Available online at www.giornaleitalianoendodonzia.it

ORIGINAL ARTICLE

Effectiveness of a new electronic apex locator in two modalities in detecting the working length: an *ex vivo* study

ABSTRACT

Aim: *This ex vivo study aims to compare the accuracy of two electronic apex locators, Wirele-X (Forum Engineering Technologies Ltd., Israel), tested in two modalities, alone and connected to the display screen and Dentaport ZX (J. Morita, Tokyo, Japan) in determining the working length.*
Methodology: *15 single-rooted teeth were selected for this study. The actual microscopic working length was measured using a size 10 K-file that was advanced until the tip of the file could be visualized just within the apical foramen under a stereomicroscope. Then each tooth was placed into the alginate to simulate the clinical conditions. Wirele-X and Dentaport ZX were used according manufacturer's instructions. Three measurements were performed for each tooth and each apex locator and modality and differences between the electronic and actual working lengths were calculated. Positive values indicated measurements that extruded beyond the apical foramen, while negative values indicated measurements that were short of the apical foramen. Means and standard deviation were calculated and the statistical analysis was performed using One-way ANOVA and Tukey tests (P<0.05).*
Results: *The difference between electronic and actual working length was 0.05±0.34 mm for Wirele-X alone, 0.003±0.37 mm for Wirele-X connected to the display screen and 0.08±0.35 mm for Dentaport ZX. No statistical differences were found among Wirele-X alone, Wirele-X connected to the display screen and Dentaport ZX (p>0.05).*
Conclusions: *Wirele-X in both modalities and Dentaport ZX showed a high accuracy in determining working length and were accurate to within ±0.5 mm, without any statistical differences among them.*

Raffaella Castagnola[1,2*]
Rosalba Diana[1,2*]
Mauro Colangeli[1,2]
Claudia Panzetta[3]
Luca Marigo[1,2]
Nicola Maria Grande[1,2]
Gianluca Plotino[4]

[1]*Department of Operative Dentistry and Endodontics, "Fondazione Policlinico Universitario A. Gemelli IRCCS", Rome, Italy*

[2]*Institute of Dentistry and Maxillofacial Surgery, Catholic University of the Sacred Heart, Rome, Italy*

[3]*Physics Institute, Catholic University of the Sacred Heart, Rome, Italy*

[4]*Private practice in Rome, Italy*

Received 2021, January 24
Accepted 2021, February 1

KEYWORDS *apex locator, apical foramen, Dentaport ZX, Wirele-X*

Corresponding author
Raffaella Castagnola | Department of Operative Dentistry and Endodontics, "Fondazione Policlinico Universitario A. Gemelli IRCCS", Largo A. Gemelli 8, 00168 Rome | Italy
Phone: +39 06 3051159 | email raffaellacastagnola@inwind.it

Peer review under responsibility of Società Italiana di Endodonzia

10.32067/GIE.2021.35.01.21

Introduction

The outcome of root canal treatment depends on shaping, cleaning and disinfection, removing the microorganisms from the entire root canal space, followed by an homogenous root canal filling (1).
The ideal end-point of a root canal therapy have been debated by many authors (2, 3). The cemento-dentinal junction is credited to be the ideal limit of a root canal therapy (4, 5), but this position is usually variable and cannot be clinically detected (3, 6). Clinically, the success rate of a root canal therapy increase when the shaping, cleaning and filling are located within 2 mm from the radiographic apex, in the region of the apical constriction (7, 8). However, the apical constriction, usually the narrowest part of the root canal, is also not easily identified (6).
Different methods have been used to establish the working length: radiography, tactile sensation, the anatomical average length of teeth and moisture of a paper point (5). The measuring of working length using radiographs has been used for many years and it had the limit of providing a two-dimensional image of a three-dimensional complex structure. ElAyouty et al. showed that the use of radiographs alone in working length determination led to an overstrumentation in 33% of molars and 56% of premolars (9). The introduction of electronic apex locators (EALs) has enabled, in addiction to appropriate radiographs, to determine a more predictable and accurate working length (10,11) and led to a reduction of the patient x-ray radiation exposure (12). In the last decades, different generations of EALs have been developed. The first generation measured the electrical resistance while the last generations measure alternating current impendance using one or more frequencies (13). Several studies have been conducted on different EALs to evaluate their accuracy in different conditions (14-17). Dentaport ZX (J. Morita, Tokyo, Japan) is a third generation EALs based on dual frequencies (8 and 0.4 kHz) and it is considered the gold standard EAL to which any new device should be compared. In fact, several studies have clearly demonstrated *ex vivo* (18) and *in vivo* (19) its precision. Among these studies, as an example, Puri et al. (2013) showed that Dentaport ZX had an accuracy in 93.3% of the samples and found a difference of the electronic measurement with the actual working length of 0.05±0.25 mm (20).
Wirele-X (Forum Engineering Technologies Ltd., Israel) is a new wireless EAL that can be used alone or in association with a 7" high-resolution touch display screen. The measurements are performed utilizing alternating current signals at two frequencies (500 Hz and 8 kHz) and are transmitted from the EAL to the display unit using Bluetooth technology. The manufacturer claims that the frequencies are alternated and not mixed, thus canceling the need for signal filtering and eliminating the noise caused by non-ideal filters. The signal measuring method utilized in Wirele-X has been patented (US Patent No. 6,425,875). To calculate file tip position, the RMS (Root Mean Square) level of the signal is used and not signal amplitude or phase. The RMS value, representing the energy level of the signal, is much more immune to various kinds of electromagnetic noises then other parameters of the measured signal.
To our knowledge, scientific data on this new EAL are still not available in the literature. Thus, the aim of this *ex vivo* study was to compare the accuracy of two EALs, Wirele-X in two modalities, alone and connected to the display screen and Dentaport ZX in determining working length in extracted teeth.

