Comparative Evaluation of the Remaining Dentin Thickness Using Different Root Canal Retreatment Techniques: A Cone-Beam Computed Tomography Study

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Abstract

This study was to evaluate the best technique to preserve radicular dentin after performing different retreatment procedures. Twenty maxillary central incisors were cleaned and shaped with the ProTaper Next and later obturated. The dentinal thickness were then measured from the axial views in the scanned CBCT images at 0mm, 5mm, 10mm and 13mm from the root apex. The teeth were then randomly placed into four groups and different systems were employed to remove the gutta percha. These were Hedstrom file without and with xylene (Groups 1 & 2) and ProTaper Universal Retreatment files without and with xylene (Groups 3 & 4).

The dentin thicknesses dimensions were then measured again on subsequent CBCT scanned axial views. Group 1 showed significant difference in the pre and post retreatment dentinal thickness at 0 and 5 mm ($p < 0.05$). Group 2 and 4, which were the groups with xylene showed significant difference in the dentinal thickness at 5 and 13 mm. Interestingly, Group 3 showed significant difference only at 0 mm.

In conclusion, H-files and Protaper Universal Retreatment files (with or without xylene) were effective in the removal of the obturating material. However, ProTaper Universal Retreatment system without xylene, showed the least amount of changes in dentinal thickness.

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Introduction

The success of root canal therapy relies on thorough cleaning, shaping and complete sealing of the root canal space[1,2]. Successful endodontic therapy has classically been based on fulfilling the criteria of reducing or eliminating apical lesions and ensuring absence of clinical symptoms[3]. The outcome of endodontic treatment is dependent on the technical quality of the endodontic filling. Well filled and condensed gutta percha are expected to provide an overall three dimensional seal against the ingress of microorganisms[4]. Under controlled clinical conditions, the average percentage of success of primary root canal treatment in the absence of preoperative apical periodontitis is about 90%[5]. In cases where there was preoperative apical periodontitis during root canal treatment, the percentage of favourable outcome drops to about 75% - 85%[6].

Despite recent advances in endodontics, the goal of treatment is not always achieved and infection may be persistent or even reoccur after treatment[7]. Persistent intra-radicular, and in some instances presence of extra-radicular infections are the major causative factors of failure of poorly treated and well-treated root canals[8].

Recently, there is a growing interest in the area of endodontic retreatment. This is due to the increasing awareness and demand to preserve the existing dentition, including those

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cases where endodontic therapy has failed[9]. Orthograde retreatment, compared to other modes of treatment is one of the best approaches in management of endodontic failures with a success rate of 74 to 98%[10,11]. This procedure involves retrieval of the endodontic filling materials, further meticulous cleaning and shaping, and obturating again[9]. Safe and efficient removal of endodontic filling material from the root canal systems is extremely vital for the success of the treatment[6]. Although the outcome of these retreatments is favourable, it was often associated with a lower healing rate than the primary root canal treatment[12]. Procedural errors during root canal retreatment like perforations, excessive dentinal removal and insufficient root filling length were shown to be the most important factors to influence the outcome, as well as presence of periapical lesion and good coronal seal[13]. Fenoul et al.[14] in 2010 stated that the efficient and complete removal of the filling material from the root canal system is pivotal to ensure a favourable outcome when orthograde retreatment is indicated. However, researchers have reported that complete removal of gutta percha and sealer from the root canal system could be considered difficult or nearly impossible[15].

Rotary nickel-titanium (NiTi) instruments such as ProTaper Universal Retreatment system (Dentsply Maillefer, Ballaigues, Switzerland) and R- Endo systems (Micro-Mega, Besancon, France) are widely used for endodontic retreatment[16]. Stainless steel files such as H and K-files are also being used to remove gutta percha in retreatment cases. There are numerous studies conducted to determine the best technique to remove gutta percha and sealers in retreatment cases. According to Kasam et al.[17], retreatment done using ultrasonic retreatment tip proved to be the most effective and efficient followed by ProTaper Rotary Retreatment files and H-files. Xylene is a commonly used solvent in cases of retreatment as it has the ability to dissolve the gutta percha slowly. Softening and mechanical removal of gutta percha rather than dissolving is considered to be an efficient and a biologically safe procedure in retreatment cases[18].

