

Performance of two different electronic apex locators during the removal of calcium silicate-based sealers

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Abstract

Aim: The aim of this in vitro study is to evaluate the accuracy of Root ZX and Propex Pixi during the retreatment of root canals obturated with different calcium silicate-based root canal sealers.

Methodology: Root canals of ninety human premolar teeth were shaped with ProTaper universal rotary files up to size F2 under 5.25% NaOCl irrigation for the present study. Root canal filling was carried out by lateral condensation technique using with gutta-percha and sealers; MTA Fillapex, CeraSeal or AH Plus. After seven days, the obturating materials were removed using D-Race files. While actual working length was recorded by direct observation, electronic working lengths were determined by Propex Pixi or Root ZX for tolerance limits of 0.5 mm and 1.0 mm. Data were analyzed using Shapiro Wilk, Mann-Whitney U, and Kruskal-Wallis tests ($p < 0.05$).

Results: The performance of Propex Pixi and Root ZX was found to be statistically similar and did not differ on the root canals filled with different root canal sealers ($p < 0.05$). Propex Pixi and Root ZX demonstrated more accurate measurements in the range of ± 1 mm compared to ± 0.5 mm in all groups, regardless of the type of root canal sealer used when filling the root canals before retreatment ($p < 0.05$).

Conclusion: Root ZX and Propex Pixi can be used confidently in the retreatment of the root canals in which CeraSeal, MTA Fillapex, and AH Plus are used as sealers.

Keywords: Apex locator, apical constriction, calcium silicate-based sealer, retreatment, working length

Introduction

The first option is non-surgical endodontic retreatment in cases where root canal treatment fails for various reasons, such as residual bacteria and necrotic tissue, coronal leakage, and tooth cracks (1, 2). Success in retreatment can be achieved by removing the previously infected root canal filling, chemomechanical re-instrumentation, and obturating the root canals hermetically (3). The chemomechanical instrumentation should be performed within the root canal and should end at the minor apical constriction, which most commonly exists 0.5-1.0 mm short of the radiologic apex (4, 5).

Bergenholtz et al. highlighted the importance of determining the working length correctly during retreatment by their findings in a radiographic follow-up study (6). They found out that the apical lesion repair in retreatment cases significantly decreased in over-instrumented and over-filled root canals. Electronic apex locators (EALs) have been used as an adjunct to radiographic method for the determination of accurate root canal working length (7). EALs are classified due to their generations (8). Between the different generations of EALs, the first and second generations have not been manufactured recently and have not been used in dentistry due to the inaccurate measurements, especially compared with the radiographic methods in establishing the working length (8-11). With the development of dentistry science and technology, new generations of EALs from third to sixth generations have been advanced with higher validity in determining working length (12, 13). Third-generation EALs, such as Root ZX, use a double frequency (ratio method) to measure working length. In this method, impedance values at two frequencies, ie high (8 kHz) and low (400 Hz), are measured simultaneously. A quotient of impedances is calculated, and this value demonstrates the location of the file in the root canal. The third-generation is able to locate the narrowest part of the root canal (8-10,14). Despite this, the fourth generation, such as Propex Pixi, measures the resistance and capacitance of the electrical circuit individually to determine the narrowest part of the canal (8, 10).

According to the findings of the four meta-analyses of the 15 research studies, the third, fourth, fifth, and sixth generations of EALs are not different in measurement accuracy of working length (11). There are several studies that have investigated the performance of different apex locators in different situations, such as file size, root canal instrumentation, and irrigation solutions (15, 16). However, very few studies have evaluated the accuracy of EALs during retreatment with different root canal filling materials (16, 17).

The aim of this study was to evaluate the accuracy of Root ZX and Propex Pixi during the retreatment of root canals obturated with different calcium silicate-based root canal sealers. The null hypothesis was "Accuracy of Root ZX and Propex Pixi is similar and not affected by the root canal sealers during retreatment".

Materials and Methods

Sample size calculation

According to the power analysis (G*Power software, ver.3.1.9.2; Heinrich-Heine-Universität, Düsseldorf, Germany), the minimum sample size was calculated as 84 with a theoretical power of 0.80 at 95% confidence level and the study sample size established as 90.

Sample selection and preparation

The ethics committee approval of this study was obtained from Marmara University Faculty of Dentistry, Clinical Research Ethics Committee (2020/9-2000072922).

Ninety human permanent premolar teeth that were freshly extracted because of orthodontic or periodontal reasons were used in this study. Periapical radiographs were taken mesiodistally and buccolingually to eliminate any deviant root canal morphology and to confirm one single canal. In order to obtain a flat reference point for working length measurements, all specimens were decoronated at the level of the cemento-enamel junction using diamond discs (Horico H557F220; Pflingst & Company, South Plainfield, NJ, USA) by an air motor handpiece. After decoronation, a size 15 K-file (Dentsply Maillefer, Tulsa, OK, USA) was inserted into the root canal and pushed forward until the tip was visible at the foramen apicale. EyeMag Loupes (EyeMag Smart system; Carl Zeiss, Oberkochen, Germany) with a magnification of 2.5x was used to visualize the file and the apical tip and the file.

