Efficiency and complications in root canal retreatment using nickel titanium rotary file with continuous rotation, reciprocating, or adaptive motion in curved root canals: A laboratory investigation

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Research Article

Keywords: Gutta percha, root canal filling removal, broken instrument, perforation, NiTi rotary file, Micro-Computed Tomography

Posted Date: July 28th, 2023

DOI: https://doi.org/10.21203/rs.3.rs-3152407/v1

Abstract

Objectives

Study compared efficacy, efficiency, and complications of curved root canal retreatment using single-use NiTi rotary files with different motions.

Materials and Methods

Forty mesial curved root canals of extracted mandibular molars, obturated with gutta-percha and AH Plus sealer, were randomly divided into four groups. Reciproc blue R25 was used with reciprocating motion (RB), VDW.ROTATE retreatment files with continuous rotation (VR), and ProTaper Next X2 with continuous rotation (X2c) or adaptive motion (X2a). The percentage of root canal filling removal was analyzed using Micro-Computed Tomography. The retreatment time and complications were recorded and statistically analyzed (p-value < 0.05).

Results

The study found a statistically significant difference in the percentage of root canal filling removal between the X2c and VR groups in both the whole canal and apical-third. Additionally, VR demonstrated a shorter retreatment time compared to RB and X2a. Instrument fracture occurred in 40% of the VR group and 20% of the X2a group.

Conclusions

X2 (continuous rotation) and RB files are highly effective and efficient for curved root canal retreatment. Continuous rotation is more efficacious and efficient than adaptive motion with NiTi rotary files.

Clinical Relevance

Single-file retreatment is highly efficacious, cost-effective, and time-efficient in small curved canals.

Introduction

Variations in methodologies across studies contribute to differences in reported efficacy and efficiency of NiTi rotary systems. Evaluations encompass root canal wall complications, NiTi rotary file complications, cleanliness, and time consumption. Prior studies often reused files, potentially impacting their true efficacy and efficiency due to stress accumulation during retreatment [1–3].

Studies comparing the different file motions have generated disparate results. Some studies found similar efficacy and efficiency between using continuous rotation and reciprocating motions in root canal filing removal in curved canals [4–6]. However, other studies found that reciprocating motion significantly removed 2-fold more root canal filling than continuous rotation [7]. Furthermore, another study found that continuous rotation removed more root canal filling and faster than reciprocating motion [8]. Moreover, studies demonstrated that adaptive motion significantly removed 6–10% more root canal filling than continuous rotation [9, 10]. However, rotary files using adaptive motion failed to retain their original shape, including 50% deformation and 50% fracture [11].

It is currently unknown whether Twisted file adaptive (TF adaptive) files or adaptive motion leads to instrument complications during retreatment. Furthermore, there has been no report comparing the three motions in curved root canal retreatment using rotary files. Therefore, the efficacy of which NiTi rotary file motion can retreat a curved root canal without root canal or rotary file complications is currently unknown.

The aim of this experimental study was to compare the efficacy, efficiency, and complications of single-use NiTi rotary files using continuous rotation, reciprocating, and adaptive motions in root canal filling removal in curved root canals. The null hypotheses of this study are that there is no significant difference in the percentage of root canal filling removal, time consumed and rotary file or root canal wall complications during curved root canal retreatment between these instruments using different motions.

Materials and Methods

This experimental study was approved by the Ethics Committee.

Sample collection

The sample size calculation was based on Crozeta BM. 2016 [10], using the G*Power 3.1 program with a type I error of 0.05 and 0.8 power. The calculation indicated that an adequate sample size was 40 canals (10 per test group). Freshly twenty extracted mandibular first and second molars with separate mesial root canals (type IV Vertucci's classification) [12] with curvatures between 20°–40° and a radius of curvature between 5–10 mm were included. The inclusion criteria were teeth without prior endodontic treatment, without calcification, no resorption, closed apex, no root caries, and no cracks. Buccolingual and mesiodistal radiographs were used to determine the root canal curvature.

