

Research Article**Measuring three apex-finders' accuracy in determining root canal length:
Experimental study**

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ABSTRACT

Introduction: Precise positioning of root canal length is an important factor especially for success of root canal treatment. Completely cleaning and shaping the root canal system, sealing it completely and then filling with a good, strong, impenetrable and three-dimensional, so that there is no leakage is the main purpose for these kinds of study. The aim of this study was to evaluate the accuracy of three apex locators in determining the length of root canal (in vitro).

Materials and Methods: This experimental (in vitro) study was performed on 44 single root teeth straight extracted. All teeth were placed in the alginate model. After access cavities and coding teeth, actual length of each canal was determined and recorded by taking the appropriate files into the canal and inserting it in the position of edge to edge the apical foramen. The canal length of each tooth were measured by using three Rotor, Root ZX, Ray pex 5 devices according to the manufacturer's instructions. Paired sample T-test was used to analyze the data. The significance level was ($P > 0.05$).

Results: By accepting error ± 0.5 mm of apical foramen, the number of accepted cases were 43 cases (%97.7) for Root zx, 44 samples (100%) for Rotor and Raypex 5. The mean difference of the actual length was 0.0182, 0.0523 and -0.0386 mm for Root ZX, Rotor and Ray pex 5, respectively. There was no significant difference between actual working length with measured working length by Rotor ($P > 0.05$). There was also no significant difference between the measured working length by Root ZX and Raypex 5 with a measured working length by Rotor ($P > 0.05$).

Conclusion: The results of this study showed that the maximum accuracy was related to Root zx, Raypex 5 and Rotor apex locators, respectively. Also, there was no statistically significant difference between the average working length of Rotor apex locator compared to the actual length, and measured working length by Root zx and Raypex 5 devices. Clinically, evaluation of accuracy of Rotor device from apical foramen by accepting error ± 0.05 mm, the number of accepted cases was 44 samples (100%). These results suggest that clinically accuracy of measured working length by Rotor is acceptable.

Keywords: pex Locator, Working Length, Accuracy, Rotor, Root zx, Raypex

INTRODUCTION

Precise determining root canal length, completely cleaning and shaping the root canal system, sealing it completely and then filling with a good, strong, impenetrable and three-dimensional are main goals, so that there is no leakage is the main purpose so for cleansing process there is need to determine precise canal length. Consequently, determining precise ending point of treatment is the main step for root treatment. Clinically, good location of final treatment of tooth root canal is apical constriction. Determining working length and working in this range during canal preparation is popular challenge of root canal treatment. There have been many methods of obtaining the length so far including applying mean length of teeth statistically, feeling finger touch, and radiography (2). Generally, for 100 years, radiography has been popular and acceptable method of measuring root canal length (3). However, it is difficult to obtain precise length of canal because apical constriction, and technique difference, severe bending and abnormal forms are making error (1). Radiography has technical disadvantages including inappropriate film positioning in oral cavity, problems caused by lack of patient's collaboration and wrong X-angle adjustment which all cause to take bad picture, so there is need to repeat imaging while x-ray is risky for both patients and employers. In addition, radiography is not possible for patients that are moving a lot and have severe nausea when film is placed in their mouth (4). Thus, besides using radiography, determining canal length by electronic machines is very important. Since 1962, electronic apex finder machines have been used broadly for determining root canal length in endodontic (5). Electronic apex finder machines are used in endodontic for determining apical foreman location and so determining root canal space. Root apex is resistance to electric current and it is measurable with a pair of electrode normally to Lip Clip and connecting to endodontic file. Electronic apex finders reduce required radiography numbers and when radiography

technique causes an error they can be helpful considerably. Apex finders may indicate cases in that there is a gap between anatomic foramen apical and radiography apex. Apex finders have 6 generations (6). Apex finders also provide immediate detection of iatrogenic perforations during pulp treatment (4). Today using electronic apex finders for determining root canal length is recommended. These machines reduce treatment time, and decrease received ray rate by patient and also cause tooth root canal length improve (7).

Using electronic system for length determining has been represented for 50 years and different versions have been made so far. However, apex finders are not 100% accurate. It is clarified that new versions of these apex finders are not sensitive to the type of detergents in the canal, size of applied files, and necrosis or vitality of pulp tissue (7). Root ZX is version 3 of apex finder and has high accuracy (7,9). Different studies investigated accuracy rate of Root ZX in permanent teeth with ± 0.5 millimeter distance between apical foramen and concluded it was 90% and in 1 millimeter distance between apical foramen as 100% (7). Raypex5 is 4th version of apex finder with two frequency including 400 hertz and 8 kilo hertz (8). Rotor (Meta Biomed, Cheongwon-gun, Korea) apex finder is a modern apex finder, from 3th version of EALs which use two frequencies (0.5 kilo hertz and 5 kilo hertz) (10). Few studies (10) have been performed on analysis of rotor apex finder accuracy in measuring real canal length. In addition, this apex finder has low cost and higher accuracy so we decided to evaluate electronic apex finder accuracy and compare it with two other useful machines (Raypex5 and Root zx) in determining root canal length in laboratory condition.

