

In vitro evaluation of Root ZX and Raypex 6 in teeth with different apical diameters

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Abstract

Background: There is a growing interest about electronic apex locators for working length determination. There are several studies dealing with their performance in different conditions.

Aims: The aim of this study is to evaluate the accuracy of Root ZX and Raypex 6 in teeth with different apical diameters.

Materials and Methods: Actual working length (AWL) of 80 single rooted teeth were determined as 0.5 mm short of apical foramen. The teeth were divided into 4 groups ($n = 20$). First group (G 0) included teeth with mature apices. Root canals of the other groups (G 32, G 57 and G 72) were enlarged until apical sizes of 0.32, 0.57 and 0.72 mm were obtained. Samples were embedded in alginate and electronic measurements (EM) were performed.

Statistical analysis: was achieved with Fisher exact test.

Results: Both devices revealed a high rate of success in G 0 and G 32. Their accuracy decreased significantly in G 57 and G 72 groups ($P < 0.05$). Intra-group results of Root ZX and Raypex 6 were similar ($P > 0.05$).

Conclusions: Root ZX and Raypex 6 are reliable in teeth with mature apices. At foramen diameters exceeding 0.57 mm, their accuracy is susceptible.

Keywords: Apical constriction; electronic apex locator; Raypex 6; Root ZX; working length determination

INTRODUCTION

Working length determination is crucial for the success of root canal treatment. Apical constriction, which is the narrowest part of the root canal and the connection site of periodontal and pulpal tissues is the recommended point for the apical terminal of working length.^[1] To determine this critical point, a number of techniques, including tactile sensation, radiographs and electronic apex locators (EALs) are in daily use.^[1] Although the radiographic method is widely used, it is unsatisfactory because it relies upon the interpretation of the clinician due to its two-dimensional image.^[2] Furthermore, anatomic landmarks such as zygomatic arch and maxillary sinus may adversely affect the determination of working length with radiographs.^[3] Positioning of apices on the lateral surfaces of the roots is another limitation of the radiographic method.^[4]

To overcome these limitations of radiographic method, EALs are continually improving since the first device developed by Sunada.^[5] Especially, during the last two

decades advanced third-generation EALs such as Root ZX (J Morita, Tokyo, Japan) were introduced as their accuracy is not affected in the presence of electrolytes, irrigants, exudates and tissue remnants.^[6] The diameter of apical foramen may also influence the accuracy of EALs.^[7] Over-instrumentation, pulp necrosis at the early developmental stages of root formation and root resorptions are the main reasons for open apices.^[8]

Raypex 6 (VDW, Munich, Germany) is the last member of Raypex series whose clinical performance was previously found to be successful with the evaluation of Raypex 4 and 5.^[9-11] To the best of our knowledge, the only one study evaluating the performance of this new device was done by Moscoso *et al.*^[12] They found that Raypex 6 is accurate 88.22% at ± 0.5 mm and 100% at ± 1 mm. However, there is no study evaluating its performance in teeth with open apices.

For this reason, the present study aimed to evaluate the performance of Root ZX and Raypex 6 in teeth with

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both closed apices and open apices with different apical diameters.

MATERIALS AND METHODS

Preparation of the samples

A total of 80 single rooted teeth with mature apices were selected for this study. The teeth were kept in 10% formaldehyde after extraction. Roots representing fractures, resorptions or any other anatomical irregularities were not included. Presence of only one straight non-calcified canal was confirmed with radiographs. Occlusal or incisal surfaces of the teeth were flattened with a diamond bur until a reliable reference point was obtained. Access cavities were prepared. A size 10 K-file was progressed throughout the root canal until it became visible at the apical foramen (AF) under stereomicroscope (Leica Microsystems) with a magnification of 20 \times . The file was withdrawn 0.5 mm from this point, the length between file tip and reference was measured with a digital caliper (Aydal, Istanbul, Turkey). This distance was recorded as actual working length (AWL). A new file was used for each tooth to avoid the misleading effect of the stoppers resulting from detente of them. Then all teeth were grouped as follows.

Group 0

Mature apex. Only EAL measurement was achieved.

Group 32

Canals were progressively enlarged until a size 30 K-file was advanced 1 mm beyond the AF.

Group 57

Canals were progressively enlarged until a size 55 K-file was advanced 1 mm beyond the AF.

Group 72

Canals were progressively enlarged until a size 70 K-file was advanced 1 mm beyond the AF. Thus, an apical widening of 0.32 mm, 0.57 mm and 0.72 mm was obtained.