Specimen preparation

The specimens were prepared by the single operator (B.T.) from decoronation to root canal obturation. The tooth crown was removed using a round-ended taper diamond bur to obtain a standard root length of 13 mm. Teeth with an initial apical file greater than 25 were excluded from the experiment. The specimens were then shaped with ProTaper NEXT X1 (tip size 17; variable taper; Dentsply Maillefer) followed by ProTaper NEXT X2 (tip size 25; variable taper; Dentsply Maillefer) rotary files at 300 rpm and 2.5 Ncm torque. Final irrigation was conducted with 10 ml 17% ethylenediamine tetraacetic acid (EDTA) followed by 10 ml 2.5% NaOCl. The canals were dried with paper points.

The dried canals were obturated with ProTaper NEXT X2 matched cones (Dentsply Maillefer) and AH Plus, epoxy resin-based sealer (Dentsply Maillefer) using the continuous wave of condensation technique. After down-packing the gutta percha using Fast-Pack PRO (Eighteeth, Changzhou, China) to 5 mm from the working length, the canal was backfilled with warm regular gutta-percha (Eighteeth) to the canal orifice using Fast Fill (Eighteeth) and BL-S Kondenser (B&L Biotech, Fairfax, VA, USA). After obturation, the specimens were radiographed to determine the root canal filling quality and re-calculate the root canal curvatures.

Pre-Micro-Computed Tomography (µCT) analysis of the root canal filling volume

To measure the root canal filling volume, the specimens were scanned using a Micro-CT scanner 35 SCANCO MEDICAL (CH-8306 Bruettisellen, Switzerland) using µCT Tomography V.6.4 software, voxel size 18.5 µm, 231 slices, 70 kVp, 114 µA, and 8 W. µCT Tomography V 6.6 software was used to determine the root canal filling volume.

Root canal retreatment

The prepared specimens were randomly divided into four experimental groups according to the rotary file system and motion used (n = 10). The root canal retreatment was done using a dental operating microscope (DOM) (Zeiss, Munich, Germany) by the single operator (S.K.), an 8-years' experienced endodontist. The coronal 3 mm of the root canal filling was removed by a no.3 Gates-Glidden drill (Kerr Dental, Orange, CA). After the Gates-Glidden drill created the path, the rotary file was used for penetrating and removing the root canal filling.

Group 1

Reciproc® *Blue* system (RB)

The retreatment procedure was performed with the Reciproc Blue R25 files (tip size 25; variable taper; VDW, Munich, Germany) using the Endodontics motor X-SMART IQ™ (Dentsply Maillefer) set in reciprocating mode. The instrument was advanced apically using an in-and-out pecking motion with an amplitude of approximately 3 mm. Gentle apical pressure was applied with a brushing action against the lateral walls according to the manufacturer's instructions. After every three pecking motions, the instrument was removed from the canal and cleaned with sterile gauze.

Group 2

VDW.ROTATE retreatment system (VR)

The retreatment procedure was performed with the VDW.ROTATE retreatment files (tip size 25; 5% taper; VDW) using the Endodontics motor X-SMART IQ™ set in continuous rotation mode at 500 rpm and 3.5 Ncm torque. The retreatment technique was the same as that described for Group 1.

Group 3

ProTaper Next® X2 continuous rotaion (X2c)

The retreatment procedure was performed with the X2 files (tip size 25; variable taper) using the Endodontics motor X-SMART IQ™ (Dentsply Maillefer) set in continuous mode at 500 rpm and 3.5 Ncm torque. The retreatment technique was the same as that described for Group 1.

Group 4

ProTaper Next® X2 adaptive motion (X2a)

The retreatment procedure was performed with the X2 files using the Endodontics Elements Motor (SybronEndo, Glendora, CA) set in adaptive mode. The retreatment technique was the same as that described for Group 1.

In all groups, after the NiTi rotary file reached the working length and the time was recorded, the operator (S.K.) continued using the file to completely remove the root canal filling until the root canal was clean as seen using the DOM and no filling material was observed on the instrument flutes. If the file was deformed at any stage of the root canal retreatment, the retreatment procedure continued until the working length was reached and root canal was clean as seen using the DOM and no filling material was observed on the instrument flutes or until the file was broken. The specimens with broken files were not included in the Post-Micro-CT analysis, because the remaining root canal filling volume was assumed to be overestimated in these specimens.

