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A Comparative Evaluation of Canal Transportation and Centering Ability with Three Different Retreatment File Systems– An *In vitro* CBCT Study

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

AIM: The study aimed to compare the canal transportation and centering ability of the three different retreatment file systems using cone-beam computed tomography imaging (CBCT).
Methodology: Thirty three single-rooted, mandibular premolars were prepared up to ProTaper Gold size F2. Post intrumentation CBCT imaging was taken for all the samples. Obturation is done.

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The samples were randomly assigned to three different retreatment groups (n = 11), Group I: Pro Taper Universal retreatment kit, Group II: Mtwo R, and Group III: Xp endoshaper. Retreatment was done for all the samples using respective file systems followed by a Post-retreatment CBCT imaging. The two scans were compared both bucco-lingually and mesiodistally to determine canal transportation and centering ability at 3 mm, 6 mm, and 9 mm from the apex using DICOM Software. The results obtained were tabulated and statistically analyzed using One way Anova and Post hoc tukey test.

Results: The mean canal transportation was least for Xp endoshaper (Group III). A Significant difference in canal transportation and centering ability was not observed at all three levels from the apex.

Conclusion: Under in-vitro conditions, all three file systems have shown similar efficacy concerning canal transportation and centering ability. Based on mean values, canal transportation was higher for PTUR, followed by Mtwo R and Xp endo shaper in mesiodistal and buccolingual directions at 3, 6 and 9mm, and canal centering ability XP endo shaper stay centered followed by Mtwo R and PTUR in mesiodistal and buccolingual directions at 3, 6 and 9 mm.

Keywords: Retreatment; Xp endo shaper; mtwo R; canal transportation; centering ability.

ABBREVIATIONS

PTUR : Protaper Universal Retreatment
Mtwo R : Mtwo Retreatment
CBCT : Cone Beam Computed Tomography
CT : Computed Tomography

1. INTRODUCTION

The success of endodontic therapy has significantly improved in the last few years due to the introduction of novel materials and techniques. However, the failure of therapy requiring retreatment still comprises a significant percentage of patients.

“The main factor in endodontic failures is the persistence of bacteria in the root canal system as a result of poor root canal cleaning and filling, technical mistakes, or a deficiency in fluid-tight seals, which allows bacteria to survive in dentinal tubules, apical ramifications, accessory canals, and secondary canals” [1]. Conventional or nonsurgical endodontic retreatment is the initial choice for saving such teeth.

“The pivot goal of root canal retreatment is to restore healthy periapical tissue” [2]. The retreatment procedure involves completely removing the previous filling material to allow thorough re-instrumentation, disinfection and refilling of the root canal system.

“Traditionally, hand and rotary nickel-titanium [NiTi] instruments with or without solvent and ultrasonic instruments were used to remove root-filling material” [3]. Today, a variety of specialist rotary instruments, including the M two R, R Endo, Pro taper R and D-Race, Neoniti, and Xp endo shaper plus finisher R, are created for retreatment procedures.

“ProTaper rotary retreatment files consist of three instruments (D1, D2, D3) with various tapers and diameters at the tip (size 30, 0.09 taper; size 25, 0.08 taper; and size 20, 0.07 taper). The complete lengths of these retreatment files are 16 mm for D1, 18 mm for D2, and 22 mm for D3. D1, D2, and D3 are used to remove filling materials from the coronal, middle and apical portions of canals, respectively” [4].

“Mtwo Retreatment Files consist of two instruments with active cutting tip: R1 (size 25, 0.05 taper) and R2 (size 15, 0.05 taper). They have an S-shaped cross-section as do the files of the basic sequence, but a shorter pitch length for the advancement of the file into the filling material. These instruments are characterized by two cutting edges, which are claimed to cut dentine effectively” [5].

“The XP-endo Shaper instrument is made of MaxWire alloy and can undergo phase transformation at body temperature, assuming a snake-like shape that expands and contracts to adapt to the canal morphology” [6].

“Retreatment results in more mechanical manipulations in the root canal” [7]. “The primary retreatment procedure goal is to produce a preparation without any deviation from the original canal curvature and procedural errors” [7].