Materials and Methods

15 freshly extracted single-rooted teeth were selected for this study. Teeth were collected, debrided and disinfected in 5.25% sodium hypochlorite (NaOCl) for 2 hours and then stored in normal saline (0.9% NaCl) until used.
Two digital radiographs were taken in a bucco-lingual and mesio-distal direction to exclude samples with two canals, open

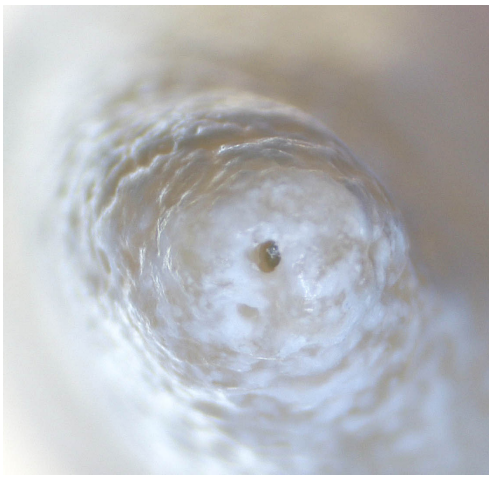
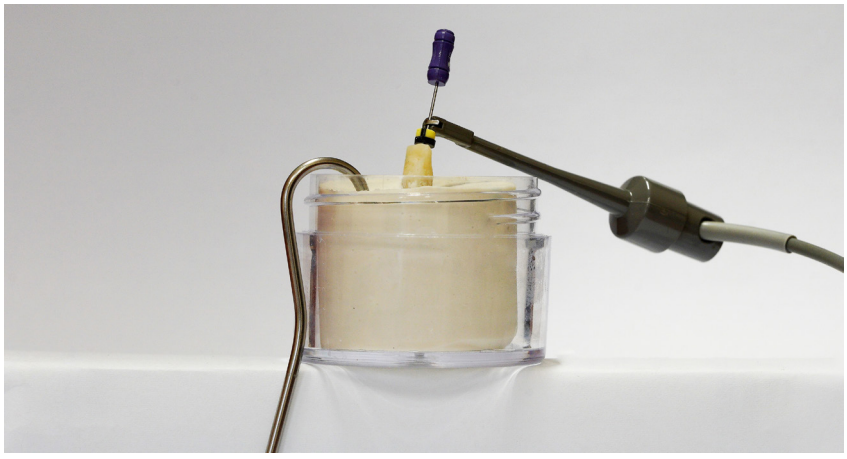


Figure 1
The determination of the actual working length (AWL) under stereomicroscope at 20X magnification. The file is visible through the major apical foramen.

apices, amalgam or composite fillings and previous root canal treatments. An access cavity was performed and size 10 and 15 K-files were inserted until the apex to confirm patency. When a size 20 K-file reached the apex, the tooth was excluded and replaced.
The actual microscopic working length (AWL) was measured using a size 10 K-file that was advanced until the tip of the file could be visualized just within the apical foramen under a stereomicroscope Zeiss Axiophot (Carl Zeiss Jena Gmbh, Zeiss Group, Jena, Germany) connected with a digital camera (Moticam Pro SMP) at a 20X microscopic magnification (Figure 1). Double stoppers were positioned for all measurements taken to decrease the possibility of stopper movement during all measurements.
Then each tooth was placed in a container filled with alginate that was obtained mixing the alginate powder with physiological solution to replicate the electric conductivity and simulate the oral environment. The teeth were inserted leaving 5 mm of the coronal root surface exposed (21). The lip clip was placed into the alginate and the wire of the EAL was connected to the file (Figure 2).