Each NiTi rotary file was used only once for each canal. When the retreatment procedure was completed, the canals were irrigated with 10 ml 2.5% NaOCl and then dried with paper points. The total time and motor running time were recorded by The DENTSPLY ENDO iQ Application in groups 1–3, or by a digital clock in group 4. The total time included the motor running time, file cleaning time, and irrigation time.

Post-Micro-Computed Tomography (µCT) analysis of the root canal filling volume and data collection

To measure the root canal filling volume after the retreatment procedures, the specimens were scanned by a Micro-CT scanner 35 SCANCO MEDICAL (CH-8306 Bruettisellen, Switzerland) using the same parameters as in the Pre-Micro-CT analysis.

During the Post-Micro-CT analysis, the operator (B.T.) knew the specimen number, but not which type of NiTi rotary file was used. The Micro-CT volumes measurements before and after the retreatment procedures were conducted by the same operator and the volumes were evaluated twice to determine the intraobserver reliability, using the intraclass correlation coefficient (ICC) [13]. The observer re-evaluated 20% randomly selected root canal filling volumes at least 1 week later.

The root canal complications (ledge or perforation) and instrument complications (deformation or separation) during the retreatment procedures were collected. All rotary files used in the experiment were inspected under DOM and captured. The percentage of root canal filling removal between each area of each specimen was calculated. In addition, the retreatment time, i.e., total time and motor running time, were analyzed.

Statistical analyses

The IBM® SPSS® Statistics Version 28 (IBM Corp.©) was used for the statistical analyses. The Shapiro-Wilk test was used to evaluate the normality of the data. If the data had a normal distribution (Shapiro-Wilk, $P > .05$), the difference between groups was compared using One-way ANOVA followed by Bonferroni test. Whereas, if the data had a skewed distribution (Shapiro-Wilk, $P < .05$), the difference between groups was compared using the Kruskal-Wallis test followed by Dunn's test. P values less than 0.05 were considered significant for all tests.

Results

The pre-operative canal characteristics between the groups were analyzed. The mean values of the angle and radius of curvature in the mesio-distal and bucco-lingual aspects were similar between the groups (Table 1). Moreover, the mean pre-operative root canal filling volume was similar between groups. The intraobserver reliability based on an ICC of 0.99 indicated excellent reliability [13].

Table 1
The mean values of angle and radius of root canal curvature of each group.

	Mean angle of curvature of samples		**Mean radius of curvature of samples**	
	Mesio -Distal^{A}	**Bucco - Lingual^{A}**	**Mesio -Distal^{A}**	**Bucco - Lingual^{B}**
Group 1 (RB)	21.95 ± 2.36	9.40 ± 6.70	7.71 ± 1.46	10.88 ± 5.41
Group 2 (VR)	22.15 ± 2.26	9.80 ± 7.71	7.96 ± 0.90	11.23 ± 6.19
Group 3 (X2c)	22.25 ± 1.84	8.30 ± 7.38	7.83 ± 1.61	11.74 ± 6.01
Group 4 (X2a)	22.05 ± 1.98	8.10 ± 6.92	7.60 ± 1.23	12.24 ± 5.64
^{A}From the ANOVA test ($p < 0.05$)				
^{B}From the Kruskal-Wallis test ($p < 0.05$)				

In the whole canal analysis, a significant difference of percentage of root canal filling removal was found between the X2c and VR groups ($p = 0.006$). The coronal- and middle-third analyses demonstrated that the percentage of root canal filling removal was similar between groups. In apical-third analysis, significant difference was again found between the X2c and VR groups ($p = 0.004$) (Table 2).

Table 2
The mean percentage of root canal filling removal of each group in whole canal, coronal-, middle-, and apical thirds of the root canal.