The ProTaper Universal Retreatment System consists of 3 instruments: D1 with tip 30 and taper 0.09, D2 with tip 25 and taper 0.08, and D3 with tip 20 and taper 0.07[19]. The lengths of these retreatment files are 16 mm for D1 files, D2 files were 18mm and D3 files were 22 mm. It must be emphasized here that the retreatment files have a convex cross section which can effectively penetrate into the gutta percha and enable efficient removal with the sealer[20].

Although specifically developed for endodontic retreatment, there are a number of studies that have concluded that rotary instruments show the same efficacy as hand files, but with shorter working time (Saad et al., 2007)[11]. Patil et al.[21] in 2018 stated that there were no statistically significant difference while comparing the amount of remnants of filling material in the canals after using hand files and rotary retreatment files. Fariniuk et al.[22] further reported that none of the techniques were effective in removing all the obturating materials from the canals.

Furthermore, the effect on the surrounding dentin when using these files have not been studied in detail. Increased dentinal removal with the use of rotary instruments during retreatment was an important concern[23].

Tomer et al.[24] in 2017 reported that strip perforation, ledges and vertical root fractures are possible consequences of excessive removal of radicular dentin. Bier et al.[25] stated that root canal preparation with rotary NiTi instruments can damage the dentin and create defects on the root canal walls. They further added that undertaking procedures for an endodontic retreatment will increase the number of defects. Therefore it is necessary to preserve the walls of the dentin during retreatment to enhance the success and longevity of the tooth.

Although the effectiveness of different techniques in the removal of endodontic filling material from tooth in root canal retreatment has been studied, there are no established reports to ascertain which technique is most conservative in preserving the radicular dentin. Therefore, the aim of this study is to determine which technique of retreatment removes lesser amount of radicular dentin in root canal retreatment. The above aim will be accomplished by fulfilling the following research objectives, namely to; a) determine the dentinal thickness after using rotary retreatment files with and without solvent, b) compare the difference in the remaining dentinal thickness before and after retreatment using different techniques and c) assess which retreatment technique conserves the radicular

dentin.

Materials and methods

This in an ex- vivo study which compares the remaining dentinal thickness (using CBCT images) in monoradicular root canal treated teeth and subsequently after appropriate retrieval of gutta percha and sealer. The inclusion criteria included extracted teeth with single root canal and fully formed apex, absence of any visible root caries, fractures or cracks. Teeth were excluded when they had caries or pathological root resorption (internal or external resorption). The materials used in this study are listed in Table 1.

Materials	Size	Manufacturers	Lot No
K-files	Size 10 and 15	Dentsply Maillefer Ballaigues, Switzerland	H100344600
Headstrom files	Size 20,25 and 30	Dentsply Maillefer Ballaigues, Switzerland	1479118 1502395
Gates Glidden	Size 2 and 3	Dentsply Maillefer Ballaigues, Switzerland	P15H091800
ProTaper Next	Size X1, X2, X3	Dentsply Maillefer Ballaigues, Switzerland	1394048
Paper points		Dentsply Maillefer Ballaigues, Switzerland	011018
ProTaper Universal Retreatment Files	Size D1, D2, D3	Dentsply Maillefer Ballaigues, Switzerland	1577994
Gutta Percha	Size X3	Dentsply Maillefer Ballaigues, Switzerland	010718
AH Plus		Dentsply DeTrey, Konstanz, Germany	1807000288
Xylene		Nippon Shika Yakuhin Co. Ltd, Japan	0120-8020-96
Kalzinol		Dentsply Sirona, Germany	1803000131
Sodium Hypochlorite		Dentsply Maillefer Ballaigues, Switzerland	
Ethylenediaminetetraacetic acid (EDTA)		DiaPrep Pro, DiaDent Europe S.V, Korea	DPP1801231
Saline		Braun, Melsungen, Germany	183968001
Splitting Disc		Kerr Corporation, California, America	
Modelling Wax		Metrowax, Metrodent Limited, England	1WAX500

Table 1. Materials used in this study.