The stopper of the file was set to the flat reference surface. The file was removed, and the length between the stopper and the file tip was measured with an endodontic ruler. The initial working length was recorded by reducing 0.5 mm from this measured length. The root canal instrumentation was performed by ProTaper universal rotary files (Dentsply Maillefer, Tulsa, OK, USA) to the initial working length (SX to F2). The root canals were irrigated with 2 mL 5.25% sodium hypochlorite (NaOCl) with an endodontic needle (27-gauge) between each file during the instrumentation. The final irrigation of the root canals was carried out with 10 mL 5.25% NaOCl and 17% ethylenediaminetetraacetic acid (EDTA) solution. The root canal working length was then measured again by visualizing the file at the tip (subtracting 0.5 mm) and recorded as actual working length (AWL).

Root canals were dried with paper points (Dentsply Maillefer, Tulsa, OK, USA), and the specimens were divided into three main groups according to the root canal sealer (RCS) to be used during the filling of the root canals (n=30). Root canals were filled with lateral condensation technique using MTA Fillapex (Angelus, Londrina, Brazil) in Group 1, AH Plus (Dentsply De Trey GmbH, Konstanz, Germany) in Group 2 and CeraSeal (Meta Biomed Co., Cheongju, Chungcheong, South

Korea) as RCS in Group 3. Temporary filling material (Cavitimi, Imicryl, Konya, Turkey) was set on the canal entrances.

The specimens were placed in a sponge and stored at 100% humidity, 37°C. After seven days, periapical radiographs were taken to obtain a provisional working length before retreatment for each specimen. Then, root canal fillings were removed using D-Race (FKG Dentaire, La Chaux-de-Fonds, Switzerland) files, and root canals were irrigated with 2 ml of 5.25% NaOCl between each retreatment file. No attempt was made to remove the residual RCS on the canal wall. After removal of the root canal filling, the teeth put in the florist's sponge were placed in a plastic box that was filled with 0.9% NaCl.

The apex locator lip clip was placed in contact with the water between the plastic and the sponge. The file clip was attached to #25 K file, which was inserted into the root canal. Working lengths of the specimens in Groups 1, 2, and 3 were measured with Root ZX (J. Morita Co., Tokyo, Japan) and Propex Pixi (Dentsply Maillefer, Ballaigues, Switzerland), respectively, according to the manufacturers' recommendations. When measuring with Root ZX, the file was advanced to the 'apex' indicated as the major foramen. A measurement was made at the flashing point between the "1" and "apex" marks, and this length was noted as "Root ZX retreatment working length (rRWL)". When measuring with Propex Pixi, the file was advanced until it reached the 0.0 indicator on the screen, and the measurement was made at this point. The working length was determined to be 0.5 mm shorter than the measured value and noted as "Propex Pixi retreatment working length (pRWL)".

Statistical analysis

Data were analyzed using IBM SPSS 25 software (IBM Corp., Armonk, NY, USA).

The normality assumption of the data was checked by Shapiro-Wilk test, and Mann-Whitney U test was used to compare the means of two groups that did not have a normal distribution. Kruskal-Wallis test was used to compare the means of three or more groups that did not have a normal distribution. Post Hoc Bonferroni test was used to reveal the group or groups that made the difference. The relationship between variables was checked with Pearson Chi-Square test in the analysis of categorical data when the sample size assumption ($n > 5$) was met. When the sample size assumption was not met, the relationship between the variables was checked with Fisher's Exact test. Data were evaluated at $p < 0.05$ significance level.

Results

When AWL and pRWL averages were compared according to RCS, no statistically significant differences were found between the mean AWL and pRWL values in Groups 1, 2, and 3 (root canals filled with MTA Fillapex, AH Plus and

CeraSeal) ($p > 0.05$) (Table 1). There were also no significant differences between mean AWL and rRWL values in Groups 1, 2, and 3 (Table 2).

When the measurement averages of different apex locators were compared according to the sealers used, no significant difference was found between pRWL and rRWL ($p > 0.05$). The evaluation of pRWL and rRWL in Groups 1, 2, and 3 with AWL in the deviation ranges of ± 0.5 mm and ± 1.0 mm are given in Table 3.

Table 1. Comparison of actual and Propex Pixi-retreatment working length values.

