Original Article

INFLUENCE OF THE POSITION OF THE APICAL FORAMEN ON THE ACCURACY OF ELECTRONIC APEX LOCATOR

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ABSTRACT

Deviation of apical foramen from the long axis of the anatomic apex is often undetectable on periapical radiographs. Use of electronic apex locators (EALs) in such cases might be prudent. Conflicting results have been reported regarding the influence of the position of an apical foramen in relation to the anatomic apex on the accuracy of EALs. This study was designed to shed further light on this potential influence. Fifty-six extracted human maxillary and mandibular molars were decoronated at the cementoenamel junction and canals were coronally flared with Gates-Glidden burs. Under 4X, Actual Canal Length (ACL) was determined by inserting K-file size 8 until its tip was leveled with the most coronal border of the apical foramen, file was withdrawn and measured with a digital caliper. This was done thrice and lengths were averaged to obtain ACL. Target Working Length (TWL) was obtained by deducting 0.5 mm from ACL. Teeth were embedded in freshly-mixed alginate. After irrigation with 2 mL 5% sodium hypochlorite, the blinded operator used Root ZX mini by attaching K-file size 8 to the file clip and apically advancing it to the APEX mark then withdrawing it to the 0.5 mark followed by file length measurement. This was done thrice and averaged to obtain Electronic Working Length (EWL). There was no significant difference between EWL and TWL neither in teeth with centered apical foramina (P=0.053) nor in teeth with deviated ones (P=0.246). The position of the apical foramen did not affect the precision of Root ZX mini.

Key words: Apex locator accuracy, Centered apical foramen, Deviated apical foramen, Tooth apex, Working length.

Introduction

The discrepancy between the positions of the anatomic apex and the apical foramen is well-documented. While the anatomic apex represents the end of the root based on morphological inspection, the apical foramen is the main opening of the root canal that generally contains neural, vascular and connective elements [1]. Depending on the age and the type of teeth investigated, the frequency of apical foramen deviation from the center of the anatomic apex ranged between 17-100%. Meanwhile, the average distance between these two landmarks was mostly reported to be less than 1 mm [2].

Conflicting findings on the effect of the position of an apical foramen in relation to anatomic apex on the performance of electronic apex locators have been published [3]. Root ZX recorded significantly higher accuracy in teeth with apical foramina centered over the anatomic apex compared to teeth with deviated foramina [4]. Deviation of apical foramen did not affect the accuracy of Root ZX or Apex Finder [5]. The accuracy of Root ZX and Apex ID was not affected by the position of the apical foramen of mandibular premolars [6]. Results in mesial canals of mandibular molars were slightly different, as Apex ID recorded significantly more readings within the more precise ± 0.5 mm range in teeth with centered apical foramina compared to teeth with deviated foramina, while the position of apical foramen did not affect the performance of CanalPro or Root ZX mini [7]. Another study reported that Root ZX, Raypex 5, and Elements Apex Locator registered significantly more accurate readings in teeth with deviated apical foramina [8].

Deviation of apical foramen from the anatomic apex predisposes to faulty radiographic working length determination [9, 10]. It might be prudent to depend on the apex locator in such cases [11-13]. Since the effect of the position of the apical foramen in relation to the anatomic apex on the performance of electronic apex locators is still poorly understood and requires further elucidation, this study aimed at evaluating the impact of the position of the apical foramen on the precision of Root ZX mini (J. Morita Co., Kyoto, Japan). The null hypothesis was that the position of the apical foramen as centered over the anatomic apex or deviated from the long axis of the root would not affect the precision of Root ZX mini.

Materials and Methods

A total of 56 extracted human maxillary and mandibular molars with a total of 136 root canals were inspected under 4X magnification to confirm they were free of caries, restorations, and cracks and that they had fully-formed roots. All teeth were radiographed in buccolingual and mesiodistal directions to confirm the absence of calcification or internal resorption. Teeth were kept in 5% sodium hypochlorite (NaOCl) for 24 hours and then stored in numbered bottles filled with saline until use. Teeth were decoronated at the cementoenamel junction to produce stable flat coronal reference points then canals were

coronally flared with Gates Glidden sizes 4, 3, and 2 (MANI Inc, Tochigi, Japan) [14]. Canals were frequently irrigated with 2 mL 5% NaOCl with a 27-gauge side-vented needle inserted as deep as possible without binding [15].

Under 4X magnification, K-file size 8 (Dentsply, Maillefer, Switzerland) with two stoppers [16] was apically advanced as passively as possible until its tip was apparent at the most coronal border of the apical foramen [14]. The position of the file tip in relation to the anatomic apex was registered as centered or deviated. Then rubber stoppers were adjusted to the coronal reference point, and the file was withdrawn and measured with a digital caliper (Mitutoyo, Corp., Tokyo, Japan) to an accuracy of 0.01 mm. Length measurements were done thrice and then averaged to obtain the actual canal length. The operator obtained the first reading for all teeth and then started over to acquire the second and third readings similarly. Target working length (TWL) was obtained by subtracting 0.5 mm from the actual canal length.

Roots were placed in small plastic containers filled with freshly mixed alginate and canals were irrigated as mentioned earlier [15, 17]. An operator blinded to TWL obtained the electronic working length (EWL) utilizing the Root ZX mini apex locator following the manufacturer's instructions [14]. The lip clip was firmly secured in the alginate and a file that had a size compatible with the apical diameter of the canal being measured was attached to the file clip. The file was advanced into the canal until the "APEX mark" flashed. After that, the file was withdrawn until the meter pointed to the flashing bar representing the "0.5 mark". The meter gauge had to be stable for five seconds to accept the reading [14]. The two rubber stoppers were adjusted to the coronal reference point, and the file was withdrawn and measured with a digital caliper. This step was done three times and the obtained lengths were averaged to determine EWL. The operator obtained the first reading for all teeth and then started over to acquire the second and third readings similarly. The alginate mix was refreshed every 30 minutes [18].