Sample selection and preparation

All twenty samples used in this study were freshly extracted maxillary central incisors. The extracted teeth were washed under running water and gentle scrubbing to remove any attached tissue and then they were stored in normal saline at room temperature. Calculus was mechanically removed from the root surfaces using ultrasonic scaler to ensure they did not hinder in our measurements. The teeth were then immersed for 15 minutes in 5.25% sodium hypochlorite for disinfection. The crowns of the teeth were decoronated at the level of cemento-enamel junction (CEJ) using a splitting disc with copious coolant (Figure 1a).

All roots were standardized to have a uniform 15 mm length from the apex. The working length determination was done by introducing size 15 K-file into the canal until it exited from the apex and the apical patency was confirmed; this length was measured, and the working length (WL) was set till the anatomic apex.

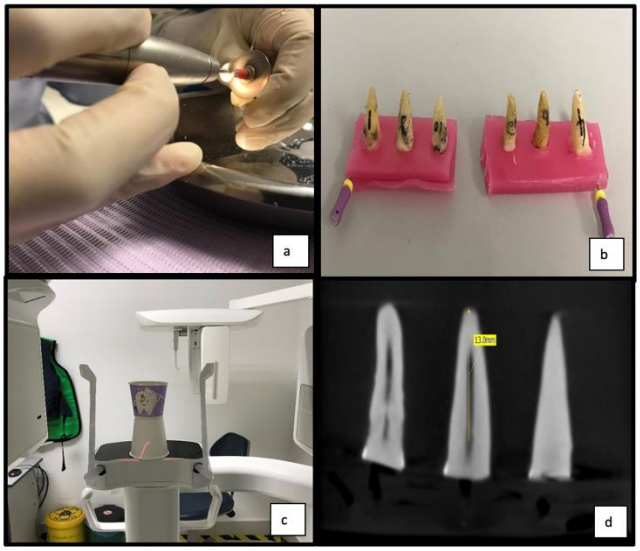

Figure 1. a) Sectioning of tooth at the cemento-enamel junction using a disc. **b)** Mounting of teeth on wax block (after cleaning and shaping) prior to scanning with CBCT. **c)** Mounted samples to be scanned using the CBCT machine. **d)** The measuring of the vertical distance from tooth apex using an orthogonal view from CBCT scans.

Root canal filling

Samples were mounted on wax blocks before starting cleaning and shaping. Cleaning and shaping was done in all teeth using ProTaper Next (X1,X2,X3) (Dentsply Maillefer, Ballaigues,Switzerland) using crown down technique with torque of 2.5 Nm^{-1} and 300 rpm. During root canal instrumentation, the canals were irrigated between each successive instruments with 2.5 mL of 5.25% sodium

hypochlorite(NaOCL). A final flush was done with 2 mL of 17% EDTA solution for 30 seconds followed by a rinse with 5 mL or saline solution. The canals were then dried with paper points. The samples were mounted on wax blocks, 3 teeth per wax block (Figure 1b). The wax block was then placed in a paper cup, stabilized on the CBCT machine's chin rest and the scans were taken (Figure 1c). Seven wax blocks were made to accommodate 20 teeth. The CBCT EzDent-Vatech Imaging Systems (Korea) was set at parameters of 90 kV and 4.5 mA with the smallest voxel size of 0.125 mm with a field-of-view (FOV) 5cm x 5cm throughout the whole imaging procedure. Measurement of the dentinal thickness was taken from apical to coronal at 0 mm, 5 mm, 10 mm and 13 mm from the axial views (Figure 1d and Figure 2a).

