Revista Odonto Ciência
Journal of Dental Science

ORIGINAL ARTICLE

Rev Odonto Cienc 2015;30(4):138-142
http://revistaseletronicas.pucrs.br/ojs/index.php/fo
http://dx.doi.org/10.15448/1980-6523.2015.4.15023

Open Access

Accuracy of an electronic foramen locator in determining working length during retreatment: an *in vitro* study

Cauê Lassen[a], Ronise Ferreira Dotto[a], Paulo Silva dos Santos[a], Márcia Helena Wagner[a], Renata Grazziotin-Soares[b], Fernando Branco Barletta[c]

[a] UNISC, School of Dentistry, Department of Endodontics, Santa Cruz do Sul, RS, Brazil
[b] UFRGS, School of Dentistry, Department of Endodontics, Porto Alegre, RS, Brazil
[c] ULBRA, School of Dentistry, Department of Endodontics, Canoas, RS, Brazil

Abstract

Objective: To assess, *in vitro*, the accuracy of MiniApex® for electronic working length (EWL) determination during three stages of root canal treatment/retreatment: EWL-1 (during treatment), EWL-2 (after filling removal), and EWL-3 (after reinstrumentation).

Methods: EWL was determined when the MiniApex® display showed the green light at the '0.5' mark and compared with radiographic findings. Results were classified as accurate when the file tip was located in a range of (1) 0.5 to 1.0 mm and (2) 0.5 to 2.0 mm from the radiographic apex, and as inaccurate when the file tip was outside that range of values. Means were compared between groups, considering all values and only accurate measurements, for both tolerance limits.

Results: MiniApex® was highly accurate at the larger tolerance range (0.5-2.0mm): 82.3% (EWL-1), 88.2% (EWL-2), and 91.1% (EWL-3). During root canal retreatment, EWL-3 provided more accurate measurements than EWL-2, but without statistical difference ($p>0.05$). There was no statistical difference ($p>0.05$) when only accurate measurements were evaluated.

Conclusion: MiniApex® was highly accurate to determine the location of the instrument tip at 0.5 to 2.0mm from the radiographic apex during treatment and retreatment (EWL-2 and EWL-3).

Key words: Odontometry; Retreatment; Dental pulp cavity; Endodontics

Precisão de um localizador foraminal eletrônico na determinação do comprimento de trabalho durante o retratamento: um estudo *in vitro*

Resumo

Objetivo: Avaliar, *in vitro*, a precisão do localizador MiniApex® na determinação do comprimento de trabalho eletrônico (CTE) em três estágios do tratamento/retratamento de canais: CTE-1 (durante o tratamento), CTE-2 (após a remoção da obturação) e CTE-3 (após o repreparo do canal radicular).

Métodos: O CTE foi definido quando o display do MiniApex® mostrou luz verde na marca de '0,5', e foi confirmado radiograficamente. Os resultados foram classificados como precisos quando a ponta do instrumento se localizava a (1) 0,5-1,0 mm ou a (2) 0,5-2,0 mm do ápice radiográfico, e como imprecisos quando a mensuração ficava fora desses valores. As médias foram comparadas entre os grupos considerando todos os valores e apenas valores precisos, para ambos os limites de tolerância.

Resultados: O MiniApex® foi efetivo considerando-se o limite maior de tolerância (0,5-2,0mm): 82,3% (CTE-1), 88,2% (CTE-2) e 91,1% (CTE-3). Durante o retratamento, CTE-3 demonstrou mensurações mais precisas do que CTE-2, porém sem diferença estatística ($p>0,05$). Não foram observadas diferenças estatísticas ($p>0,05$) entre as mensurações precisas.

Conclusão: O MiniApex® foi confiável na determinação do comprimento de trabalho considerando as medidas compreendidas no intervalo de 0,5-2,00mm do ápice radiográfico durante o tratamento e retratamento de canal (CTE-2 e CTE-3).

Palavras-chave: Odontometria; Retratamento; Cavidade pulpar; Endodontia

Correspondence:
Ronise Ferreira Dotto
ronise.odonto@gmail.com

Received: September 18, 2013
Accepted: December 19, 2015

Conflict of Interests: The authors state that there are no financial and personal conflicts of interest that could have inappropriately influenced their work.