	Mean percentage of volume reduction			
	Whole canal^{A}	Coronal 1/3^{A}	Middle 1/3^{A}	Apical 1/3^{A}
Group 1 (RB)	96.93 ± 1.52^{a}	97.98 ± 1.66^{b}	97.66 ± 2.60^{c}	90.43 ± 9.18^{abc}
Group 2 (VR)	93.14 ± 4.86^{ay}	98.45 ± 1.21^{b}	97.43 ± 2.64^{c}	56.32 ± 35.31^{abcz}
Group 3 (X2c)	98.51 ± 0.95^{ay}	99.03 ± 0.70^{b}	99.69 ± 0.43^{c}	93.22 ± 7.39^{abcz}
Group 4 (X2a)	95.89 ± 3.70^{a}	98.14 ± 2.34^{b}	97.45 ± 3.22^{c}	80.04 ± 21.63^{abc}
^{A}From the ANOVA test followed by Bonferroni test ($p < 0.05$)				
Same superscript lowercase letters indicate a significant difference between groups (^{abc} for rows and ^{yz} for columns)				
Sample with broken rotary files not included.				

The motor running time and total time until reaching the working length and until complete removal using a DOM in the VR group was significantly shorter compared with the RB and X2a groups ($p < 0.001$) (Table 3). In addition, the total time until reaching the working length, and until complete removal in the X2c group was significantly shorter compared with the X2a group ($p < 0.001$) (Table 3).

Table 3
The mean total time and motor running time in retreatment procedure of each group.

	Mean total time		Mean motor running time	
	Reach WL^{A} (sec)	Complete removal under DOM^{A} (sec)	Reach WL^{A} (sec)	Complete removal under DOM^{A} (sec)
Group 1 (RB)	117.20 ± 26.25^{a}	256.00 ± 84.01^{a}	62.00 ± 14.41^{a}	91.20 ± 20.68^{a}
Group 2 (VR)	$24.50 \pm 10.29^{a,b}$	$89.17 \pm 54.97^{a,b}$	$14.33 \pm 6.44^{a,b}$	$30.00 \pm 11.90^{a,b}$
Group 3 (X2c)	72.90 ± 28.82^{c}	139.20 ± 56.84^{c}	35.90 ± 12.85	62.00 ± 14.29
Group 4 (X2a)	$154.88 \pm 64.93^{b,c}$	$297.75 \pm 127.22^{b,c}$	63.63 ± 19.53^{b}	97.00 ± 29.43^{b}
^{A}From the ANOVA test followed by Bonferroni test ($p < 0.05$)				
Same superscript lowercase letters indicate a significant difference between groups				
Sample with broken rotary files not included.				

During the retreatment procedure, the maximum torque was not reached, and root canal complications were not observed in any specimen. However, instrument complications were observed in the VR and X2a groups, but none in RB and X2c groups. In the VR group, 30% of the instruments were deformed and 40% of the instruments were deformed and separated. Moreover, 20% of the instruments had deformations and 20% of the instruments had deformations and separations in the X2a group (Fig. 1).

Discussion

The present study found that the percentage of root canal filling removal, time consumed, and complications were significantly different between the file groups. Based on these results, the null hypotheses were rejected.

In the present study, the angle of curvature in the original root canals ranged from 21°–29° with a mean of 23.5°. This corresponds to the average angle of curvature in mesial root canals of mandibular molars (23°–27°) [14, 15]. Thus, our specimens can be considered as the typical mesial root canals in mandibular molars that would be encountered in the clinic.

Retreatment in curved root canals studies usually reported the original canal curvature of their specimens. However, a previous study found that the angle of curvature in the root canal was significantly reduced up to 3% after instrumentation [16]. The angle of curvature in the root canals in the present study was also reduced 5.9% after instrumentation. Therefore, the present study reported the angle of curvature in the root canals after instrumentation and obturation that were between 21.95°–22.25° with a mean of 22.1°. The percentages of root canal filling removal in the coronal- and middle-thirds in this study were high at 97–99%. The ratio of the coronal- and middle-third volumes to the whole canal volume was 89%, therefore, the percentage of root canal filling removal in the whole canal ranged from 93–98%. The coronal- and middle-thirds of the curved root canals are usually straight and large, thus the rotary file can operate easily in these thirds. Our findings were higher than previous studies that found that the percentage of root canal filling removal in the coronal- and middle-thirds ranged from 78–96% [4, 17]. The differences might be caused by two factors. First, the previous studies' specimens had a greater mean angle of curvature (35.5°–42.5°). Second, our study inspected the cleanliness of the root canal using a DOM during retreatment. Thus, we encourage the use of a DOM for inspecting the remaining root canal filling after retreatment.