Sealers	Working length	Mean	SD	p
MTA Fillapex	AWL	17.6	2.67	.702
	pRWL	17.9	2.63	
AH Plus	AWL	19.0	1.27	.636
	pRWL	19.1	1.36	
CeraSeal	AWL	14.1	1.43	.271
	pRWL	14.2	1.31	

Mann Whitney U test, * $p < 0.05$

*AWL: Actual Working Length, pRWL: Propex Pixi-Retreatment Working Length

Table 2. Comparison of actual and Root ZX-retreatment working length values.

Sealers	Working length	Mean	SD	p
MTA Fillapex	AWL	17.6	2.67	.827
	rRWL	17.5	2.83	
AH Plus	AWL	19.0	1.27	.723
	rRWL	18.9	1.26	
CeraSeal	AWL	14.1	1.43	.383
	rRWL	14.0	1.36	

Mann Whitney U test, * $p < 0.05$

*AWL: Actual Working Length, rRWL: Root ZX-Retreatment Working Length

Table 3. Retreatment working length measurement distributions with Propex Pixi and Root ZX with deviation range of ± 0.5 mm and ± 1.0 mm, according to root canal sealers used.

Sealers	Propex Pixi-RWL		Root ZX-RWL	
	± 0.5 mm	± 1.0 mm	± 0.5 mm	± 1.0 mm
MTA Fillapex	69.0%	100.0%	75.9%	89.7%
AH Plus	86.2%	96.6%	89.7%	100.0%
CeraSeal	82.8%	93.1%	79.3%	86.2%

*RWL: Retreatment Working Length

AWL and pRWL, and rRWL differences were compared, and the results are given in Table 4. No statistically significant difference was found between the mean differences of AWL and pRWL measurements and AWL and rRWL measurements in Groups 1, 2, and 3 ($p < 0.05$).

The distributions of the differences (positive or negative) obtained when the AWL and pRWL, and rRWL values are subtracted according to the pastes used in root canal filling are given in Table 5.

Table 4. Comparison of the subtraction of Propex Pixi and Root ZX-retreatment measurement values from the actual working length during retreatment according to the sealers used.

Sealers		Mean	SD	p
MTA Fillapex	AWL - pRWL	.544	.354	.625
	AWL - rRWL	.531	.459	
AH Plus	AWL - pRWL	.344	.367	.826
	AWL - rRWL	.310	.318	
CeraSeal	AWL - pRWL	.437	.466	.865
	AWL - rRWL	.431	.438	

Mann-Whitney U test, * $p < 0.05$

*AWL: Actual Working Length, pRWL: Propex Pixi-Retreatment Working Length, rRWL: Root ZX-Retreatment Working Length,

Table 5. Distribution of actual working length-retreatment working length measurements according to the sealers used in root canal filling.

Sealers	Propex Pixi		Root ZX	
	AWL - pRWL (negative)	AWL - pRWL (positive)	AWL - rRWL (negative)	AWL - rRWL (positive)
MTA Fillapex	55.1724%	44.8276%	41.3793%	58.6207%
AH Plus	34.4828%	65.5172%	31.0345%	68.9655%
CeraSeal	41.3793%	58.6207%	17.2414%	82.7586%

*AWL: Actual Working Length, pRWL: Propex Pixi-Retreatment Working Length, rRWL: Root ZX-Retreatment Working Length,

Discussion

The present study investigated the accuracy of Root ZX and Propex Pixi during the retreatment of the root canals that were filled with CeraSeal, MTA Fillapex, and AH Plus as RCSs. According to the results of this study, no significant difference was found between Root ZX and Propex Pixi in case of accuracy during the retreatment of

different RCSs. Besides, the tested RCSs did not affect the accuracy of Root ZX and Propex Pixi. Therefore, the null hypothesis was accepted.

Root ZX is the best representative of the third-generation EALs, and it is considered as the gold standard in studies evaluating the accuracy of newly presented EALs (10). It has been the most investigated EAL in Endodontics (18). Aggarwal et al. reported the successful usage of Root ZX in the retreatment of the teeth filled with gutta-percha, AH Plus, zinc oxide ojenol, and resilon (17). In a recent study, De-Devus et al. found that the accuracy of Root Zx II was 100% in the 0.5 mm deviation range (19). Propex Pixi is a fourth-generation EPL that can determine the root canal WL, in dry or wet canals, in vital or devital teeth without calibration (20). Ferreira et al. stated that Propex Pixi showed 100% accuracy in ± 1 mm deviation range (21). In a study investigating the measurement accuracy of EALs in retreatment procedure, Propex Pixi has been found to measure more accurately than Dentaport ZX and iPex2 (22). In the light of these studies, Root ZX and Propex Pixi were used as examined EALs to determine the working length in root canals due to their high measurement accuracy in this study.