Introduction

Information on the relationship between root canal retreatment and accuracy of electronic foramen locators (EFLs) is still scarce [1,2]. In the clinical practice of endodontics, electronic working length (EWL) determination is a challenge due to factors that might interfere with the EFL accuracy, such as the possibility of remaining filling material after removal of dental filling and/or modifications that may have occurred in the internal anatomy of the tooth [3]. Aiming at an adequate removal of filling materials, the ProTaper Universal rotary retreatment system has been recently investigated and considered safe and effective in reaching the working length during retreatment [4]. The use of this retreatment technique has been associated with different variables, such as solvent [5], file size and taper, reciprocating movement [6], and the influence of sealer type [7]. Nevertheless, even with the use of the ProTaper Universal rotary retreatment system, filling debris were left in canal thirds after filling removal and reinstrumentation, as observed *in vitro* under an operative clinical microscope [7].

Different brands of EFLs are commercially available and have been studied aiming to improve working length determination [8-10]. One of the EFLs currently available is MiniApex® (SybronEndo Corp. – Orange, USA), which operates based on a multifrequency measurement system (http://www.sybronendo.com) to calculate the distance from the file tip to the foramen by measuring changes in impedance between two electrodes [11]. To date, only a few studies have reported on the accuracy of MiniApex® EFL. Mull et al. [11] showed that MiniApex® had greater accuracy in the presence 1% sodium hypochlorite and 2% chlorhexidine root canal irrigants than Root ZX®. Also, Root ZX® II and MiniApex® EFL proved useful and accurate for apex foramen location during root canal length measurement in primary incisors and molars [12].

Current scientific evidence addressing EFL accuracy during root canal retreatment focuses on different variables, such as filling materials [1] and root-end resected teeth [2]. To our knowledge, there have been no published studies designed to investigate the accuracy of EFLs during different stages of treatment and retreatment.

Therefore, for an improved understanding and interpretation of EFL readings in root canal retreatment, this *in vitro* study aimed to assess the accuracy of MiniApex® EFL for EWL determination during three different stages of root canal treatment/retreatment: during treatment (EWL-1), after removal of dental filling (EWL-2), and after reinstrumentation (EWL-3). The null hypothesis was that EWL determination during the three different stages would have similar values, evidencing EFL accuracy.

Methods

Thirty-four extracted, human premolar teeth with a single canal were obtained from the School of Dentistry at our institution. The study was approved by the local Research Ethics Committee.

Dental X-rays were taken to evaluate root canal anatomy. Teeth with previous endodontic treatment, presenting radiographically visible resorption, calcification, metal restoration, prosthesis, a post or a cast post and core, or incomplete root formation were excluded. After access to the root canal, the cusps were worn to obtain a fixed and stable point of reference for all measurements. The coronal and medium thirds were prepared using Largo #2 and #3 drills.

Electronic working length (EWL) at three stages

All measurements were performed by one single operator. Electronic measurements were carried out in triplicate and the mean value of the three measurements was considered as the result [13,14].

Teeth were attached to the inside walls of acrylic boxes. The boxes were filled with (and roots immersed in) alginate and sodium hypochlorite solution. The labial clip of the MiniApex® EFL (SybronEndo Corp. – Orange, USA) was placed in contact with the alginate. Using the MiniApex®, the file was advanced into the root canal (filled with sodium hypochlorite) to just beyond the major foramen, as indicated by the 'past apex' mark. The file (adjusted to the apical third) [9] was then withdrawn until the display showed the green light at the '0.5' mark. This measurement, performed before instrumentation of the apical third, was recorded and considered as EWL determination during treatment (EWL-1). The file was maintained at that position and a radiograph was taken.

Subsequently, instrumentation was completed (apical third and step-back preparation). The apical third was prepared up to a #30 K-type file (Dentsply Maillefer® – Ballaigues, Switzerland). Root canals were irrigated with 2.5% sodium hypochlorite throughout the instrumentation process and with 17% EDTA + 2.5% sodium hypochlorite as a final flush. Patency was constantly verified using a #10 K-type file.