The percentage of root canal filling removal in the apical-third ranged from 56–93% that was 6–42% significantly less than the coronal- and middle-thirds. These findings corresponded to those of previous studies in which the percentage of root canal filling removal in the apical-third was 68–84% [4, 17]. The significant difference in the percentage of root canal filling removal in the apical-third resulted from a 37% difference between the X2c and VR groups. Because the apical part of the curved root canal is usually curved and small. Therefore, the percentage of root canal filling removal in the apical part of the curved root canal can be an indicator for the efficacy of NiTi rotary files and motions.

Many previous studies used motor running time to compare the rotary systems [5, 18, 19]. This is because the motor running time reflects the time that the instrument is active inside the canal. However, the motor running time and total time in the experimental groups ranged from 30–97 sec and 89–297 sec respectively. The specimens required less than 5 min to perform the retreatment procedures, and the differences between the groups might not be clinically meaningful.

The present study found instrument complications in the VR and X2a groups. There were file deformations and separations in VR and X2a groups. The complications in the X2a group were most likely due to the adaptive motion, because there were no file complications in the X2c group.

In mechanical instrumentation, clockwise rotation generates stress in the file as it penetrates the root canal dentin. In contrast, counterclockwise rotation helps release the stress generated in the rotary file. However, during retreatment, clockwise rotation generates stress in the file while it penetrates the root canal filling material and counterclockwise rotation generates additional stress on the other side of the rotary file as it penetrates the root canal filling on the other side. Therefore, reciprocating and adaptive motions have a greater likelihood of instrument fracture due to torsional failure based on their respective motion parameters than continuous rotation [20–22].

This study found no deformation or separation of the X2c and RB files. These results correspond to a previous study that reported no instrument complications in the ProTaper NEXT group [4]. In contrast, a previous study found two ProTaper NEXT X2 fractures during curved canal retreatment. These fractures might have occurred because the rotary file was used in three root canals before being replaced [1].

Our pilot study evaluated a retreatment protocol using TF adaptive files (ML1; tip size 25; 8% taper) in adaptive motion. In that study, the ML1 files were deformed and could not completely remove the root canal filling. Moreover, a previous curved root canal retreatment study reported that 100% of TF adaptive files using adaptive motion had defects after retreatment [11]. Therefore, the ML1 file was excluded from the present study and was replaced with X2 files in adaptive motion.

The strength of the study is that using one file per root canal can indicate the true efficacy and efficiency of the NiTi rotary file. The results from the ProTaper NEXT group using continuous rotation and adaptive motion suggest that using continuous rotation is more efficacious and efficient than adaptive motion in curved root canal retreatment when using the same rotary file system. Single file retreatment using X2c or RB in a small curved root canal can be done with high efficacy, efficiency, and cost-effectiveness.

The limitation of the current study was that the cleanliness of the retreatment procedure in the present study may be due to the approximate sizes of the NiTi rotary files and root canals. Therefore, the results of this study can only be generalized to retreating teeth with small curved root canals, such as the mesial root of the mandibular molars and the buccal roots of the maxillary molars [14, 15, 23]. However, X2c and RB can be used for penetrating to the working length of a curved canal in the original canal path without complications. Therefore, X2c and RB can be used for creating the path in large or oval root canals up to the working length, and then a bigger rotary file or sequent rotary files should be used for complete root canal filling removal.

Conclusions

Based on our results, X2 with continuous rotation and RB files can be used with high efficacy in curved root canal retreatment. Furthermore, continuous rotation has been found to be more efficacious and efficient than adaptive motion when using the same NiTi rotary file. Single file retreatment can be performed in small canals with high efficacy and in a cost-effective manner, with less time consumed.

Declarations

Ethics approval

This experimental study was approved by the Ethics Committee of the Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand (HREC-DCU 2021-019).

Data availability statement

The data of this study are available from the corresponding author upon request.

Funding

This study was supported by the Faculty of Dentistry Research Grant (DRF 64031), Chulalongkorn University.

Conflict of interest

The authors declare no conflicts of interest.

