Journal of Advanced Medical and Dental Sciences Research

@Society of Scientific Research and Studies

Journal home page: www.jamdsr.com doi: 10.21276/jamdsr UGC approved journal no. 63854

(e) ISSN Online: 2321-9599; (p) ISSN Print: 2348-6805 SJIF (Impact factor) 2017= 6.261; Index Copernicus value 2016 = 76.77

Original Article

Working length determination with two contrasting techniques - Radiographs and Two electronic apex locators

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ABSTRACT

Aim: To evaluate the accuracy of the Root ZX and Propex II apex locators when compared with radiographs for locating the canal terminus or minor foramen. **Methodology:** The canal terminus of 482 canals in 160 maxillary and mandibular teeth was located in vivo with both locators and radiographically. After extraction, the actual location of the minor foramen was determined visually and with magnification. A paired samples t-test, chi-square test and a repeated measure anova at the 0.05 level of significance were used to determine differences between the groups. **Results:** The Root ZX located the minor foramen correctly 68% of the time in anterior and premolar teeth, and 58% of the time in molar teeth. The Propex II located the minor foramen correctly 58% of the time in anterior and premolar teeth and 49% of the time in molar teeth. Radiographs located the minor foramen correctly 20% of the time in anterior and premolar teeth and 11% of the time in molar teeth. There was no statistically significant difference between the two locators, but there was a significant difference between them and radiographs. For all teeth, the measurements made by the apex locators were within ±0.5 mm of the minor foramen 100% of the time, whereas for the radiographs, the measurements were within this range only 15% of the time. This difference was significant (P = 0.05). **Conclusion**: Measuring the location of the minor foramen using the two apex locators was more accurate than radiographs and would reduce the risk of instrumenting and filling beyond the apical foramen.

Key words: apical constriction, apex locator, Propex II, Root ZX, working length determination.

Received: 20 March 2018 Revised: 14 May 2018 Accepted: 25 June 2018

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This article may be cited as: Talesara K, Khatri M. Working length determination with two contrasting techniques - Radiographs and Two electronic apex locators**.** J Adv Med Dent Scie Res 2018;6(8):100-103.

INTRODUCTION

Root canal preparation and filling should not extend beyond the tooth root nor leave un-instrumented areas inside the root canal. Anatomically, the apical constriction (AC), also called the minor apical diameter or minor diameter (Kuttler 1955), is a logical location for working length (WL), as it often coincides with the narrowest diameter of the root canal (AAE 2003). However, locating the AC clinically is problematic. Dummer et al. (1984) concluded that it is impossible to locate the minor foramen clinically with certainty because of its position and topography. The cementodentinal junction (CDJ) has also been suggested as the location for WL, because it represents the transition between pulpal and periodontal tissue (Grove 1931). The location of the CDJ is widely accepted as being 0.50–0.75 mm coronal to the apical foramen (Ricucci & Langeland 1998) but, as with the AC, the exact location of the CDJ is impossible to identify clinically. In general, the CDJ is considered to be co-located with the minor foramen (Stein et al. 1990); however, this is not always the case (Dummer et al. 1984). Working length is defined as 'the distance from a coronal reference point to the point at which canal preparation and filling should terminate' (American Association of Endodontists (AAE) 2003). Radiographic determination of WL has limitations such as distortion, shortening and elongation, interpretation variability and lack of three-dimensional representation. Even when a paralleling technique is used, elongation of images has been found to be approximately 5% (Van de Voorde & Bjondahl 1969).A WL 1 mm short of the radiographic apex may result in over or under instrumentation because of the variability in distance between the terminus of the root canal (minor foramen) and the radiographic apex

(Gutie´rrez & Aguayo 1995). Thus, this often used 'rule' is not predictable or reliable.

Custer (1918) was the first to determine WL electronically. Suzuki (1942) investigated the electrical resistance properties of oral tissues and developed the first electronic apex locator (EAL). The device was resistance-based and measured the resistance between two electrodes to determine the location of an instrument in the canal. Later devices were impedance-based (Nekoofar et al. 2006) and used multiple frequencies. More recently, resistance- and capacitance-based devices emerged that measure resistance and capacitance, directly and independently.

The purpose of this study was to evaluate in vivo the accuracy and predictability of two EALs for determining WL as compared with radiographs.

MATERIALS AND METHODS

One hundred and sixty teeth (482 canals) with fully formed apices and without apical resorption were used (Table 1).