MATERIAL & METHODS

This experimental-laboratorial study was performed on single-root tooth and withdrawn human tooth based on insert and exit standards. These standards include: central, lateral and premolar teeth. These teeth were good for study

because they did not have calcification, internal and external resorption, severe curvature of root or its breakage. Exit standards included: teeth with periodontal diseases with severe corrosion were withdrawn. Sample volume was determined as 44 teeth by statistics consultants and based on 0.2 error with significance level of 0.05 for evaluating accuracy of electronic apex finder machines including Root ZX (Raypex 5 and Rotor). After withdrawn from teeth, mentioned teeth were kept in 5/25% sodium hypochlorite for three hours and then in 10% formalin in order to remove periodontal yarns (2). Firstly, all corruptions of dentinal filling materials were removed and then accessible holes were provided and shampire pulp tissue was removed by excavator. In addition, for providing an stable and repeatable occlusal, teeth occlusal surface was flattened. Coronal surface of root canal were flared. Then, by a nail polish for marked by a stable indicator. Furthermore, all teeth were numbered and kept in containers. For each plastic container, a firm lid was provided and code of each tooth was written on the container (2).

Measuring actual length of teeth:

Firstly, a file number 10 or number 15 (Mani, made in Japan), based on tooth root canal, were placed inside the root canal until file tip came out from apical foramen. Then file were pulled back slowly until file tip was observed from foramen opening point. This condition was studied by microscope and movement of catheter on apex more accurate. Then file stop was matched with references point of each sample. Next, the gap between stop and file tip was measured by a coulisse with 0.01 millimeter accuracy. After measuring length of each tooth, the measurement was recorded based on the code. In next step, measuring canal length was performed by three machines: Rotor (meta biomed co, Korea) (Root zx (VDW, Munich, Germany) and (dentaport, US) Ray pex 5 which are made based o manufacturer factory (pages 1 to 3. As alginate causes maximum difference between apical foramen and file tip which is 0.1, alginate was used for PDL

imitator environment (11). In order to measure each tooth canal length, probe holder of the machine was placed on file fitted to canal and Lipclip inside of environment in a way that 3 millimeter of apex end was placed in alginate. Then, file was transferred to apex side until the machine indicated target point based on factory claim about apical constriction. In order to prevent error, blind method was used for measurement and teeth were selected randomly (2). Then each tooth was placed on each coded container while researcher did not know anything about measurement results of other apex finders.

Due to difference in tooth length, measured lengths differentials were calculated for apex finder machines with initial AL for each tooth ($\Delta L = LAPEX0_AL$). Positive difference means that apical foramen file was rejected, difference means that file did not access to apical foramen. Zero difference means that file is matched with the hole. All measurements were repeated three times and the mean was reported too (12). Obtained results were analysed by SPSS version 20. In order to describe data, descriptive statistic (mean, standard deviation) was used. Paired T test was applied for comparing accuracy of three mentioned apex finders (RootZX, Rotor, Raypex) in determining root canal working length. Level of significance was $p < 0.05$.

RESULTS

Investigating accuracy of Root ZX machine resulted in precise compatibility of canal length of 30 teeth (68.2%) with measured actual function (file was proportional to apical foreman). By accepting $5/0 \pm$ mm error from apical foramen, acceptable number was 33 samples (7.97%). By accepting ± 1 mm error from apical foramen, acceptable number was 44 samples (100%). In 7 teeth (9.15%) apical foramen file was rejected; in 7teeth (15.9%) reach to apical foramen (table 1). Investigating accuracy of Rotor machine is indicator of precise compatibility of canal length of 24 teeth (0.54%) with measured actual function (file was proportional to apical foreman). By considering $5/0 \pm$ mm error of apical foramen was

acceptable number of 44 samples (100%). By considering ± 1 mm error of apical foramen, acceptable number was 44 samples (100%). In 16 teeth (36.4%) apical foramen file was rejected; in 4 teeth (9.1%) reach to apical foramen (table 2).

Investigating accuracy of Raypex 5 machine is indicator of precise compatibility of canal length of 24 teeth (54.5 %) with measured actual function (file was proportional to apical foreman). By considering $5/0 \pm$ mm error of apical foramen, acceptable number was 44 samples (100%). By considering ± 1 mm error of apical foramen, acceptable number was 44 samples (100%). In 8 teeth (18.2%) apical foramen file was rejected; in 12 teeth (27.3%) reach to apical foramen (table 3).