“Rotating NiTi instrumentation may make the process go more easily and quickly by reducing

operator and patient fatigue. Yet, due to a lack of literature evidence, the canal centering and transportation characteristics of rotating NiTi retreatment systems remain uncertain" [8].

"Canal centering ability becomes crucial during endodontic retreatment to prevent deviation from the originally prepared canal" [8].

"Any undesired deviation from the canal's natural path is referred to as canal transportation. During shaping and cleaning, the asymmetric material removal could shift the long axis of the curved root canal. Transport through the canal may result in ledging, perforation, zip development, and damage to the apical foramen" [9].

Cone-beam computed tomography (CBCT), a development in imaging technology, has made it possible to evaluate the structure in three dimensions and provide a complete assessment of morphologic aspects without damaging the tooth sample [10]. The preferred modality in sectional imaging for endodontic diagnosis is cone-beam computed tomographic (CBCT) imaging. It can be useful for periapical lesions differential diagnosis, showing the intricate anatomy of the root canal system, internal and external resorptions, detecting vertical root fractures, and locating lateral and auxiliary canals [11]. The current study used CBCT imaging to examine the centering ability and canal transportation of three different retreatment files.

A literature search revealed that rotary file systems were more focused in the canals and showed less dentin loss than hand files performed. In order to examine the canal transportation and centering abilities of three alternative retreatment files, the null hypothesis was considered as well.

2. MATERIALS AND METHODS

2.1 Sample Size Calculation

The G*Power 3.1 Software was used to calculate the sample size. The sample size of 11 per group was maintained with a confidence interval of 95% and a power of at least 80% and a 5% significance level.

A total of thirty-three human permanent mandibular premolars were collected from the Department of Oral Surgery. The samples were cleaned, sterilized, and checked for cracks and cavities using an operational microscope (Labomed Inc., USA) at a magnification of 1.6x.

The Radiographs of each sample were evaluated to confirm the presence of a single root and single canal with no calcifications. The teeth which were previously root canal treated, open apices, and pathological resorptions were excluded from the study.

2.2 Root-canal Preparation

Samples were decoronated to obtain standardi-zation of 15 mm working length.

The gliding path was formed using the No. 10 K-file (MANI Inc., Japan) after preparing the access cavity, and the working length was noted as being one millimeter short of the apical foramen. Protaper gold files up to the F2 sequence mounted in an endomotor (EConnect S Eighteenth, China) with a speed of 300 rpm and 3 N/m torque

During the shaping and cleaning process, the canals were irrigated with 3% sodium hypochlorite (Parcan, Septodont Healthcare PVT LTD., India), 0.9% saline, and 17% ethylene-diaminetetraacetic acid (Parcan, Septodont Healthcare PVT LTD., India).Mounting of the samples

To reproduce the clinical situation, the instrumentation procedures were done under a surgical operating microscope. These samples were positioned using putty silicone impression material to stabilize the teeth in the same position for both pre obturation and post retreatment scan.

2.3 Pre-obturation cone-beam Computed Tomography Scan

Pre-obturation CBCT scanning was performed. The template was horizontally fitted to chin support with its occlusal plane parallel to the plate. A pre-CBCT scan is done for all teeth before obturation. The exposure period was 3.0 s, operating at 75 kV and 2.0 mA, and the images are accumulated in the computer's hard disk for further comparison between Pre-Obturation and Post-Retreatment data using DICOM software.

2.4 Root-canal Obturation

Using the cold lateral compaction technique, the root canal was sealed off with gutta-percha cones from Dentsply Sirona in the USA and AH Plus sealer from Dentsply Detrey in Konstanz,

Germany. Using radiography, the obturation's quality was assessed. For seven days, samples were kept at 37 degrees and 100% relative humidity.

2.5 Retreatment Procedure

All the samples were randomly divided into 3 groups:

Group 1: ProTaper Universal Retreatment files PTURs (Dentsply Maillefer, Switzerland).

D1 (30/0.09), D2 (25/0.08), and D3 (20/0.07) are all treated in the coronal third, middle third, and apical third of the root canal, respectively. In the end, WL used an F3 ProTaper file (size 30, 0.09 taper).