Table 1: Distribution of 160 teeth (482 canals)

Tooth (n)	Number of canals	
	Maxillary	Mandibular
Central incisor (10)	7	3
Lateral incisor (8)	6	2
Canine (5)	3	2
Premolar (17)	11	6
Molar (120)	225	217
Total (160)	252	230

All teeth gave positive responses to hot and cold tests and were extracted for periodontal or prosthodontic reasons. Ethical approval for the study and an informed consent to participate was signed by the patients. After local anaesthesia, rubber dam isolation and access cavity preparation were performed, the canals were flared coronally with size 1 and 2 Orifice Shapers (Dentsply Tulsa Dental, Tulsa, OK, USA) using 3% sodium hypochlorite (NaOCl) for irrigation. The final rinse was aspirated, but no attempt was made to dry the canals.

The AC of each tooth was located with two EALs and radiographically. The minor foramen was located with the Root ZX by advancing a size15 stainless steel K-file in the canal, until the locator indicated that the minor foramen had been reached, according to the manufacturer's instructions (J. Morita Corp. 2004). The LCD showed a flashing bar between APEX and 1 and a flashing tooth. The silicone stop on the file was positioned at the reference point. The file was removed from the canal and the length was measured to the nearest 0.01 mm with a digital caliper. This was the insertion length. The AC was located with the Propex II by advancing the same size 15 K-file in the canal, until the locator indicated that the minor foramen had been reached, as per the manufacturer's instructions (Dentsply Sirona Maillefer). The stop was positioned at the reference point and the insertion length measured. The sequence of testing alternated between the two locators. The minor foramen was located radiographically by advancing the size15 K-file, until its tip was 1.0 mm from the radiographic apex (determined from a pretreatment parallel technique radiograph). A radiograph was exposed and if the file tip was seen not to be 1.0 mm from the radiographic apex, the file was repositioned and another radiograph taken to ensure that it was. The distance from the stop to the tip was the insertion length. The file was then re-inserted to the insertion length (1 mm from the radiographic apex) and cemented in place with Fuji II LC dual-cure glass ionomer cement (GC Corp, Tokyo, Japan). The file handle was sectioned with a high-speed bur and the tooth was extracted without disturbing the file, placed in 6% NaOCl for 15 min to clean the root surface and stored in a 0.2% thymol solution. All of the clinical procedures were conducted by the principal investigator. After the tooth was removed from the solution and with the file still in place, the apical 5 mm of the root was ground parallel to the long axis of the canal with a fine diamond bur and abrasive discs. When the file became visible, additional dentine was removed under 20X magnification (OPMI Pico microscope; Carl Zeiss, Munich, Germany) until the file tip, the canal terminus, and the foramen were in focus. A digital photograph was taken and stored in Adobe Photoshop 5.5 (Adobe Systems Inc., San Jose, CA, USA) and the distance of the file tip to the minor foramen was measured. This distance was recorded as being: -1.0 mm from the minor foramen; -0.5 mm from the minor foramen; at the minor foramen; +0.5 mm from the minor foramen or +1.0 mm from the minor foramen. A minus symbol (-) indicated a file short of the minor foramen; a plus symbol (+) indicated it was long. Once the actual length to the minor foramen was measured visually, the distance from the minor foramen determined by the two EALs was also completed (-1.0 mm from the minor foramen; -0.5 mm from the minor foramen, etc.), by comparing their insertion lengths to the actual length (distance to the AC) (Tables 2–4). The measurements obtained by the two EALs and radiographs relative to the actual location of the minor foramen were compared using a paired samples t-test, chi-square test and a repeated measure. Anova evaluation was conducted at the 0.05 level of significance.

Table 2:Distance of file tip from minor foramen determined by Root ZX, Propex II and radiograph (anteriors)

Distance from minor foramen (mm)	Root ZX	Propex II	Radiograph
	n = 23 (%)	n = 23 (%)	n = 23 (%)
-1.0	-	-	-
-0.5	-	-	-
MF	17 (73.9)	15 (65.2)	5 (21.7)
+0.5	6 (26.08)	8 (34.7)	10 (43.47)
+1.0			8 (34.78)
MF, minor foramen. (+) and (-) values indicate file tip beyond (+) or short (-) of the AC.			

Table 3:Distance of file tip from minor foramen determined by Root ZX, Propex II and radiograph (premolars)

Distance from minor foramen (mm)	Root ZX n = 17 (%)	Propex II n = 17 (%)	Radiograph n = 17 (%)
-1.0	-	-	-
-0.5	-	-	-
MF	9(52.94)	7(41.17)	6(35.29)
+0.5	8(47.05)	10(58.82)	5(29.41)
+1.0			6(35.29)

MF, minor foramen. (+) and (-) values indicate file tip beyond (+) or short (-) of the AC.