MTA Fillapex, a bioceramic, and calcium silicate-based RCS, has been preferred due to its good sealing properties, radiopacity, and the ability not impairing the healing process in case of extrusion into the periapical tissues (23). Silva et al. revealed that the high pH value of MTA Fillapex neutralizes the acid which secreted by osteoclasts, thus preventing the destruction of mineralized tissue and prevents the penetrated irregular areas and lateral canals more easily than AH Plus (24). CeraSeal is a calcium silicate-based RCS that shows high adhesion to the root canal wall. It can be chemically bonded to the hydroxyapatite of dentin due to its bioactive structure (25). AH Plus is the most commonly used epoxy resin-based RCS with some features, such as high sealing ability, long working time, and sufficient radiopacity (26, 27). Besides, AH Plus has advantages, including strong adhesion to the dentinal wall, high fluidity, and low solubility in oral liquids (27, 28). Based on the mentioned information, CeraSeal, MTA Fillapex, and AH Plus were preferred as experimental RCSs in the present study.

It was notified that the rubber stoppers must be placed on a flat surface to reduce process errors in vitro studies investigating the accuracy of EALs (29). Therefore, in our study, the teeth were decoranated from the cemento-enamel junction using diamond discs to create a flat surface for the reference point before measuring the root canal working length.

Kuttler stated that in all teeth, the apical constriction is approximately 0.5-1 mm shorter than the apical foramen (30). However, Shabahang et al. reported that the deviation of ± 1 mm apical constriction point is a clinically acceptable value (31). While some of the studies in which apex locators tested the deviation range for apical constriction were accepted as 0.5 mm (32), other studies evaluated both deviation ranges of ± 0.5 mm and ± 1 mm (33, 34). We also took into account both

deviation rates for apical constriction measurements in this study.

In the literature, several researchers found that EALs are more accurate in the ± 1 mm deviation range than in the ± 0.5 mm range (32, 35). Supporting their findings, we found that Propex Pixi and Root ZX demonstrated more accurate measurements in the range of ± 1 mm compared to ± 0.5 mm in all groups, regardless of the type of RCS used when filling the root canals before retreatment.

According to the findings of our study, negative and positive results were obtained in all groups when subtracting the working length measurements achieved by EAL from AWL. Negative results mean that EAL measures beyond the apical constriction, while positive results mean that EAL measures cannot reach the apical constriction and lag behind (19). In the groups in which the root canals were filled with MTA Fillapex, AH Plus, and CeraSeal, 55.1%, 34.4%, and 41.3% of the measurements obtained with Propex Pixi were negative values, respectively. On the other hand, Root ZX has given negative values in the same RCS groups at a rate of 41.3% (MTA Fillapex), 31% (AH Plus), and 17.2% (CeraSeal). Propex Pixi and Root ZX did not show a significant difference between the measurement rates beyond the apical constriction. In contrast to our findings, Plotino et al. stated that longer measurements were obtained with Propex Pixi when compared with Root ZX (32). The difference between the results may be explained by different methodologies of the studies.

Goldberg et al. found that the Propex Pixi was 95% accurate in the deviation range of ± 1.0 mm (36). Ebrahim et al. demonstrated that Propex Pixi measured 100% accurately within the deviation range of ± 1.0 mm during retreatment (37). Consistent with these results, in our study, Propex Pixi measured 100%, 96%, and 93% accurately in the MTA Fillapex, AH Plus, and CeraSeal groups, respectively with a deviation range of ± 1.0 mm. Chirila et al. revealed that Propex Pixi measured 90% accurate in the range of ± 0.5 deviation in retreatment of the root canals which filled with Endofill as RCS (38). In our study, the accuracy of measurements after retreatment in root canals filled with MTA Fillapex, AH Plus, and CeraSeal was found to be 69%, 86.2%, and 82.8%, respectively, within the ± 0.5 mm deviation range of Propex Pixi. The difference between the results of the studies may be explained by the different sealers that were used filling the root canals.

According to the findings of the present study, the measurement accuracy of Root ZX in the deviation range of ± 1 mm was 91.6% on average in all specimens. Similar to our results, Aggarwal et al. found the measurement accuracy of Root ZX to be 96% in the range of ± 1 mm deviation in retreatment (17).

The most important limitation of our study is that it was carried out in in vitro circumstances. Thus, the results of this study need to be supported by future in vivo studies.

Conclusion

According to the findings of this in vitro study, it can be concluded that the accuracies of Root ZX and Propex Pixi are similar, and they are more accurate in the ± 1 mm deviation range than ± 0.5 mm deviation. Root ZX and Propex Pixi can be used confidently in the retreatment of the root canals that CeraSeal, MTA Fillapex, and AH Plus are used as sealers.

Disclosures

Ethical Approval: Ethics committee approval was received for this study from Marmara University Faculty of Dentistry, Clinical Research Ethics Committee, in accordance with the World Medical Association Declaration of Helsinki, with the approval number: 2020/9-2000072922.

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