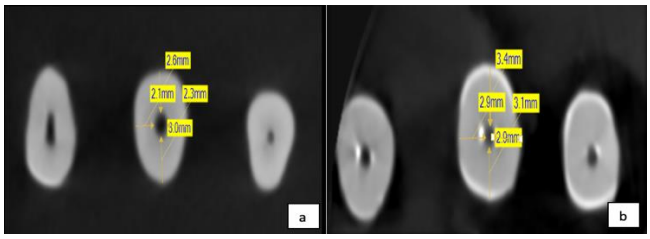

Figure 2. a) Measurement of dentinal thickness from axial view/section from corresponding distance from apex. **b)** Measurement taken from axial view after retreatment of the same section. Dentinal thickness was measured from buccal, palatal, mesial and distal to the canal space.

AH plus sealer was mixed and coated around the root canal walls with a size 10-k file. The corresponding X3 gutta percha (Dentsply Maillefer, Ballaigues,Switzerland) was slightly coated with AH plus sealer and positioned in the root canal. The gutta percha cones were seared off with the use of a heated instrument. A plugger was then used to vertically compact the gutta-percha. Images of all 20 samples were then captured again using CBCT to assess the adequacy of the obturation. The teeth were then sealed with Kalzinol (Dentsply Sirona, Germany), a temporary restorative material. After two weeks, teeth were randomly divided into four groups of five samples each. The temporary filling material was removed with scaler.

Grouping and Retreatment

Specimens were randomly distributed into 4 groups (n=5) according to retreatment techniques.

Group 1 : Hedstrom file without xylene
Group 2 : Hedstrom file with xylene
Group 3 : ProTaper Universal Retreatment system without xylene
Group 4 : ProTaper Universal Retreatment system with xylene

In Group 1, root canal retreatment was done using Hedstrom or H-files (Dentsply Maillefer, Ballaigues,Switzerland), size 20, 25, and 30. Hand instrumentation was done using a circumferential quarter turn push pull motion in order to remove the endodontic filling material. The criteria used for assessment of removal of the filling material were the absence of gutta percha and sealer on the H-file that was used last. Each instrument was only used for five samples and then discarded. If any deformation or fracture was seen on the file, the instrument was discarded.

In Group 2, Gates Glidden burs size 2 and 3 were used to remove 3 mm of endodontic material from the cervical part of the canal creating a reservoir. This step allows access to the more apical portions of canals and it provides a vessel for the placement of the xylene. Two drops of xylene were then place to soften the gutta-percha. Hand instrumentation was performed with Hedstrom files 20, 25, and 30 in a circumferential quarter turn push pull motion. Two drops of xylene were then placed into the canal until the file reaches the working length. The criteria used for assessment of removal of the filling material were the absence of gutta percha and sealer on the H-file that was used last. Similar to Group 1, each instrument was only used for five samples and then discarded.

In Group 3, ProTaper Universal Retreatment files were used based on manufacturer's instructions, together with a rotary electric motor. The canals were instrumented using crown down technique, starting with D1 file to remove the coronal filling material. Then, ProTaper D2 was used for removal of gutta percha and sealer from middle third of the canal and D3 subsequently used at the apical third of canal. The retreatment files were used at 300 rpm and torque of 2 Nm^{-1}. The files were used with brushing action together with lateral pressing movements. ProTaper D3 was taken up to the determined working length. The criteria used for assessment of removal of the filling material were the absence of gutta-percha and sealer on the last file used which is the D3

file. Again, the set of D1, D2 and D3 instrument were only used for five samples (maximum) and the discarded.

In Group 4, ProTaper Universal Retreatment instrument was used together with xylene as solvent. D1 ProTaper file was used to remove the endodontic material 3 mm from the coronal part of tooth. Two drops of xylene were placed in the reservoir created and then instrumentation with D2 and D3 files were done in the corresponding middle and apical third of the root canal. The retreatment files were used at 300 rpm and torque of 2 Nm^{-1}. Brushing action employed with lateral pressing movements were used during instrumentations to remove gutta-percha from the walls. Similarly, the criteria used for assessment of removal of the filling material were the absence of gutta-percha and sealer on the last file used which is the D3 file and files were then discarded.