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Figures

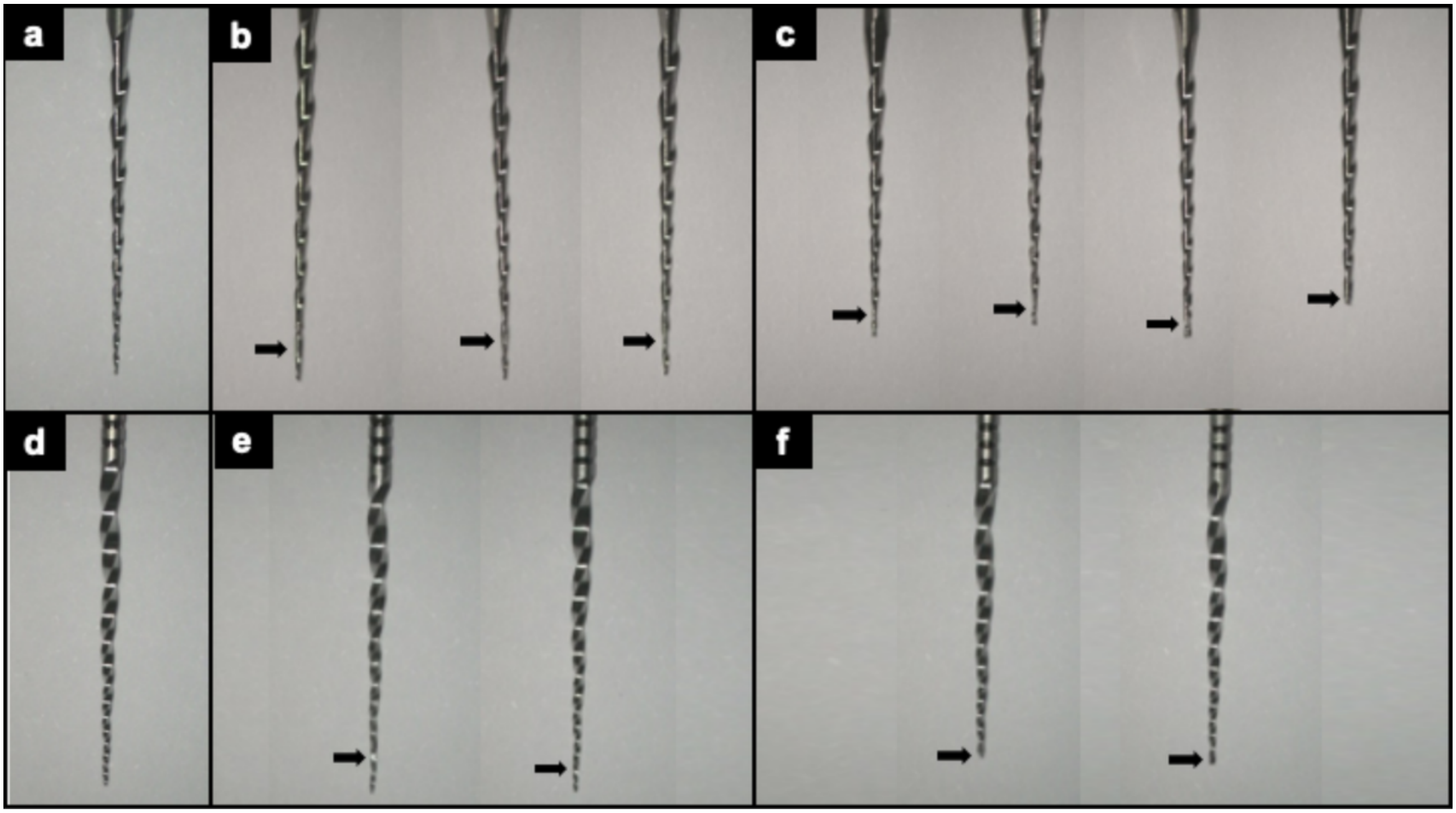

Figure 1

Rotary files used in retreatment procedure captured under DOM (magnification 2.5x) (a) pre-experiment: new VR file, (b) post-experiment: three VR files with only deformations, (c) post-experiment: four VR files with deformations and separations, (d) pre-experiment: new X2 file, (e) post-experiment: two files in the X2a group with only deformations, and (f) post-experiment: two files in the X2a group with deformations and separations. All images were captured by same DOM with controlled magnification and setting. Arrows indicate file deformation.