Figure 2
Image showing the experimental set-up.



Wirele-X and Dentaport ZX were used according to the manufacturer's instructions. When the Wirele-X was used alone without the Bluetooth connection with the display unit, the size 10 K-file was inserted gently until the last red bar appeared on the device and then retracted until the apical position was reached (orange bar at the mark "0.0") (Figure 3). When the Wirele-X was used connected via Bluetooth with its display unit, the size 10 K-file was gently advanced until the red "blood drop" icon appeared on the screen and warning sound designated that the file has passed the Apex and then withdrawn to the red bar at the mark "0" and reading "APEX" (Figure 4). For Dentaport ZX the size 10 K-file was inserted until the apex reading was reached at the first red bar and then withdrawn to the last green flashing bar on display (Figure 5). Measurements were considered as valid if the reading remained stable for at least 5 seconds. Each measurement was repeated three times for each tooth and each EAL and modality and all working lengths were measured on the file using a digital caliper.
Differences between the electronic working length (EWL) and the AWL were calculated. Positive values indicated measurements that extruded beyond the apical foramen, while negative values indicated measurements that were short in the apical foramen. Means and standard deviation were calculated for each group and the statistical analysis was performed using One-way ANOVA and Tukey tests with a significant difference set at $P<0.05$.

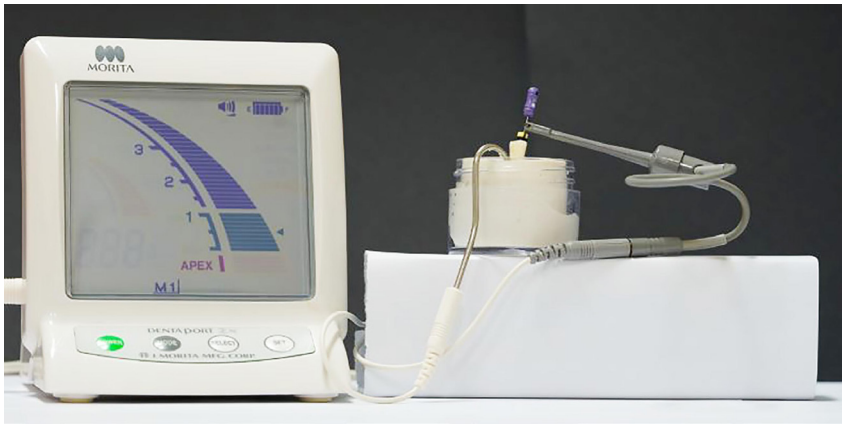
Results

Considering the margin of accuracy ±1 mm, all the EALs showed an accuracy of 100%. When considering the margin of accuracy ±0.5 mm, Wirele-X alone, Wire-

Figure 3
The orange bar at the mark "0.0" of Wirele-X device that appears when the file reached the apical position.

Figure 4
The display unit connected via Bluetooth to Wirele-X device with the screen showing the red bar at the mark "0".

Figure 5
Dentaport ZX showing the last green flashing bar on display.



le-X/Display and Dentaport ZX showed an accuracy of 88.8 %, 82.2% and 86.6% respectively. The main difference between EWL and AWL was 0.05±0.34 mm for Wirele-X, 0.003±0.37 mm for Wirele-X/Display and 0.08±0.35 mm for Dentaport ZX (Figure 6). No statistical differences were found among Wirele-X alone, Wirele-X/Display and Dentaport ZX (p>0.05).

Discussion

The goal of this study was to evaluate *ex vivo* the accuracy of the new Wirele-X EAL in two modalities, alone and connected to the display screen and compare it to the Dentaport ZX. Many authors have evaluated the accuracy of EALs considering the apical constriction (22) or the major foramen (23), which seems to be more reproducible (24).