PTURs were used at a speed of 500 rpm with a 3 N/cm torque in brushing motion till the sequence.

Group 2: Mtwo R (VDW, Munich)

Additionally, Mtwo Retreatment Files (Mtwo R) were employed per the supplier's specifications. Utilizing Mtwo R2 (size 25, 0.05 taper) in a simultaneous approach, root canals were instrumented to the working length using brushing and lateral pressing motions. The rotary file was advanced using gentle apical pressure, and the files were frequently taken out to examine the blades and clear the flutes of debris. Last but not least, WL employed a standard M2 rotary instrument (size 30, 0.05 taper).

Group 3: Xp endo shaper (FKG Dentaire, Switzerland)

One instrument was used to conduct XPS at 800 rpm and 1 N/cm torque. To change the shape of the canal walls and facilitate infill removal, the file was forced against them throughout the procedure. The instrument was also used three times, with each cycle including in and out oscillations with an amplitude of 3–4 mm up to the working length.

While utilizing XPF-R, there is an additional step to take; otherwise, the XPF usage guidelines are applicable.

The Root canal was irrigated using 2.5% Naocl between each file and the final irrigation was performed using 5 ml of 2.5% Naocl and 17%EDTA, followed by 5 ml of distilled water.

2.6 Post-retreatment Cone-beam Computed Tomography Scanning

The teeth were again prepared for post-retreatment CBCT scanning using the same parameters, and the pre-obturation data stored are compared with post- retreatment data using the same CBCT software. Three axial tomograms were selected for each specimen which were 3 mm, 6 mm and 9 mm from the root apex.

2.7 Evaluation of Canal Transportation

The amount of canal transportation was calculated by the shortest distances from the Mesial, Distal, Buccal and Lingual edges of root, to the related edges of the canal , respectively after cleaning and shaping which is considered as M1, D1, B1, and L1.

The shortest distances from the Mesial, Distal, Buccal, and Lingual edges of the root, to the related edges of the canal, respectively after retreatment is M2, D2, B2, and L2. As seen in image [1].

Using the formula introduced by Gambill et al.

(M1-M2)-(D1-D2) indicates canal transportation in Mesio-Distal Dimension and

(B1-B2)-(L1-L2) indicates canal transportation in Bucco-Lingual Dimension.

According to the formula given above, a result other than 0 indicates that transportation has occurred in the canal. +ve and –ve Values show mesial or buccal and distal or lingual transportation respectively.

2.8 Evaluation of Canal Centering Ability

It is calculated by using the following ratio:

$\frac{(M1-M2)}{(D1-D2)}$ – Indicates Canal Centering Ability in Mesio-Distal Dimension

$\frac{(B1-B2)}{(L1-L2)}$ - Indicates Canal Centering Ability in Bucco-Lingual Dimension

Value of 1 indicates complete canal centering. Any value other than 1 denotes change in canal pathway.

3. RESULTS

3.1 Canal Transportation and centering ability in bucco lingual direction using one way ANOVA

Statistical analysis for Canal transportation and canal centering ability between all groups showed no statistically significant difference.

The mean values based on Table 1. In canal transportation at 3 mm Group 1 had the maximum canal transportation followed by group II and III, at 6mm Group II had the maximum canal transportation followed by Group I and III, at 9mm Group II had the maximum canal transportation followed by Group I and Group III.

In centering ability at 3mm Group 1 had the maximum centering ability followed by group II and III, at 6mm Group III had the maximum centering ability followed by Group I and II, at 9mm Group I had the maximum centering ability followed by Group II and Group III

3.2 Canal Transportation and centering ability in mesio distal direction using one way ANOVA

The mean values based on Table 2. In canal transportation at 3 mm Group 1 had the maximum canal transportation followed by group II and III, at 6mm Group I had the maximum canal transportation followed by Group III and II, at 9mm Group I had the maximum canal transportation followed by Group III and Group II.

In centering ability at 3mm Group III had the maximum centering ability followed by group I and II, at 6mm Group I had the maximum centering ability followed by Group III and II, at 9mm Group III had the maximum centering ability followed by Group I and Group II.