Data recording was done on Excel sheets (Microsoft Corp, Washington, USA). Statistical comparisons of the recorded lengths were done utilizing an independent *t*-test with the level of significance set at $P<0.05$.

Results and Discussion

Out of the 136 canals measured, 86 canals (63.2%) were for maxillary molars while the rest were for mandibular molars. Deviation of apical foramen was recorded in 37 canals (27.2%); 20 deviated in the buccal direction, 11 were lingually positioned, 5 were located mesially while only one canal had a distally-located apical foramen. The majority of deviations occurred in maxillary molars (23/37 canals= 62.2%).

There was no significant difference between EWL and TWL in teeth with centered apical foramina ($P=0.053$). There was no significant difference between EWL and TWL in teeth with deviated apical foramina ($P=0.246$). **Table 1** lists the mean ± standard deviation of TWL and EWL in relation to the position of the apical foramen. **Table 2** lists the frequency of EWL measurements which were longer than, equal to, or shorter than the actual canal length.

Table 1. Mean ± Standard Deviation of TWL and EWL in relation to the position of the apical foramen

Location of Apical Foramen	Measurement	Mean ± Standard Deviation (mm)
Centered (99 canals)	TWL[a]	13.56 ± 2.03
	EWL[b]	13.00 ± 2.04
Deviated (37 canals)	TWL	14.19 ± 2.10
	EWL	13.59 ± 2.28

[a] TWL= Target working length
[b] EWL= Electronic working length

Table 2. Frequency of long, exact, and short EWL readings compared to actual canal length in relation to the position of the apical foramen

EWL[a] Measurements	Centered Apical foramina (%)	Deviated Apical Foramina (%)
Longer than the actual canal length	12.1	5.4
Exactly equal to the actual canal length	2.0	5.4
Shorter than the actual canal length	85.9	89.2

[a] EWL= Electronic working length

Several measures were undertaken to improve the validity of the current study. Coronal preflaring was done because it improved the accuracy of Root ZX [19-21]. The most coronal border of the apical foramen was used as a guide to standardize the apical advancement of the file during actual length measurement [14]. Two rubber stoppers were always used with the hand files to reduce the chance of their movement [14]. All measurements were done in triplicates while obtaining the first reading for the entire sample and then starting over to acquire the second and third readings similarly. The operator who obtained EWL was blinded to TWL and vice versa [14].

Embedding teeth in freshly-mixed alginate that simulate periodontium enabled testing the null hypothesis in a standardized approach over a large sample. Alginate has been frequently used as an embedding medium for *ex vivo* assessment of Root ZX [17, 22]. The type of embedding

medium did not affect the accuracy of Root ZX [23]. However, the insatiability of the electrical resistance of alginate with time has been highlighted [24]. Hence, alginate was refreshed every 30 minutes [18]. Several studies observed alginate deterioration when NaOCl was used for irrigation [10, 14]. However, we did not encounter that probably because of the continuous refreshment of the mix.

Our results indicated that the position of the apical foramen did not affect the precision of Root ZX mini since there was no significant difference between TWL and EWL neither in canals with centered apical foramina nor in those with deviated ones **(Table 1)**. Thus, the null hypothesis was accepted. This was in support of several previous studies that assessed the Root ZX [4-6, 25, 26]. However, Ding *et al.* [8] reported that Root ZX was significantly more accurate when operated in canals with deviated apical foramina. This could be attributed to the fact that their sample included a larger number of teeth with deviated foramina compared to the current study (49.4% and 27.2%, respectively). Further, Ding *et al.* [8] reported the medians of their measurements instead of reporting the means. Meanwhile, Pagavino *et al.* [4] found that Root ZX was significantly more accurate in teeth with centered apical foramina. This might have been a consequence of their decision to adopt the APEX mark of the digital display of Root ZX instead of using it according to the manufacturer's recommendation. The "APEX mark" and the "0.5 mark" of Root ZX recorded different lengths when were used in the same canals [5, 6, 27]. It must be pointed out that Root ZX mini operates on the same electrical principles of the Root ZX [22, 28]. Root ZX determines the impedance ratio of two frequencies to preferentially locate the apical constriction [29]. Hence, findings of studies evaluating Root ZX can be extrapolated to Root ZX mini [14, 28].

Mean EWL was shorter than (coronal to) mean TWL in canals with centered and deviated apical foramina **(Table 1)**. Further, as seen in **Table 2**, most of the EWL readings were also shorter than (coronal to) the most coronal border of the apical foramen. Nevertheless, 12.1% of the recordings in canals with centered apical foramina and 5.4% of the readings in canals with deviated apical foramina were in fact beyond the confines of the canals. The frequency of readings that were equal to the actual canal length was 2% and 5.4%, respectively. This highlights the importance of obtaining a radiographic confirmation of the length acquired by an apex locator to reduce the chances of over-instrumentation [10, 13, 30-32].

Conclusion

Within the limitations of this *ex vivo* study, the accuracy of the Root ZX mini apex locator was not affected by the position of the apical foramen in relation to the anatomic apex.

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Ethics statement: This study fulfills the ethical requirements of King Abdulaziz University.

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