Retreatment was deemed complete when the last file of all four groups reached the working length and when there was no filling material coated around the files. All root canals were irrigated at each change of instrument with 2 mL of 5.25% sodium hypochlorite using an endodontic syringe and also a final flush with 5mL of saline solution. This was to ensure a clean, debris free canal. Complete removal of gutta-percha and sealer was also assessed from scanned CBCT images.

Once the retreatment was done for all samples, they were scanned employing the CBCT again. The teeth were mounted on the exact same wax block at the same position and placed into a paper cup for stabilization prior taking the scan. The dentinal thickness was then measured, from the axial views of CBCT images at 0 mm, 5 mm, 10 mm and 13 mm from the apex (Figure 2b). Measurements included the amount of dentin remaining on mesial, distal, labial and palatal side of the canal. The differences obtained in the remaining dentinal thickness were then calculated, tabulated and analysed.

Statistical analysis

Data entry and analysis was performed by using SPSS version 25.0. Initially the intra-rater reliability test was done and intraclass correlation (ICC) showed good agreement between the two readings obtained from the pilot study (ICC=0.7). The distribution of data was reported as Mean, SD and Median (IQR). The pre and post changes in the remaining dentinal thickness within each group were analysed using Wilcoxon Signed Rank test due to normality assumption violated. Kruskal-Wallis test was used to compare pre and post-instrumentations between the groups. Any variable with *p*-value less than 0.05 was considered to have significant difference.

Results

Distance	Group	Pre (Mean ± SD) Median (Interquartile Range)	Post (Mean ± SD) Median (Interquartile Range)	*p* -value*
0 mm	1(*n*=5)	0.99 ± 0.21 0.95(0.31)	0.93 ± 0.19 0.88(0.33)	0.042
	2(*n*=5)	1.01±0.24 0.98(0.30)	0.98 ± 0.26 0.93(0.34)	0.416
	3(*n*=5)	0.81 ± 0.20 0.68(0.38)	0.73 ± 0.14 0.65(0.26)	0.042
	4(*n*=5)	0.81 ± 0.11 0.85(0.16)	0.73 ± 0.12 0.70(0.23)	0.066
5 mm	1(*n*=5)	1.87 ± 0.21 1.85(0.41)	1.80± 0.21 1.78(0.41)	0.038
	2(*n*=5)	1.83 ± 0.25 1.88(0.48)	1.74± 0.26 1.78(0.45)	0.042
	3(*n*=5)	1.31 ± 0.44 1.38(0.78)	1.24 ± 0.36 1.35(0.63)	0.068
	4(*n*=5)	2.01± 0.22 2.08(0.38)	1.94 ± 0.21 2.00(0.35)	0.038
10 mm	1(*n*=5)	2.28 ± 0.33 2.20(0.60)	2.18 ± 0.33 2.08(0.59)	0.390
	2(*n*=5)	2.18 ± 0.33 2.0(0.61)	2.10 ± 2.60 2.00(0.46)	0.109
	3(*n*=5)	1.79 ± 0.50 1.95(0.94)	1.74 ± 0.50 1.88(0.92)	0.066
	4(*n*=5)	2.39 ± 0.12 2.43(0.20)	2.33 ± 0.13 2.33(0.25)	0.066
13 mm	1(*n*=5)	2.45 ± 0.40 2.33(0.74)	2.37 ± 0.39 2.25(0.69)	0.066
	2(*n*=5)	2.31 ± 0.23 2.18(0.38)	2.15 ± 0.27 2.03(0.38)	0.043
	3(*n*=5)	2.26 ± 0.27 2.15(0.51)	2.20 ± 0.28 2.15(0.52)	0.068
	4(*n*=5)	2.52 ± 0.24 2.45(0.46)	2.48 ± 0.24 2.40(0.46)	0.038

Table 2. Pre and post difference of the dentinal thickness between groups (*n*=20).
***Wilcoxon Signed Rank Test**
Group 1 : Hedstrom file without xylene.
Group 2 : Hedstrom file with xylene.
Group 3 : ProTaper Universal Retreatment system without xylene.
Group 4 : ProTaper Universal Retreatment system with xylene.

