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Original Article

Assessing the Reliability of Electronic Apex Locators in Different Apical Foramen Configurations

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ABSTRACT

In periapical radiographs, the deviation of the apical foramen from the long axis of the anatomic apex is often invisible. In certain situations, it could be wise to use electronic apex locators or EALs. Conflicting findings were documented regarding the influence of the apical foramen's location concerning the anatomic apex on the accuracy of EALs. The present study aimed to clarify this possible influence. The cementoenamel junctions of 56 removed human maxillary and mandibular molars were decorated, and Gates-Glidden burs were used to flare the canals coronally. To find the actual canal length (ACL) under 4X, a K-file size 8 was inserted until its tip was level with the most coronal boundary of the apical foramen. After that, the file was taken out and evaluated with a digital caliper. The lengths were averaged after three attempts to determine the ACL. The target working length (TWL) was calculated by subtracting the ACL by 0.5 mm. The alginate was prepared fresh and used to implant the teeth. The operator wearing a blindfold affixed K-file size 8 to the file clip utilizing Root ZX mini, progressed it apically to the APEX mark, and then retracted it to the 0.5 mark. Following watering with 2 mL of 5% sodium hypochlorite, the file length was determined. The average of three iterations of this procedure allowed for the calculation of electronic working length (EWL). No significant distinction was observed between EWL and TWL in teeth with centered apical foramina (P = 0.053) and teeth with deviation (P = 0.246). The orientation of the apical foramen does not affect the accuracy of the Root ZX mini.

Keywords: Apex locator accuracy, Centered apical foramen, Deviated apical foramen, Tooth apex, Working length

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Introduction

It is commonly known that the anatomic apex and the apical foramen are at different locations. The major aperture of the root canal, the apical foramen, often comprises neuronal, circulatory, and connective components, whereas the anatomic apex, based on morphological examination, signifies the end of the root [1, 2]. The frequency of the apical foramen's displacement from the anatomic apex's center varied from 17-100%, depending on the age and kind of teeth examined. In the meantime, it was generally claimed that there was less than 1 mm between these two landmarks [3].

There are conflicting results about how the performance of electronic apex locators is impacted by the location of an apical foramen concerning the anatomic apex [4, 5]. In contrast to teeth with deviating foramina, Root ZX reported much greater precision in teeth with apical foramina centered around the anatomic apex [6]. Apical foramen variation did not

affect Root ZX or Apex Finder sufficiency [7]. The location of the mandibular premolars' apical foramen had no bearing on the precision of Root ZX and Apex ID [8]. Although the location of the apical foramen did not affect the effectiveness of CanalPro and Root ZX mini, the mesial canals of the mandibular molars showed somewhat distinct results because Apex ID documented substantially greater readings in the more precise ± 0.5 mm range in teeth with centered apical foramina than in teeth with deviated foramina [9]. According to a different study, teeth with deviated apical foramina showed noticeably more accurate readings when using Root ZX, Raypex 5, and Elements Apex Locator [10].

A radiographic working length estimation that is inaccurate is predisposed when the apical foramen deviates from the anatomic apex [11, 12]. Under such circumstances, relying on the apex locator may be wise [13–15]. Since the relationship between the apical foramen and the anatomic apex and how it affects the operation of electronic apex locators is still unclear and needs more research, the current study set out to ascertain how the position of the apical foramen affected the accuracy of Root ZX mini (J. Morita Co., Kyoto, Japan). According to the null hypothesis, neither the apical foramen's placement over the anatomic apex nor its divergence from the root's long axis would affect Root ZX mini's accuracy.

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 decorated 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) [16]. Canals were frequently irrigated with 2 mL 5% NaOCl with a 27-gauge side-vented needle inserted as deep as possible without binding [17].