The root canals were obturated using the cold lateral condensation technique and were kept inside an incubator at 37°C and 100% humidity for 30 days. After this period, for all samples, the filling material was removed using ProTaper Universal NiTi rotary retreatment files D1, D2, and D3 (Dentsply Maillefer® – Ballaigues, Switzerland), which were activated by an electric engine (Endo-Pro, Driller, São Paulo, Brazil; 3N/cm torque, 500rpm speed) and used with a brushing action in a crown-down manner at the cervical, middle, and apical canal thirds, respectively, until reaching the working length [7].

Working length determination after filling removal (EWL-2) was performed using a file adjusted to the apical third. The file was maintained at that position and a radiograph was taken.

Reinstrumentation was then performed using #35 and #40 K-type files (Dentsply Maillefer – Ballaigues, Switzerland). Working length determination after reinstrumentation (EWL-3) was performed using a #40 K-type file. The file was maintained at that position and a radiograph was taken.

Tolerance limits

Two tolerance limits were used to classify the results as accurate: when the file tip was located in a range of (1) 0.5 to 1.0 mm and (2) 0.5 to 2.0 mm short of the radiographic apex. For both tolerance limits, the results were classified as inaccurate when the file tip was outside that range of values. The distance was measured manually on the radiograph using a high-precision digital caliper (Mitutoyo, series 500, accuracy of 0.01 mm – Suzano, Brazil).

Statistical analysis

For both tolerance limits, the accurate measurements were reported descriptively (frequency, percentage, mean, standard deviation, and minimum/maximum values), and the inaccurate measurements were reported as frequency, percentage, means, and shorter/longer values. Student *t* test for paired samples was used to compare means between groups, and subsequently to compare means between groups from only accurate measurements, for both tolerance ranges. All data were analyzed using the SAS statistical package, version 10.0 (SAS Institute – Cary, USA). Significance was set at $p<0.05$.

Results

Table 1 shows the accurate and inaccurate results for the three different measurements: during treatment (EWL-1) and during retreatment, after filling removal (EWL-2) and after reinstrumentation (EWL-3), according to the tolerance limits. For the tolerance range of 0.5-1.0 mm, the number of accurate measurements was 14 (41.5%) during treatment, 7 (20.5%) after filling removal, and 11 (32.5%) after reinstrumentation. For the tolerance range of 0.5-2.0 mm, the number of accurate measurements was 28 (82.3%), 30 (88.2%), and 31 (91.1%), respectively. Table 2 shows the comparison of means at the different stages of treatment/retreatment (EWL-1, EWL-2, EWL-3) including all values (accurate and inaccurate measurements). There was no statistically significant difference between measurements ($p>0.05$). Table 3 shows the comparison of means at the different stages of treatment/retreatment from only accurate measurements, for both tolerance ranges. There was no statistically significant difference between measurements ($p>0.05$).

Table 1. Frequency (n), percentage (%), mean and standard deviation (SD), and minimum/maximum values of accurate measurements and frequency (n), percentage (%), mean, and shorter/longer values of inaccurate measurements during treatment (EWL-1) and during retreatment – after filling removal (EWL-2) and after reinstrumentation (EWL-3), according to the tolerance range (distance from the radiographic apex)

Tolerance range	EWL-1	EWL-2	EWL-3
0.5-1.0mm			
Accurate, n (%)	14 (41.5%)	7 (20.5%)	11 (32.5%)
Mean (SD)	0.64mm (0.13)	0.69mm (0.16)	0.70mm (0.13)
Minimum/maximum	0.50mm/0.97mm	0.54mm/0.95mm	0.50mm/0.97mm
Inaccurate, n (%)	20 (58.8%) 19 shorter; 1 longer	27 (79.4%) 27 shorter	23 (67.6%) 22 shorter; 1 longer
Mean	1.69mm	1.51mm	1.60mm
0.5-2.0mm			
Accurate, n (%)	28 (82.3%)	30 (88.2%)	31 (91.1%)
Mean (SD)	1.08mm (0.49)	1.22mm (0.37)	1.26mm (0.49)
Minimum/maximum	0.50mm/1.85mm	0.54mm/1.95mm	0.50mm/2.00mm
Inaccurate, n (%)	6 (17.6%) 5 shorter; 1 longer	4 (11.7%) 4 shorter	3 (8.8%) 2 shorter; 1 longer
Mean	2.12mm	2.26mm	1.77mm

EWL = electronic working length, as measured with the MiniApex® electronic foramen locator.