4. DISCUSSION

Retreatment of root-filled teeth is recommended in cases when there is persistent disease due to microleakage, insufficient cleaning, shaping, technical issues, or complex anatomy.

“Mandibular premolars were selected because of an oval-shaped root canal, poses a special challenge for adequate chemomechanical preparation resulting in uninstrumented recesses. However, a study by Wu et al. has revealed that oval or flat root canal morphology is present in up to 25% of root canals, and in some root groups, it may exceed 50%” [12]. “Such oval canals present an anatomic challenge for chemomechanical preparation” [13].

The ProTaper Gold has been selected for biomechanical preparation due to its convex triangular cross-section and progressive taper. It also has a noncutting tip design, allowing the instrument to follow the original shape of the root canal. It has been metallurgically enhanced through heat-treatment technology.

“Cold lateral condensation has been done as it is known as the benchmark technique against which all obturation techniques are evaluated. This technique has good control over canal obturation length with any type of sealer” [14].

“Radiographic imaging, longitudinal root severance for microscopic analysis using a stereomicroscope, scanning electron microscopy, and other techniques are used to quantify residual obturating materials but these methods failed to provide computable volumetric information before and after the retreatment. To transmit accurate three-dimensional information about teeth with a significant reduction in radiation exposure, CBCT has been carefully engineered” [15].

The development of the CT scan allowed for a 3D examination of the complete root canal system. Compared to CT, CBCT has a much lower effective radiation dosage and supports 3D analysis. CBCT offers thorough viewing of morphologic properties, including root canal networks, without requiring the destruction of tooth specimens [16].

“CBCT imaging is a noninvasive method for superimposing pre- and post-instrumentation pictures to analyze the geometry of canals and the effectiveness of shaping procedures” [17].

“The Centering ratio is a measurement of the ability of the instrument to stay centered in the canal” [18]. “It may aid in understanding the advantages and limitations of specific design characteristics of instrument systems” [18].

“Due to canal transportation, endodontic instruments do not touch the complete perimeter of the root canal leaving debris, and microorganisms, thus contributing to endodontic failure and affecting the biological sealing of the obturating material” [19].

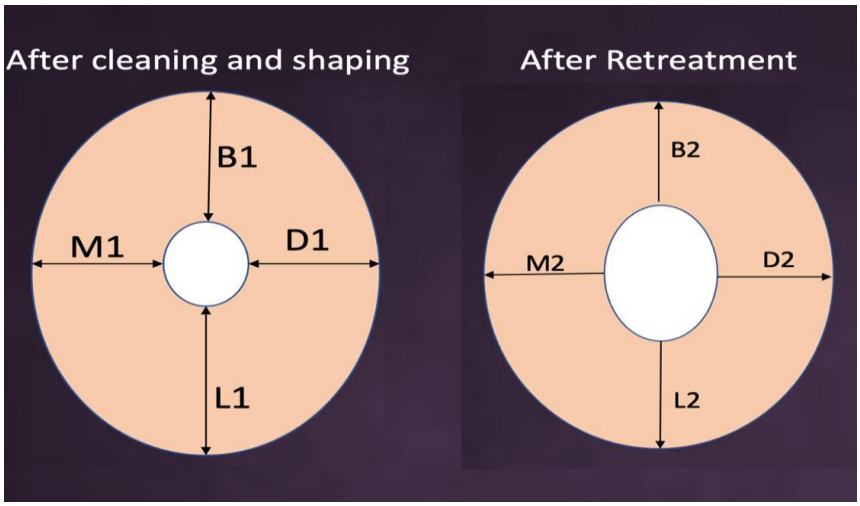

Image 1. Canal transportation and centering ability

Table 1. Canal transportation and canal centering ability (Result 1)