EAL measurements

After determining AWLs, measurements with EALs were achieved. All samples were embedded in an alginate-filled mold. The lip clip was inserted in alginate. Canals were rinsed with 2.5% NaOCl and excess of NaOCl was removed from pulp chamber with a cotton pellet. The EAL measurements were performed according to the manufacturer's instructions. For group 0, a K-file snugging the apical region at the working length was attached to the EALs while master apical files were selected for other groups. The file was advanced throughout the canals until the working length. For Root ZX, working length determination was established at the point when the screen displays the line just in the middle of apex and 1 marks

which corresponds to 0.5 mm short of radiologic apex. For Raypex 6, the third green line, just before the yellow lines, which corresponds to 0.5 mm short of radiographic apex was determined for working length. The measures were recorded as electronic measurement (EM) if they were stable for at least 5 seconds.

Data analysis

The results of two apex locators were assessed both inter-group and intra-group. Statistical analysis was performed with Fisher exact test. Significance was set at $P < 0.05$.

RESULTS

Tables 1 and 2 represent the accuracy of Root ZX and Raypex 6 within ± 0.5 mm and ± 1 mm. Within ± 0.5 mm, both devices performed best at G 0 and G 32 ($P > 0.05$). Their accuracy significantly decreased at G 57 and G 72 ($P < 0.05$). There was no significant difference between G 0 and G 32. Also there was no significant difference between G 57 and G 72.

The inter-group evaluation of the two apex locators was represented in Table 3. Root ZX and Raypex 6 revealed similar results in each group ($P > 0.05$).

DISCUSSION

Numerous studies emphasized the importance of accurate working length determination.^[6,13,14] Negishi *et al.*,^[15] stated that the best treatment outcomes may be obtained within a distance of 0-2 mm from radiographic apex. However, ElAyouti *et al.*,^[3] found that instrumentation within a distance of 0-2 mm from radiographic apex resulted in over-instrumentation in 51% of premolars and 22% of molars and concluded that radiographic measurement should be supplied with electronic measurement. Inadequate instrumentation leads to inadequate cleaning and shaping while over-instrumentation may result in extrusion of debris and irrigants. Especially, in teeth with open apices, it is challenging to accurately determine the working length and to avoid complications mentioned above. Akisue *et al.*,^[8] evaluated the performance of 5 EALs in teeth with different apical diameters and found that the accuracy of iPex and Propex II apex locators reduced significantly with increasing apical diameter. The present study aimed to evaluate the efficiency of Root ZX and Raypex 6 in teeth with both mature and open apices.

The success of Root ZX was proved with several studies and the accuracy of different EALs were compared to that of Root ZX.^[2,5,16,17] In accordance with previous studies,^[2,4,18,19] the results of the present study represented that Root ZX revealed success rate of 80% within ± 0.5 mm and 100% within ± 1 mm in teeth with mature apices.

Table 1: The distance of file EMs to AWLs for Root ZX.
***0 indicates EM is exactly the same as AWL. Negative values indicate EM is shorter than AWL. Positive values indicate EM is exceeding AWL**

Distance to apex	G0 (%)	G32 (%)	G57 (%)	G72
Sample size (N)	20	20	20	20
1 to 0.51	0	2	3	3
0.5 to 0.01	6	6	5	5
0*	0	0	0	0
-0.01 to -0.5	10	9	6	5
-0.51 to -1	4	3	4	4
Accuracy (± 0.5 mm)	80 ^b	75 ^a	55 ^a	50 ^b
Accuracy (± 1 mm)	100	100	90	85

Table 2: The distance of file EMs to AWLs for Raypex 6.
***0 indicates EM is exactly the same as AWL. Negative values indicate EM is shorter than AWL. Positive values indicate EM is exceeding AWL**

Distance to apex	G0 (%)	G32 (%)	G57 (%)	G72
Sample size	20	20	20	20
1 to 0.51	0	1	2	2
0.5 to 0.01	5	5	4	4
0*	1	1	0	1
-0.01 to -0.5	11	9	6	4
-0.51 to -1	2	2	5	5
accuracy (± 0.5 mm)	85 ^a	75 ^a	50 ^b	45 ^b
accuracy (± 1 mm)	95	90	85	80

Table 3: The inter-group (two EALs in the same apical diameter size) comparison of the accuracy of the two apex locators within ± 0.5 mm in each group

Distance to apex	Root ZX	Raypex 6
G 0	16 ^a	17 ^a
G 32	15 ^a	15 ^a
G 57	11 ^a	10 ^a
G 72	10 ^a	9 ^a

For open apices, the accuracy of Root ZX varies. In two studies of Herrera *et al.*,^[20,21] the ratio of acceptable measurements for Root ZX decreased with the increasing diameter exceeding 0.6 mm and 1.02 mm, respectively. In the study of Akisue *et al.*,^[8] the performance of Root ZX was evaluated in teeth with apical diameters of 0.27 mm, 0.47 mm and 0.72 mm. The results revealed that despite the success of Root ZX decreased with increasing apical diameter, there was no statistically significant difference. In accordance with the studies of Herrera *et al.*,^[20,21] in the present study the accuracy of Root ZX decreased at 0.57 mm and 0.72 mm within ± 0.5 mm. According to Nguyen *et al.*,^[22] Root ZX determines the narrowest region of the root canal even if the apical constriction is disturbed. We hypothesize that with increasing apical size, the taper toward apex disappears and canal walls become parallel. This may be the reason why the accuracy of Root ZX decreased in G 57 and G 72.