Table 2. Comparison of means between the different stages of treatment/retreatment – EWL-1 (during treatment), EWL-2 (after filling removal), and EWL-3 (after reinstrumentation), including all values (accurate and inaccurate measurements)

	EWL-1 and 2	EWL-1 and 3	EWL-2 and 3
Mean	-0.08588	-0.05206	0.03382
Standard deviation	0.85197	0.85103	0.69455
95% confidence interval of the difference			
Lower	-0.38315	-0.34900	-0.20852
Upper	0.21138	0.24488	0.27616
p-value	0.561 *	0.724 *	0.778 *

EWL = electronic working length, as measured with the MiniApex® electronic foramen locator.
* Student *t* test for paired samples, $\alpha=0.05$.

Table 3. Comparison of means between the different stages of treatment/retreatment – EWL-1 (during treatment), EWL-2 (after filling removal), and EWL-3 (after reinstrumentation), only from accurate measurements, for both tolerance ranges

	Tolerance range (distance from the radiographic apex)					
	0.5-1.0mm			0.5-2.0mm		
	EWL-1 and 2	EWL-1 and 3	EWL-2 and 3	EWL-1 and 2	EWL-1 and 3	EWL-2 and 3
Mean	-0.01250	-0.05333	-0.03500	-0.17280	-0.20600	-0.09214
Standard deviation	0.20918	0.24655	0.12819	0.56023	0.68333	0.48550
95% confidence interval of the difference						
Lower	-0.34536	-0.31207	-0.23898	-0.40405	-0.48807	-0.28040
Upper	0.32036	0.20540	0.16898	0.05845	0.07607	0.09611
p-value	0.912 *	0.619 *	0.623 *	0.136 *	0.145 *	0.324 *

EWL = electronic working length, as measured with the MiniApex® electronic foramen locator.
* Student *t* test for paired samples, α=0.05.

Discussion

The lack of evidence regarding EWL determination during root canal retreatment was the main reason for the development of the present study. Our main findings were (1) at higher tolerance ranges the percentage of EWL accurate measurements was also higher; (2) during root canal retreatment, EWL after reinstrumentation gave more accurate measurements than EWL after filling removal, but without statistical difference; (3) inaccurate measurements were mostly observed at shorter measurements (shorter than the tolerance range), compared to longer measurements; and (4) no statistical difference was found when only accurate measurements were evaluated across the three stages.

MiniApex® EFL was highly accurate at the larger tolerance range (0.5-2.0 mm): 82.3% (EWL-1), 88.2% (EWL-2), and 91.1% (EWL-3). The *in vivo* study by Chevalier et al. [15] found 91.3% of acceptable measurements with the NovApex® EFL when compared with the radiographic method. Similar to our study, those authors used the ‘0.5’ mark on the EFL display; but differently, they considered as acceptable those measurements when the file tip was located between 0 and 2mm from the radiographic apex. The literature has already produced studies showing that the choice of different tolerance ranges may lead to changes in the number of accurate measurements. In a recent study, Aggarwal et al. [1] found accuracy rates of 83.3% and 93.3% for Root ZX and ProPex, respectively, for a tolerance limit of ±0.5 mm and 100% for a tolerance limit of ±1.0 mm.

When considering only the accurate measurements and using the larger tolerance limit, this study found mean values of 1.08 mm (EWL-1), 1.22 mm (EWL-2), and 1.25 mm (EWL-3) from the radiographic apex to the instrument tip. These values suggest that the location detected was probably slightly shorter than the apical constriction (minor foramen). Despite this hypothesis, it is well known that the precise location of the apical constriction (recommended as the physiological apical limit for instrumentation and filling of the root canal) [16] cannot be determined [17,18], because its topography is not constant [19]. Given the impossibility to precisely determine the apical constriction, ElAyouti & Lost [20] reported that the differences in tolerance rates found in the literature may affect the results of laboratory studies, but these differences might not be clinically relevant.