Mean (standard deviation) of working length of three apex finders and actual length are indicated in table 4. Difference of mean from real length was 0.0182 mm for Root ZX, 0.0523 mm for Rotor and -0.0386 mm for Ray pex 5 (table 5).

Dependent t test indicated that there is no significant difference between real working length with measured working length of RootZX and Raypex 5 ($p > 0.05$).

There is no significant difference between real working length with measured working length of RootZX and Raypex 5 ($p > 0.05$). There is no significant difference between real working length with measured working length of Rotor ($p > 0.05$). There is no significant difference between measured working length by RootZX and Raypex5 with measured working length by Rotor ($p > 0.05$) (table 6).

DISCUSSION

One main issue in root treatment is limitation of all treatment process into root canal system. So there is need to determine precise location of treatment end in order not to damage periapical tissues while cleansing and formation of all root canal space. So specifying canal length by these machines can be used in following issues: determining perforation position of root or pulp end, determining additional canals, determining ending calcific barrier position in teeth under treatment of apexification, determining location of root end metal filling in issues that need treatment after operation of apical (2). Aim of the study was measuring accuracy of three apex-finders in determining root canal length (experimental study) endodontic sector.

Apex-finders accuracy in in vivo (13-18) and in vitro studies (10, 19-25) has been studied so far. In Duran-Sindreu et al studies (2012) accuracy of Root ZX was measured in laboratory and in vivo type. Results indicated that there was no significant difference between working length of measuring condition by Root ZX in both status of in vivo and in vitro (26).

In laboratorial studies electric conductors such as agar-agar (27), alginate (28-30), gelatin (31,32), or saline solution (2,33) were used for simulation of clinical conditions. As using alginate materials cause maximum difference between apical foramen and file tip which is 0/1 millimeter, alginate was used as PDL imitator environment (11). Using alginate model was described by Inaz et al (34). On the other hand alginate was easy,

Table 1: frequency distribution of error rate of Root ZX in all teeth

error rate	frequency	percent
0	30	68.2
$0.5 \leq x < 0$	6	13.6
$1 \leq x < 0.5 +$	1	2.3
$0 < x \leq -0.5$	7	15.9
Total	44	100

X= actual working length of root canal

Table 2: frequency distribution of error rate of Rotor in all teeth

Error rate	frequency	percentage
0	24	54.5
$0.5 \leq x < 0$	16	36.4
$0 < x \leq -0.5$	4	9.1
total	44	100

Table 3: frequency distribution of error rate of Raypex 5 in all teeth

Error rate	frequency	percentage
0	24	54.5
$0.5 \leq x < 0$	8	18.2
$0 < x \leq -0.5$	12	27.3
total	44	100

Table 4: determining working length of three apex finders and real length.

Mode of determining working length	Mean(millimeter)	Standard deviation	number
actual length	14.516	1.395	44
Root ZX	14.534	1.378	44
Rotor	14.568	1.378	44
Raypex 5	14.477	1.355	44

Table 5: Difference of mean from file tip to apical foramen (millimeter)

	Difference of mean	Standard deviation	minimum	maximum	number
Root ZX	0.0182	0.305	-0.5	1	44
Rotor	0.0523	0.189	-0.5	0.3	44
Raypex 5	-0.0386	0.331	-0.5	0.5	44

Table 6: comparing accuracy of three apex finders in determining root canal length by dependent t test

Discussion and conclusion

		Pair difference		t	Df	P value
		mean	Standard deviation			
Pair 1	Rotor _ Actual working length	.0523	.1898	1.826	43	.075
Pair 2	Root ZX_ Actual working length	.0182	.3060	.394	43	.695
Pair 3	Raypex 5_ Actual working length	-.0386	.3315	-.773	43	.444
Pair 4	Rotor Root ZX _	.0341	.2957	.765	43	.449
Pair 5	Rotor _ Raypex 5	.0909	.3703	1.628	43	.111
Pair 6	Root ZX _ Raypex 5	.0568	.3611	1.044	43	.302

cheap and stable (28), it remains around the root, simulates periodontal ligament by colloids, and has appropriate electricity properties.

Measurements were obtained in target distance of ± 0.5 mil to apical constriction because acceptable clinical error is ± 0.5 millimeter as the most

accurate distance (19). Measurements are very precise due to minimum error. (19).

Results indicated that maximum accuracy was related to Root zx, Raypex5, Rotor respectively. In addition, mean of working length of Rotor had no significant difference with actual length of Root zx, Raypex5.