Under 4X magnification, K-file size 8 (Dentsply, Maillefer, Switzerland) with two stoppers [18] was apically advanced as passively as possible until its tip was apparent at the most coronal border of the apical foramen [16]. The position of the file tip concerning 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 [19-22]. 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 [17, 23]. An operator blinded to TWL obtained the electronic working length (EWL) utilizing the Root ZX mini apex locator following the manufacturer's instructions [16]. 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 [16]. 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 [24]. 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

86 canals (63.2%) of the 136 canals that were measured belonged to maxillary molars, whereas the remaining canals were for mandibular molars. Thirty-seven canals (27.2%) showed a deviation of the apical foramen; twenty of them were buccal, eleven were lingual, five were mesially positioned, and only one had a distally positioned apical foramen. Maxillary molars accounted for the bulk of aberrations (23/37 canals = 62.2%).

EWL and TWL did not significantly differ in teeth with centered apical foramina (P = 0.053). For teeth with distorted apical foramina, there was no discernible disparity between EWL and TWL (P = 0.246). The mean ± standard deviation of TWL and EWL concerning the location of the apical foramen is shown in **Table 1**. The frequency of EWL measures that were

longer, equal to, or less than the actual canal length is shown in **Table 2**.

Table 1. Mean ± standard deviation of TWL and EWL about 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. In connection with the location of the apical foramen, the frequency of long, precise, and short EWL readings in proportion to Canal length

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 steps were made to increase the present research's accuracy. Coronal preflaring was used since it increased Root ZX's accuracy [25-27]. To standardize the apical progress of the file during actual length evaluation, the most coronal boundary of the apical foramen was utilized as a reference [16]. To lessen the possibility of the hand files moving, two rubber stoppers were usually used with them [16]. Every measurement was performed in triplicate, with the first reading being obtained for the full sample and the second and third readings being obtained similarly. TWL was hidden from the operator who received EWL, and vice versa [16].

Using freshly mixed alginate, which was widely used as an embedding medium for ex vivo testing of Root ZX, to embed teeth allowed consistent testing of the null hypothesis across a large sample [23, 28]. The precision of Root ZX was unaffected by the kind of embedding media [29]. It has been noted, meanwhile, that alginate's electrical resistance is insatiable with time [30-34]. Because of this, alginate was refilled every half an hour [24]. While some studies observed alginate deterioration when NaOCl was used for irrigation [12, 16], we did not see this, perhaps because the mix was often refreshed.

Since there was not a significant distinction between TWL and EWL in canals with centered or departed apical foramina, our findings showed that the apical foramen's location had minimal impact on Root ZX mini's precision **(Table 1)**, and the null theory was thus approved. This was consistent with several earlier studies that evaluated the Root ZX [6-8, 35, 36]. However, Root ZX was significantly more dependable when applied to canals with deformed apical foramina, according to Ding *et al*. [10]. This might be because their sample had a higher percentage of teeth with deviated foramina than the current study (49.4% versus 27.2%, respectively). Additionally, rather than publishing the means of their measurements, Ding *et al*. [10] reported the medians. In contrast, Root ZX was considerably more accurate in teeth with centered apical foramina, according to Pagavino *et al*. [6]. This might have resulted from their choice to use the Root ZX digital display's APEX mark rather than utilizing it as advised by the manufacturer. When applied to the same canals, the “APEX mark” and the “0.5 mark” of Root ZX recorded varying lengths [7, 8, 37]. It is important to note that Root ZX's small functions use the same electrical principles as Root ZX [28, 38]. Root ZX preferentially locates the apical constriction by calculating the impedance ratio of two frequencies [39]. Therefore, Root ZX mini may be inferred from the results of research assessing Root ZX [16, 38].

Table 1 shows that in canals with centered and deviated apical foramina, the mean EWL was shorter than the mean TWL. Also, most of the EWL measures were shorter than the apical foramen's most coronal edge, as **Table 2** illustrates. In actuality, however, 5.4% of the readings in canals with deviated apical foramina and 12.1% of the measurements in canals with centered apical foramina were outside the canal boundaries. The percentage of readings that matched the length of the canal was 5.4% and 2%, respectively. To minimize the likelihood of over-instrumentation, it is crucial to collect a radiographic confirmation of the length obtained by an apex finder [12, 15, 31, 40, 41].

Conclusion

The location of the apical foramen concerning the anatomic apex did not affect the Root ZX small apex locator's accuracy within the constraints of this ex vivo investigation.

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Conflict of Interest: None

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Ethics Statement: The present research meets the ethical standards of King Abdulaziz University.

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