As described by Somma et al. [10], it is very important to highlight that each device has a different reading display to visualize the apical portion of the root canal and the apical foramen. In addition, authors have chosen different methods to determine the working length [21]. This means that studies have chosen different marks on the EFL display to locate the following anatomical landmarks: apical constriction/minor foramen; a region between the narrowest diameter and the major foramen; or the major foramen/apical foramen. Such differences prevent a direct comparison of the accuracy of EFLs. In this context, most of the inaccurate measurements found in our study, for both tolerance limits, referred to short measurements (Table 1). This finding led us to conclude that our choice of using the ‘0.5’ mark on MiniApex® EFL display prevented the determination of long working lengths. Such fact was also demonstrated in the *in vitro* study by Renner et al. [9].

In vitro studies are useful because they allow for experiment standardization and the generation of new hypotheses. In the present study, some precautions were taken to ensure measurement standardization and reliability, such as the selection of files according to canal size in order to improve the accuracy of EFL readings that had been previously described both *in vitro* [22,24] and *in vivo* [8,9].

This study is potentially important because it launches the hypothesis that, during root canal retreatment, EWL measurement after root canal reinstrumentation is more reliable than that performed immediately after filling removal. Although there was no statistically significant difference between the two retreatment stages analyzed (EWL-2 and EWL-3), a greater number of accurate measurements was observed during EWL-3, regardless of the tolerance range. This probably occurred as a result of the removal of all possible contents from inside the root canal, including dentinal debris, pulp tissue, gutta-percha, and sealer. Despite previous *in vivo* studies showing that the pulp condition does not affect the accuracy of EWL readings during clinical practice [8,9], it is important to bear in mind that, as supported by the present findings, the proper performance of any EFL requires the removal of all contents from inside the root canal.

As for the analysis of accurate measurements alone, there was no statistical difference between the treatment/retreatment stages analyzed ($p>0.05$), regardless of the tolerance range (Table 3). This means that, when MiniApex® EFL was accurate, it provided similar values for the location of the instrument tip, i.e., neither shorter nor longer measurements, considering EWL-1, EWL-2, and EWL-3 stages.

Conclusions

MiniApex® EFL was highly accurate to determine EWL during three different stages of root canal treatment/retreatment, namely EWL-1 (during treatment), EWL-2 (after filling removal), and EWL-3 (after reinstrumentation), when a high tolerance limit (0.5-2.0 mm) was used. Conversely, MiniApex® EFL was poorly accurate to determine EWL at the three root canal treatment/retreatment stages when a lower tolerance limit (0.5-1.0 mm) was used. A comparison of EWL determination means at the different treatment/retreatment stages (EWL-1, EWL-2, EWL-3), including all values (accurate and inaccurate measurements), revealed no statistical difference. Likewise, when EWL determination means obtained only from accurate measurements were compared, for both tolerance limits, no statistically significant difference was observed.

In sum, the present findings suggest that MiniApex® EFL was highly accurate to determine the location of the instrument tip at 0.5 to 2.00 mm from the radiographic apex during treatment and retreatment (after filling removal and after reinstrumentation).