The axial cross section view of tooth from CBCT was used to determine the dentinal thickness at 0 mm, 5 mm, 10 mm and 13 mm from the apex of tooth. The average of three readings of the buccal, palatal, mesial and distal were taken for each tooth and for each cross section for measurement. At 0 mm, the *p*-value

in the group Hedstrom file without xylene (Group 1) was 0.042 which concludes that there was a significant difference between pre and post retreatment. ProTaper Universal Retreatment system without xylene (Group 3) had a *p*-value of 0.042 which also showed significant difference between pre and post retreatment. Hedstrom file with xylene (Group 2) and ProTaper Universal Retreatment system with xylene (Group 4) had *p*-values of 0.416 and 0.066 respectively at 0 mm and therefore no significance difference between pre and post retreatment. At 5 mm, a significant reduction was seen between the median values of pre and post retreatment in Group 1, Group 2 and Group 4 with their respective *p*-value being 0.038, 0.042, 0.038. Group 3 on the other hand showed no statistically significant difference between pre and post retreatment (*p*=0.068). In addition, at 10 mm no significant difference between all the four groups was noticed (*p*>0.05).

Distance	Group	Mean ± Standard Deviation	*p*-value
0 mm	1(*n*=5)	0.07 ± 0.45	0.739
	2(*n*=5)	0.03 ± 0.09	
	3(*n*=5)	0.08 ± 0.07	
	4(*n*=5)	0.08 ± 0.09	
5 mm	1(*n*=5)	0.07 ± 0.01	0.935
	2(*n*=5)	0.09 ± 0.08	
	3(*n*=5)	0.07 ± 0.12	
	4(*n*=5)	0.07 ± 0.01	
10 mm	1(*n*=5)	0.10 ± 0.02	0.516
	2(*n*=5)	0.08 ± 0.10	
	3(*n*=5)	0.04 ± 0.04	
	4(*n*=5)	0.06 ± 0.06	
13 mm	1(*n*=5)	0.09 ± 0.05	0.089
	2(*n*=5)	0.16 ± 0.13	
	3(*n*=5)	0.06 ± 0.06	
	4(*n*=5)	0.04 ± 0.01	

Table 3. The comparison of changes of pre and post retreatment between groups based on each of distance (n=20).
***Kruskal-Wallis test**
Group 1 : Hedstrom file without xylene.
Group 2 : Hedstrom file with xylene.
Group 3 : ProTaper Universal Retreatment system without xylene.
Group 4 : ProTaper Universal Retreatment system with xylene.

At 13 mm, there was a significant difference between the median of pre and post instrumentation in Group 2 (from 2.18 to 2.03) and Group 4 (from 2.45 to 2.40). Group 1 had a p-value of 0.066 and Group 3 had a *p*-value of 0.068 which showed that there was no significant difference between the pre and post retreatment (Table 2).

Further analysis was applied to see the mean difference of changes from pre and post retreatment between the four groups at each distance of 0 mm, 5 mm, 10 mm and 13 mm. Evidently, there was no significant difference between the four groups that were studied (*p*=0.488) but there was small amount of changes within each groups (Table 3).

Discussion

Nonsurgical endodontic retreatment is usually done in an attempt to re-establish healthy periapical tissue after inefficient treatment or reinfection of tooth due to apical or coronal leakage[26]. The successful removal of gutta percha and the coated sealer is vital to enhance the success of retreatment. However, the complete removal of these filling materials appears to be a challenge for dentists[27]. At times, applying excessive pressure to remove the filling material can lead to the removal of healthy dentinal wall. To minimize this, it is essential to determine the best method of retrieval of gutta percha and the sealer from the canal system. The commonly used techniques for retreatment are conventional method using hand files (K-files or H-files), rotary instruments made of nickel-titanium (NiTi), ultrasonics, lasers as well as chemicals like chloroform[28]. However, the current trend is the use of nickel-titanium rotary instruments and sometimes with the aid of hand files with or without solvents to remove the filling materials[29]. The rotary instruments have superseded the use of hand files in root canal retreatment. The general advantages of rotary instruments are the ability to maintain the canal shape without causing deformation and significantly shorter working time compared to conventional methods[30]. However, there are studies which have reported high incidence of instrument separation when using rotary instruments compared to hand files[31]. In order to overcome this, rotary retreatment files are

designed with non-cutting tips, radial lands, varying tapers and rake angles, and changing pitch length[32]. This has led to fewer incidence of perforations, blockages and ledge formation during retreatment[33]. One of the currently used NiTi rotary instruments are the ProTaper Universal Retreatment system.

