference length in majority of cases. Only in few case the length measured was beyond the working length (15% and 9%) respectively.

The Raypex 5 is more accurate in the present invitro conditions but accuracy is not significantly more. Thus we can consider that both the apex locators are efficient in terms of accuracy when ±.5mm tolerance is considered.

Conclusion

Electronic method for tooth length determination has progressed significantly and has been increasingly integrated into the modern practice of endodontics. Under invitro conditions of the study the tested EALs identified the apical constriction in range of ±0.5 mm with high degree of accuracy. Combined with high observer concordance, the result suggests that electronic root canal measurement can be an objective and acceptably reproducible technique. The outcome of this study indicates that Raypex 5 and Nrg Blue can accurately measure the working length and act as a very helpful aid in the success of endodontic therapy.

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