References

1. Aggarwal V, Singla M, Kabi D. An in vitro evaluation of performance of two electronic root canal length measurement devices during retreatment of different obturating materials. J Endod 2010;36(9):1526-30.
2. Uzun O, Topuz O, Tinaz AC, Alacam T. Apical accuracy of two apex-locating handpieces in root canal retreatments of root-end resected teeth. J Endod 2007;33(12):1444-6.
3. Tang L, Sun TQ, Gao XJ, Zhou XD, Huang DM. Tooth anatomy risk factors influencing root canal working length accessibility. Int J Oral Sci 2011;3(3):135-40.
4. Ersev H, Yilmaz B, Dincol ME, Daglaroglu R. The efficacy of ProTaper Universal rotary retreatment instrumentation to remove single gutta-percha cones cemented with several endodontic sealers. Int Endod J 2012;45(8):756-62.
5. Ma J, Al-Ashaw AJ, Shen Y, Gao Y, Yang Y, Zhang C, et al. Efficacy of ProTaper Universal rotary retreatment system for gutta-percha removal from oval root canals: a micro-computed tomography study. J Endod 2012;38(11):1516-20.
6. Kfir A, Tsesis I, Yakirevich E, Matalon S, Abramovitz I. The efficacy of five techniques for removing root filling material: microscopic versus radiographic evaluation. Int Endod J 2012;45(1):35-41.
7. So MV, De Figueiredo JA, Freitas Fachin EV, Hungaro Duarte MA, Pereira JR, Kuga MC, et al. Clinical microscopic analysis of ProTaper retreatment system efficacy considering root canal thirds using three endodontic sealers. Microsc Res Tech 2012;75(9):1233-6.
8. Akisue E, Gavini G, de Figueiredo JA. Influence of pulp vitality on length determination by using the Elements Diagnostic Unit and Apex Locator. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;104(4):e129-32.
9. Renner D, Grazziotin-Soares R, Gavini G, Barletta FB. Influence of pulp condition on the accuracy of an electronic foramen locator in posterior teeth: an *in vivo* study. Braz Oral Res 2012;26(2):106-11.
10. Somma F, Castagnola R, Lajolo C, Paterno Holtzman L, Marigo L. In vivo accuracy of three electronic root canal length measurement devices: Dentaport ZX, Raypex 5 and ProPex II. Int Endod J 2012;45(6):552-6.
11. Mull JP, Manjunath V, Manjunath M. Comparison of accuracy of two electronic apex locators in the presence of various irrigants: An *in vitro* study. J Conserv Dent 2012;15(2):178-82.
12. Leonardo MR, Silva LA, Nelson-Filho P, Silva RA, Raffaini MS. Ex vivo evaluation of the accuracy of two electronic apex locators during root canal length determination in primary teeth. Int Endod J 2008;41(4):317-21.
13. Plotino G, Grande NM, Brigante L, Lesti B, Somma F. Ex vivo accuracy of three electronic apex locators: Root ZX, Elements Diagnostic Unit and Apex Locator and ProPex. Int Endod J 2006;39(5):408-14.
14. Herrera M, Abalos C, Lucena C, Jimenez-Planas A, Llamas R. Critical diameter of apical foramen and of file size using the Root ZX apex locator: an *in vitro* study. J Endod 2011;37(9):1306-9.
15. Chevalier V, Arbab-Chirani R, Nicolas M, Morin V. Occurrence of no-function of two electronic apex locators: an in vivo study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009;108(6):e61-5.
16. Ricucci D, Langeland K. Apical limit of root canal instrumentation and obturation, part 2. A histological study. Int Endod J 1998;31(6):394-409.
17. Lee SJ, Nam KC, Kim YJ, Kim DW. Clinical accuracy of a new apex locator with an automatic compensation circuit. J Endod 2002;28(10):706-9.
18. Martinez-Lozano MA, Forner-Navarro L, Sanchez-Cortes JL, Llena-Puy C. Methodological considerations in the determination of working length. Int Endod J 2001;34(5):371-6.
19. Dummer PM, McGinn JH, Rees DG. The position and topography of the apical canal constriction and apical foramen. Int Endod J 1984;17(4):192-8.
20. ElAyouti A, Lost C. A simple mounting model for consistent determination of the accuracy and repeatability of apex locators. Int Endod J 2006;39(2):108-12.
21. Altenburger MJ, Tchorz JP, Somma F. In vivo accuracy of three electronic root canal length measurement devices: Dentaport ZX, Raypex 5 and ProPex II. Int Endod J 2012;45(11):1053-4.
22. Ebrahim AK, Wadachi R, Suda H. Ex vivo evaluation of the ability of four different electronic apex locators to determine the working length in teeth with various foramen diameters. Aust Dent J 2006;51(3):258-62.
23. McDonald NJ. The electronic determination of working length. Dent Clin North Am 1992;36(2):293-307.
24. Waki H. A study of the electronic method for measuring the root canal length – AC impedance of reamer tip in electrolyte. Jpn J Conserv Dent 1981;24:115-31.