Characteristics	Level	Group	Mean	Std. Deviation	F value	P value
	3 mm	Group 1	.1091	.28445	.356	.703
		Group 2	.0545	.38565		
		Group 3	.0000	.21448		
Canal transportation	**6 mm**	Group 1	.0636	.35291	1.224	.308
		Group 2	-.1000	.21448		
		Group 3	-.0636	.16895		
	9 mm	Group 1	-.0273	.43610	.403	.672
		Group 2	-.1273	.31966		
		Group 3	-.0091	.19725		
	3 mm	Group 1	1.0500	.80218	.340	.715
		Group 2	1.1273	1.68766		
		Group 3	.7591	.41159		
Canal centering ability	**6 mm**	Group 1	.7727	.47559	1.121	.339
		Group 2	.6227	.42034		
		Group 3	.9091	.44823		
	9 mm	Group 1	1.0455	1.18669	1.140	.333
		Group 2	.6636	.54868		
		Group 3	.5545	.46339		

In this study, there was no statistical difference between the three groups in canal transportation and centering ability at 3 mm, 6 mm, and 9 mm from the apex.

“This result could be attributed to all the retreatment instruments was used in standard enlarged root canals, and each canal was straightened to a certain extent during the initial preparation with Protaper Gold rotary files” [20]. “Although the canal transportation was greater in the PTUR group compared to the other 2 groups, the difference was not statistically significant” [20].

“XP-endo file’s high flexibility, zero tapers, and NiTi MaxWire technology. The MaxWire technology involved in the production of this file provides it with superelasticity and shape memory properties. Upon exposure to body temperature (35°C), the martensite phase of the file converts to the austenite phase, and the taper increases to 0.04 according to the molecular memory of the A phase, which presumes a snake-like shape” [21].

“It is capable of moving through every corner and wall of the root canal and scrubbing debris that has been left inside without deviating its

Table 2. Canal transportation and canal centering ability (Result 2)

Characteristics	Level	Group	Mean	Std. Deviation	F value	P value
		Group 1	.0727	.17939		
	3 mm	Group 2	-.0364	.14334	1.751	.191
		Group 3	-.0182	.10787		
Canal		Group 1	.1182	.46865		
transportation	**6 mm**	Group 2	.0182	.17787	.315	.732
		Group 3	.0545	.12933		
		Group 1	.0455	.12136		
	9 mm	Group 2	.0091	.24271	.116	.891
		Group 3	.0273	.14206		
		Group 1	.9909	.72864		
	3 mm	Group 2	1.2000	.64498	.456	.638
		Group 3	.9545	.56809		
Canal		Group 1	.5909	.30151		
centering	**6 mm**	Group 2	1.2727	.68715	3.310	.058
ability		Group 3	1.2091	.92245		
		Group 1	.8909	.34772		
	9 mm	Group 2	1.4318	1.15158	2.216	.127
		Group 3	.8273	.44292		

natural path of the root canal, [22,23] which could have resulted in lesser canal transportation and better centering ability".

"XPS preserved the original curvature slightly better than Wave one Gold, while WOG reported the highest buckling resistance. There was a positive correlation between canal transportation and instrument resistance to buckle" [24].

"Mtwo R instruments exhibited intermittent canal transportation and centering ability values owing to their low cross-sectional area, relatively less number of spirals, and high flexibility" [21,25].

"PTUR because of its negative rake angle, convex triangular cross-section and excessive taper make it less flexible, and removal of dentin along with Gutta-percha [12] could have resulted in poor centering ability and greater canal transportation" [26-28].

According to Gogulnath et al. "ProTaper retreatment instruments showed more tendency for eccentric canal preparation, especially in the apical third of the root canal. REndo and MtwoR instruments that have reduced core diameter and positive rake angle showed better canal centering" [29-32].

"There was no significant difference between the ProTaper Universal retreatment (PTUR), Mtwo R, and D-RaCe instruments in the apical transportation in either the mesiodistal or buccolingual direction" [2]. This result could be attributed due to all the retreatment instruments were used in standard enlarged root canals, and each canal was straightened to a certain extent during the initial preparation.

"At 3 mm level, H file resulted in more canal transportation than R-Endo (P < 0.05) in buccolingual and mesiodistal directions, although R-Endo and PTUR were similar in terms of canal transportation in buccolingual (P > 0.05). This can be attributed to the aggressive nature and relatively least flexibility of the H file" [3].

5. CONCLUSION

Under in-vitro conditions, all three file systems have shown similar behavior concerning canal transportation and centering ability.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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