Several materials have been proposed by many authors to simulate periodontal ligament to test *in vitro* EALs: gelatin (25), agar-agar (26), saline (27), flower sponge soaked in saline (28) or alginate (21). Alginate as a substitute for periodontal ligament was investigated by Lipski *et al.* who showed a 100% rate of correct measurement (29). On the contrary, gelatin, agar-agar, saline and flower sponge soaked in saline showed a rate of 96.7%, 76.7%, 73.4% and 63.4% respectively (28). For this reason, alginate was used in the present study to ensure the best medium possible for testing the EALs *ex vivo.*

In the present study, single-rooted teeth with narrow root canals were selected to standardise the samples and a size 10 K-file was used to obtain all the AWLs and EWLs. In fact, Ebrahim et al. reported that, when the diameter of a root canal increased, the electronic measurement with a small K-file become shorter (30).

The accuracy of the majority of the latest generations of EALs is not affected by irrigants within the root canal (31). Çınar et al. compared *in vivo* the accuracy of Propex Pixi, Mini Root ZX, Raypex 5 in determining working length in presence of blood-pulp tissue or sodium hypochlorite using micro-computed tomography. There were no differences among working lengths measured in different conditions. In a systematic review and meta-analysis Tsesis et al. similarly stated that the presence of vital or necrotic pulp has not effect on the precision of EALs (32). In the present experiment, conducted in normal condi-

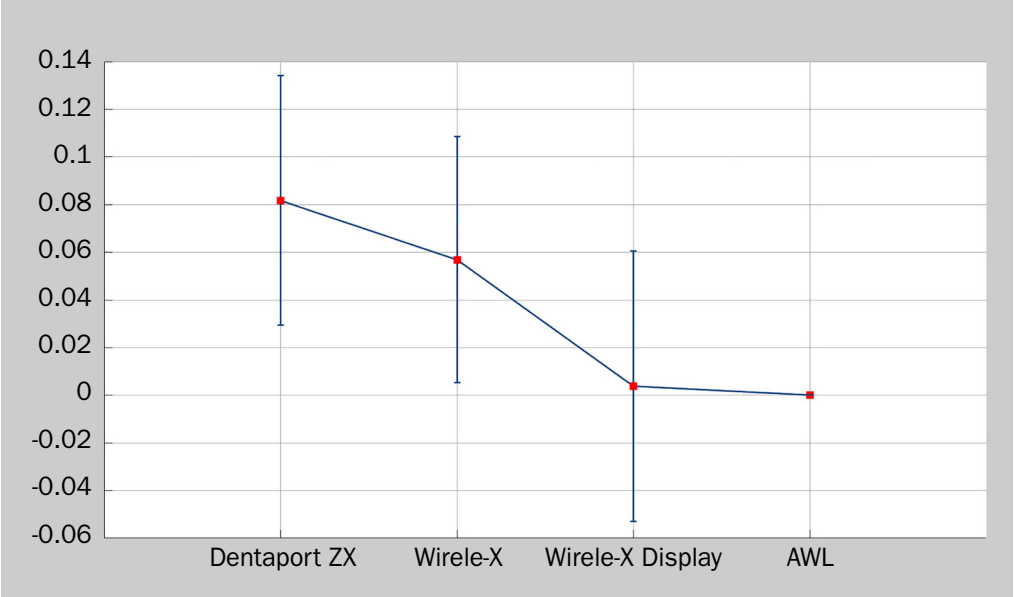


Figure 6
Distribution of positive and negative values of electronic working length (EWL), standard deviation and the actual working length (AWL).

tions, the EWL measurements have been very accurate for both Wirele-X, alone or connected to the display screen, and Dentaport ZX.

Regarding the accuracy of Dentaport Zx, the results of the presence study are generally consistent with previous *in vivo* and *in vitro* investigations. Saatchi et al. *in vivo* found that Dentaport ZX showed an accuracy within ±0.5 mm of 93.8% and 93.3% in presence, or not, of apical periodontitis (33). Piasecki et al. showed *in vivo* that the apical foramen was accurately located by Root ZX II within ±0.5 mm in 83% of the teeth with apical periodontitis and in 100% of vital teeth (34). Comparing working length determination *in vivo* and *in vitro*, Duran-Sindreu et al. reported that Root ZX was accurate 74% of the time to ±0.5 mm *in vitro* and 78.3% of the time to ±0.5 mm *in vivo* (35). Connert et al., using Micro-CT to calculate the distance between the K-file and the minor and the major foramen, found an accuracy of Dentaport ZX of 99% and 100% in detecting major foramen, within a tolerance of ±0.5 mm or ±1 mm respectively (14). Stöber et al., under *in vivo* clinical conditions, measured a mean distance from the AWL to the file tip of 0.146 ± 0.43 mm and an accuracy of 72% within ±0.5 mm and 100% of the time within ±1 mm (36). Pascon et al. reported, within a tolerance of ±0.5 mm or ±1 mm, an accuracy of Dentaport ZX of 39% or 90% respectively (18). The results obtained in the present study are in agreement with most of the mentioned studies. The different percentages obtained in all these studies for the accuracy of Dentaport XZ could be explained by the method used to establish the actual working length (AWL).