Table 4: Distance of file tip from minor foramen determined by Root ZX, Propex II and radiograph (molars)

Distance from minor foramen (mm)	Root ZX (n=444) Canal						Propex II (n=423) Canal						Radiograph (n=414) Canal					
	MB	ML	D	DB	DL	P	MB	ML	D	DB	DL	P	MB	ML	D	DB	DL	P
-1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-0.5	2	3	-	-	-	-	6	5	18	-	-	8	1	-	2	-	-	1
MF	65	61	58	19	19	38	66	59	54	18	19	2	11	8	12	6	5	5
+0.5	53	45	27	16	16	22	48	41	15	22	21	21	61	41	47	17	17	28
+1.0	-	-	-	-	-	-	-	-	-	-	-	-	43	34	26	11	12	26

MF, minor foramen. (+) and (-) values indicate file tip beyond (+) or short (-) of the AC.

RESULTS

For anterior teeth, the Root ZX, Propex II and radiographs located the minor foramen 74%, 65% and 22%of the time, respectively. For premolar teeth, the Root ZX, Propex II and radiographs located the minor foramen 53%, 41% and 35% of the time, respectively. For molar teeth, the Root ZX, Propex II and radiographs located the minor foramen 58%, 49% and 11% of the time, respectively. There was no statistically significant difference between the two EALs, but there was a difference when the EALs and radiographs were compared. (Tables 2–4).

For anterior, premolar and molar teeth, none of the measurements were 1.0 mm short of the minor foramen. For anterior and premolar teeth, none of the measurements were 0.5 mm short of the minor foramen, but for molar teeth 1%, 8% and 1% of the measurements using the Root ZX, Propex II and radiographs, respectively, were short.

For anterior teeth, the Root ZX, Propex II and radiographs were 0.5 mm long of the minor foramen a 26%, 35% and 39% roots, respectively. For premolar teeth, the Root ZX, Propex II and radiographs were 0.5 mm long of the minor foramen 47%, 59% and 29% roots, respectively, and for molar teeth it was 41%, 42% and 48%, respectively.

No EAL measurements were 1.0 mm long of the minor foramen for anterior, premolar and molar teeth, but for radiographs it was 35% for anterior teeth, 35% for premolar teeth and 37% for molar teeth. There was no statistically significant difference between the two EALs, but there was a significant difference (P = 0.05) when the EALs and radiographs were compared.

DISCUSSION

The use of electronic devices to determine WL has gained in popularity. When using them, an important consideration is being aware of the possible sources of error such as metallic restorations, salivary contamination, dehydration, etc. However, as shown in this and other studies, the accuracy of EALs is superior to radiographs (Van de Voorde&Bjondahl1969, Pratten& McDonald 1996, Venturi & Breschi 2007).

One of the reasons why a radiographically determined WL lacks accuracy is that it is based on the radiographic apex rather than the canal terminus – the minor foramen. WL is obtained with a radiograph by positioning the tip of a file a certain distance (usually 1.0 mm) from the radiographic apex. However, WL should be based on the location of the minor foramen rather than the apex, because the foramen frequently is not at the apex (Wrbas et al. 2007). In this study, radiographs correctly located the minor foramen 15% of the time, whereas for the Root ZX and Propex II itwas 63% and 53% of the time, respectively. Both EALs were within ±0.5 mm from the minor foramen 100% of the time, whereas radiographs were within ±0.5 mm of 63% of cases.

An in vivo study by Shabahang et al.(1996) reported that the Root ZX was within 0.5 mm from the minor foramen 96% of the time, a value similar to the present findings. In general, this study also agrees with others (Usun et al. 2007, 2008) that EALs are more accurate than radiographs and greatly reduce the risk of instrumenting and filling short or beyond the canal terminus.

As the minor foramen varies in location and anatomy (sharply defined, parallel, or missing) (Nekoofar et al. 2006), caution should be used to avoid overestimating WL. According to Gutie´rrez& Aguayo(1995), over-instrumentation of the root canal must be a common and unnoticed occurrence. An instrument passing through a necrotic pulp and through the foramen most likely carries bacteria and toxins into the apical tissues (Siqueira et al. 2002, Siqueira & Barnett2004). An indication by an EAL of reaching the minor foramen or foramen is very helpful

in avoiding mishaps. Indeed, this study showed that WL obtained with radiographs was 1.0 mm long of the AC 37% of the time, but 0% for the two EALs. This high incidence of error is clinically important, because a WL 1.0 mm long would result in canals being instrumented beyond the foramen.

CONCLUSION

Under clinical conditions, the EALs identified the minor foramen with high degree of accuracy. EALs were more accurate compared with radiographs with the potential to greatly reduce the risk of instrumenting and filling beyond the apical foramen.

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Source of support: Nil **Conflict of interest:** None declared