By accepting error ± 0.5 mm of apical foramen, the number of cases was accepted 43 cases (%97.7) for Root zx, 44 samples (100%) for Rotor and Raypex 5. The mean difference of the actual length was 0.0182, 0.0523 and -0.0386 mm for Root ZX, Rotor and Ray pex 5, respectively. There was no significant difference between actual working length with measured working length by Rotor ($P > 0.05$). There was also no significant difference between the measured working length by Root ZX and Raypex 5 with a measured working length by Rotor ($P > 0.05$).

In Altunbas et al study (2015) many measurements of Rotor machine (93/3%) rejected apical foramen. while there was no significant difference between Rotor with DentaPort ZX rotor had significant difference with SIROEndo Pocket (10).

Studies reported that preflaring of root canals causes increase of apex finder's accuracy before working length measurement (10), in Altunbas et al (2015) studies preflaring root canals was performed before measuring working length (10). In this study also preflaring root canals was performed before measuring working length.

Investigating accuracy of Rotor machine is indicator of precise compatibility of canal length of 24 teeth (54.5 %) with measured actual function (file was proportional to apical foreman). By considering ± 0.5 mm error of apical foramen was acceptable number of 44 samples (100%). By considering ± 1 mm error of apical foramen was acceptable number of 44 samples (100%). In 16 teeth (36/4%) apical foramen file was rejected; in 4 teeth (9/1%) reach to apical foramen. these results indicates that clinically, accuracy of working length of Rotor machine is acceptable.

In Altunbas et al (2015), results of analysis of accuracy of Rotor is indicator of precise compatibility of canal length 6/67% with measured real working length. By accepting ± 0.5 mm error, from apical foramen, accuracy of Rotor was 86.6% (10). Reason of difference in results of Rotor was dependent on experimental method, sample volume, and laboratorial environment such as applied file size (30). It is clear that when there is no similar condition, true comparison is not possible. On the other hand, it needs to be considered that this study did not compare Rotor with Raypex 5.

Investigating accuracy of Root ZX machine is indicator of precise compatibility of canal length of 30 teeth (68 %) with measured actual function (file was proportional to apical foreman). By considering $5/0 \pm$ mm error of apical foramen was acceptable number of 33 samples (97.7%). By considering ± 1 mm error of apical foramen was acceptable number of 44 samples (100%) in 7 teeth (15.9%) apical foramen file was rejected; in 7teeth (15/9%) reach to apical foramen.

Results of Aydin et al (2015) study indicated 80% accuracy of Root ZX with acceptance of ± 0.5 mm error while with accepting ± 1 mm error it showed 100% accuracy in teeth with mature apex (30). In Kumar et al study (2016), working length was evaluated by stereo microscope on milk teeth with immature teeth, and accuracy rate of Root zx mini was obtained as 95.1% by considering $5/0 \pm$ mm error. In addition, dry or humid environment had no effect on apex finder (35). In in vivo study performed by Stober et al (2011), accuracy rate of Root ZX in 0.5 mm distance was 72%. They calculated working length in 0/5 millimeter distance from apical foramen (36).

Investigating accuracy of Raypex 5 machine is indicator of precise compatibility of canal length of 24 teeth (54.5 %) with measured actual function (file was proportional to apical foreman). By considering ± 0.5 mm error of apical foramen was acceptable number of 44 samples (100%). By considering ± 1 mm error of apical foramen was acceptable number of 44 samples (100%). In 8

teeth (18/2%) apical foramen file was rejected; in 12 teeth (27/3%) reach to apical foramen.

In Hashemi nia et al (2007) study, results of analysis of Raypex 5 accuracy rate, by accepting $5/0\pm$ error, from apical foramen , for all teeth and by accepting ± 1 error, from apical foramen it has 97/6% accuracy (2). Reason of this difference is due to 160 dental canals as sample volume in Hashemi nia study and also using single and double canal teeth. In this study, 44 single canal teeth were used. In Kustarci et al (2014) study, accuracy rate of Raypex 5 was 86/7% on 30 single root canals by accepting ± 0.5 mm error from apical foramen (19).

According to results of this study and other studies, we can conclude that electronic machines which determined apex position are effective tools for root treatment especially when radiography is not the best option. In addition, choosing a machine needs accuracy and reliability, and being confident in what factory claimed. And also consideration of personal taste is important too.

CONCLUSION

The results of this study showed that the maximum accuracy was related to Root zx, Raypex 5 and Rotor apex locators, respectively. Also, there was no statistically significant difference between the average working length of Rotor apex locator compared to the actual length, and measured working length by Root zx and Raypex 5 devices. Clinically, evaluation of accuracy of Rotor device from apical foramen by accepting error ± 0.05 mm, the number of accepted cases was 44 samples (100%). These results suggest that clinically accuracy of measured working length by Rotor is acceptable.

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