Wirele-X was tested for the first time in the present study as no previous scientific literature has been published on this EAL, which has obtained comparable results with Dentaport ZX in both modalities tested ($p>0.05$). Wirele-X/Display showed the best results concerning the difference between EWL and AWL, demonstrating that the connection via Bluetooth has not affected the accuracy of this EAL. Possible advantages in the use of Wirele-X EAL can be the notably small size of the EAL unit and the possibility to attach it to the dental dam for a more comfortable and ergonomic use. The Wirele-X shows the movement of the file inside the canal from the beginning of the measurements to the end, providing uninterrupted feedback. Proprietary software algorithms are used for calculations of file tip position and file movement in different parts of root canal. Clearly distinguished graphical readings in the apex region accompanied by audio signals enable better control over the file

advance. In case of over-instrumentation a red "blood drop" icon and warning sound designate that the file has passed the Apex. Numerical values changing from +0.1 to +0.5 indicate relative depth of over-instrumentation, a useful feature for patency testing. If the file tip penetrates deeper, the "OVER" reading appears.

Conclusions

Under the limitations of this *ex vivo* study, Wirele-X, alone and connected via Bluetooth with its display, and Dentaport ZX showed high accuracy in detecting the working length and were accurate to within ± 0.5 mm, without any statistical differences among them.

Clinical Relevance

All apex locators tested in this study can be recommended for clinical practice.

Conflict of interest

The authors declare that there is no conflict of interest.

Acknowledgements

The authors thank Forum Engineering Technologies for donating the apex locators Wirele-X for this study.

References

1. *Sjögren U, Figdor D, Persson S, Sundqvist G. Influence of infection at the time of root filling on the outcome of endodontic treatment of teeth with apical periodontitis. Int Endod J. 1997;30(5):297-306.*
2. *Simon JH. The apex: how critical is it? Gen Dent. 1994;42(4):330-4.*
3. *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.*
4. *Kuttler Y. Microscopic investigation of root apexes. J Am Dent Assoc. 1955;50(5):544-52.*
5. *Gordon MPJ, Chandler NP. Electronic apex locators. International Endodontic Journal. 2004. p. 425-37.*
6. *Dummer PMH, McGinn JH, Rees DG. The position and topography of the apical canal constriction and apical foramen. Int Endod J. 1984;17(4):192-8.*
7. *Basmadjian-Charles CL, Farge P, Bourgeois DM, Lebrun T. Factors influencing the long-term results of endodontic treatment: A review of the literature. International Dental Journal. 2002. p. 81-6.*
8. *Kojima K, Inamoto K, Nagamatsu K, Hara A, Nakata K, Morita I, et al. Success rate of endodontic treatment of teeth with vital and nonvital pulps. a meta-analysis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2004;97(1):95-9.*
9. *Elayouti A, Weiger R, Löst C. Frequency of overinstrumentation with an acceptable radiographic working length. J Endod. 2001;27(1):49-52.*
10. *Fouad AF, Reid LC. Effect of using electronic apex locators on selected endodontic treatment parameters. J Endod. 2000;26(6):364-7.*
11. *ElAyouti A, Weiger R, Löst C. The ability of Root ZX apex locator to reduce the frequency of overestimated radiographic working length. J Endod. 2002;28(2):116-9.*
12. *Martins JNR, Marques D, Mata A, Caramês J. Clinical efficacy of electronic apex locators: Systematic review. Journal of Endodontics. 2014. p. 759-77.*
13. *Gehlot PM, Manjunath V, Manjunath MK. An in vitro evaluation of the accuracy of four electronic apex locators using stainless-steel and nickel-titanium hand files. Restor Dent Endod. 2016;41(1):6.*
14. *Connert T, Judenhofer MS, Hülber-J M, Schell S, Mannheim JG, Pichler BJ, et al. Evaluation of the accuracy of nine electronic apex locators by using Micro-CT. Int Endod J. 2018;51(2):223-32.*
15. *Piasecki L, José dos Reis P, Jussiani EI, Andrello AC. A Micro-computed Tomographic Evaluation of the Accuracy of 3 Electronic Apex Locators in Curved Canals of Mandibular Molars. J Endod. 2018;44(12):1872-7.*
16. *Marigo L, Gervasi GL, Somma F, Squeo G, Castagnola R. Comparison of two electronic apex locators on human cadavers. Clin Oral Investig. 2016;20(7):1547-50.*
17. *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.*
18. *Pascon EÁ, Marrelli M, Congi O, Ciancio R, Miceli F, Versiani MA. An ex vivo comparison of working length determination by 3 electronic apex locators. Oral Surgery, Oral Med Oral Pathol Oral Radiol Endodontology. 2009;108(3).*
19. *Somma F, Castagnola R, Lajolo C, Paternò 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.*
20. *Puri N, Chadha R, Kumar P, Puri K. An in vitro comparison of root canal length determination by DentaPort ZX and iPex apex locators. J Conserv Dent. 2013;16(6):555-8.*
21. *Abdelsalam N, Hashem N. Impact of Apical Patency on Accuracy of Electronic Apex Locators: In Vitro Study. J Endod. 2020;46(4):509-14.*
22. *Vieyra JP, Acosta J. Comparison of working length determination with radiographs and four electronic apex locators. Int Endod J. 2011;44(6):510-8.*
23. *Jan J, Križaj D. Accuracy of root canal length determination with the impedance ratio method. Int Endod J. 2009;42(9):819-26.*
24. *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.*