Solvents have been used in endodontic retreatment for a long time and the dissolving effect has been proven to be effective[34]. Karataş e al.[35] reported that chloroform, eucalyptol and orange oil are commonly used solvents for endodontic retreatment. Whereas others reported numerous studies available to support the efficacy of solvents in softening gutta-percha but limited studies are available to determine the dissolving capabilities of solvents on root canal sealer[36]. Xylene (dimethylbenzene) is an aromatic compound which has been considered as an effective solvent for root canal filling material. It is believed that the toxicity of xylene is considered to be inferior to benzene and chloroform[37]. A recent study in 2016 reported that xylene was most effective in dissolving root canal sealers compared to other organic solvents[38] and this was followed in this study.

Cone Beam Computed Tomography (CBCT) is a diagnostic imaging modality that allows multi-plane visualization of scanned anatomical structures of any section of the human body[39]. The use of CBCT is increasingly popular because of its higher diagnostic yield, especially in the field of endodontics[40]. CBCT is generally used to detect and visualise the morphology and number of root canals as well as diagnose periapical lesions in endodontics[41]. However, its use in determination of dentinal thickness has not been extensively studied. According to Xu et al.(2017)[42], they reported that CBCT imaging can be used to assess radicular dentin wall thickness. Therefore, CBCT images was used as a reliable mode of assessment of the remaining dentinal thickness after retreatment in this study.

Under the experimental conditions, there were some significant amount of changes in the dentinal thickness between post root canal treatment and post retreatment in few groups at different distance from the apex. It was noticed that Group 1 (Hedstrom without xylene) had the most amount of changes at the apical third of root (0 and 5mm). In Group 2 (Hedstrom with xylene) and Group 4 (ProTaper Universal Retreatment with xylene), similar changes were noticed at the apical region (5 mm) but the other change was noticed at the coronal section (13 mm). In Group 3 (ProTaper Universal Retreatment system without xylene), changes were noticed at 0 mm only. This shows that obvious dimensional changes in the radicular dentin were at the apical third of most groups and ProTaper Universal Retreatment group – Group 3 had the least removal of dentinal tissues.

However, statistical interpretation of the overall changes in dimension of dentinal thickness for all four groups appeared to be insignificant. This shows that both hand files and ProTaper Universal Retreatment files are effective in removal of most of the gutta percha and sealer without removing much of healthy radicular dentin. From the findings, it was evident that both instrumentation techniques were effective in removal of most of the root canal filling materials.

The limitations of this study were the images produced by the CBCT machine did not appear very clear, possibly due to excessive use of this machine. This may have affected the accuracy of the results produced. For further research, the sample size needs to be increased and Micro-CT scanning of the in-vitro teeth (gold standard of imaging in endodontics) should be performed. Thereafter, the scanned data can be imported into a third party software (eg. MIMICS) and 3-dimensional visualisation of the pulpal cavity carried out[43]. The images will then aid in identifying and detailing dentinal defects-ledges or perforations which were created during the retreatment procedures.

Conclusions

The findings indicate that both Hedstrom files and Protaper Universal Retreatment files, (with or without xylene) were efficient in removal of the obturating material in root canal retreatment. However, ProTaper Universal Retreatment system without xylene showed the least amount of changes in dentinal thickness when comparing pre and post retreatment. The ProTaper Universal Retreatment system is therefore effective and least invasive to the radicular dentin in root canal retreatment.

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Declaration of Interest

The authors have no conflict of interest to declare.

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