But it must not be omitted that the size of file used for electronic measurement is also important. The studies of Ebrahim *et al.*,^[23,24] and Herrera *et al.*,^[20,21] pointed out that

the file size should be as close as possible to the apical diameter for the accuracy of the results. In the present study, the first file snugging in the apical region for Group 0 and the master apical file for other groups were attached to the EALs.

Raypex is another widely used EAL. Stober *et al.*,^[11] evaluated the clinical performance of Raypex 5 found that it is 75% accurate to ± 0.5 mm and 100% to ± 1 mm. Furthermore in the study of Somma *et al.*,^[9] the accuracy of Raypex 5 is high. The previous model of this device-Raypex 4 was evaluated by ElAyouti *et al.*,^[10] in teeth with root resections. They found that the accuracy of Root ZX with a ratio of 90% was higher than Raypex 4 with a ratio of 74% within ± 1 mm. They also revealed that the success of Raypex 4 reduces with increasing apical diameter. As of yet, there is only one study evaluating the performance of Raypex 6, which was achieved by Moscoso *et al.*^[12] They found that Raypex 6 detected apical foramen in 88.22% of all cases within ± 0.5 mm and 100% within ± 1 mm. In accordance with their study, the results of the present study revealed that Raypex 6 was 85% and 95% successful within ± 0.5 mm and within ± 1 mm, respectively in teeth with mature apices. The ratio of acceptable measures decreased slightly in group 32 but significantly in group 57 and 72. As reported in the study of ElAyouti *et al.*,^[10] and similar to Root ZX, the success of Raypex 6 decreased when the apical diameter exceeds over 0.57 mm. When it was considered that EALs determine apical constriction, this result may be associated with complete disruption of this apical constriction. As mentioned above, file sizes exceeding 55-60 changes the conical shape of root canals to a parallel configuration. This may be another reason for inaccurate readings. Furthermore, as ElAyouti *et al.*, stated,^[10] electro-conductivity of the dentine walls, the presence of apical ramifications may also influence the accuracy of EALs.

In contrary to the study of ElAyouti *et al.*,^[10] there was no significant difference between Root ZX and Raypex 6. These results indicate that the manufacturer enhanced the accuracy with Raypex 6 compared to Raypex 4. The manufacturer claims that Raypex 6 utilizes the latest multi-frequency apex locator technology and by this way displays precise results. Differences in the results may be also related to the type of teeth used. They used premolars and molars while the present study utilized single-rooted teeth including incisors and mandibular premolars. For this reason the results should be supported with further studies including different types of teeth.

In vitro studies evaluating EALs utilized alginate,^[5,19-21] saline,^[6,16] agar,^[18,23,24] gelatin^[17] and other chemicals^[4,8] to simulate the apical electro-conductivity for electronic measurements. Baldi *et al.*,^[25] compared the effectiveness of alginate, agar, gelatin, saline and sponge soaked in saline

and despite the lack of a significant difference among the groups, alginate was found to be superior to other groups. Alginate is an electroconductive material, which simulates periodontal ligament with its colloidal consistency.^[26] The present study utilized alginate as a conductive media. In the studies of Lucena-Martin *et al.*,^[13] and D'Assuncao *et al.*,^[19] working length determination was established within 2 hours after setting of alginate in order to avoid the loss of humidity. However, Lipski *et al.*,^[26] completed the measurements in 30 minutes. In accordance with this study, we preferred to achieve EAL measurements within 30 minutes after setting of alginate to avoid excessive loss of humidity.

Studies evaluating the accuracy of EALs may be performed both *in vivo* and *in vitro*. In the study of Duran-Sindreu *et al.*,^[27] the accuracy of Root ZX was determined *in vivo* and *in vitro*. They concluded that no significant difference was present between *in vivo* and *in vitro* groups. Ebrahim *et al.*,^[28] stated that *in vitro* studies provide objective evaluation of different variables, which cannot be obtained with *in vivo* studies. Furthermore, Briseno-Marroquin *et al.*,^[18] pointed out that *in vitro* studies may include much more number of samples, which allow more reliable statistical analyses and repeated measurements with different EALs and file sizes. The authors of the present study preferred to evaluate *in vitro* reading to better achieve standardization and to repeat measurements in teeth with different apical diameters.

CONCLUSION

As a result, the present study revealed that both Root ZX and Raypex 6 are highly reliable in teeth with mature apices while their accuracy decreases with increasing diameter. Further *in vitro* and *in vivo* studies may be beneficial especially to better evaluate the accuracy of Raypex 6.

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