25. Guise GM, Goodell GG, Imamura GM. In Vitro Comparison of Three Electronic Apex Locators. J Endod. 2010;36(2):279-81.
26. Briseño-Marroquín B, Frajlich S, Goldberg F, Willershausen B. Influence of Instrument Size on the Accuracy of Different Apex Locators: An In Vitro Study. J Endod. 2008;34(6):698-702.
27. Stoll R, Urban-Klein B, Roggendorf MJ, Jablonski-Momeni A, Strauch K, Frankenberger R. Effectiveness of four electronic apex locators to determine distance from the apical foramen. Int Endod J. 2010;43(9):808-17.
28. Baldi J V., Victorino FR, Bernardes RA, de Moraes IG, Bramante CM, Garcia RB, et al. Influence of Embedding Media on the Assessment of Electronic Apex Locators. J Endod. 2007;33(4):476-9.
29. Lipski M, Trabska-Świstelnicka M, Woźniak K, Dembowska E, Drożdzik A. Evaluation of alginate as a substitute for root-surrounding tissues in electronic root canal measurements. Aust Endod J. 2013;39(3):155-8.
30. Ebrahim AK, Yoshioka T, Kobayashi C, Suda H. The effects of file size, sodium hypochlorite and blood on the accuracy of Root ZX apex locator in enlarged root canals: An in vitro study. Aust Dent J. 2006;51(2):153-7.
31. Jenkins JA, Walker WA, Schindler WG, Flores CM. An in vitro evaluation of the accuracy of the root ZX in the presence of various irrigants. J Endod. 2001;27(3):209-11.
32. Tsesis I, Blazer T, Ben-Izhack G, Taschieri S, Del Fabbro M, Corbella S, et al. The precision of electronic apex locators in working length determination: A systematic review and meta-analysis of the literature. Journal of Endodontics. 2015. p. 1818-1823.
33. Saatchi M, Aminozarbian MG, Hasheminia SM, Mortaheb A. Influence of apical periodontitis on the accuracy of 3 electronic root canal length measurement devices: An in vivo study. J Endod. 2014;40(3):355-9.
34. Piasecki L, Carneiro E, Fariniuk LF, Westphalen VPD, Fiorentin MA, Da Silva Neto UX. Accuracy of root ZX II in locating foramen in teeth with apical periodontitis: An in vivo study. J Endod. 2011;37(9):1213-6.
35. Duran-Sindreu F, Stöber E, Mercadé M, Vera J, Garcia M, Bueno R, et al. Comparison of in vivo and in vitro readings when testing the accuracy of the root ZX apex locator. J Endod. 2012;38(2):236-9.
36. Stöber EK, Duran-Sindreu F, Mercadé M, Vera J, Bueno R, Roig M. An evaluation of root ZX and iPex apex locators: An in vivo study. J Endod. 2011;37(5):608-10.