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EFFICACY OF THREE NICKEL TITANIUM ROTARY FILE SYSTEMS IN REMOVAL OF INTRACANAL FILLING MATERIAL (IN VITRO STUDY)

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ABSTRACT

Aim: Our study was conducted to evaluate the efficacy of three rotary retreatment nickel-titanium systems in terms of remaining obturation material on canal walls, debris extruded out of the canal, time taken to reach full working length and number of fractured files in each system.

Methodology: 120 canals (type III) in 60 mesial roots of lower mandibular first molars were divided into 3 groups of 40 canals each according to the retreatment system used. In Group (I) retreatment was done using Protaper universal retreatment file system (PTUR), Group (II) Mpro retreatment file system was used and Group (III) RT gold file system.

Results: Protaper universal retreatment system showed to be significantly more efficient in removal of root canal filling material, consumed less time during retreatment with less number of fractured instruments. While Mpro retreatment files showed the least amount of apically extruded debris.

Conclusion: Under the conditions of this study, it can be concluded that all techniques failed to clear the canals from remaining obturating material with the highest percentage on the apical area, debris extrusion remains problematic in all systems used, Protaper file is the most speed efficient and has higher efficacy in root canal filling material removal than the other two groups.

KEYWORDS: Root Canal Retreatment, debris extrusion, remaining obturating material.

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INTRODUCTION

Although endodontic treatment has a high success rate, it doesn't always lead to the anticipated outcome, and failure might occur. This may happen due to the persistence of bacteria inside the root canal system as a result of inadequate cleaning and shaping, insufficient obturation, unfilled or untreated canals.

In case of failure of initial endodontic therapy, several treatment modalities are available including conventional retreatment, peri-radicular surgery with retro-grade filling or extraction. Conventional ortho-grade retreatment should be considered as the first line of treatment as it is the most conservative method.

When the chosen treatment plan is nonsurgical retreatment, then the aim is to access the pulp chamber and entirely remove the obturation material. This allows effective cleaning and shaping to properly disinfect the root canal system, address deficiencies or repair flaws that are iatrogenic or pathologic in origin.

Several retreatment techniques have been considered to entirely improve the removal of obturating material, including usage of hand files with chemical solvents, heat pluggers, ultrasonic tips, endodontic rotary and reciprocating instruments, however none of them proved to be efficient enough to remove completely the leftovers of gutta- percha and/or sealer from the canals. [(1)]

Various types of motor-driven instruments, made from nickel-titanium alloys have been successfully used in cleaning and shaping of the root canals. Their effectiveness may be impacted by a number of variables, including radial lands, rake angle, cross section and various tapers. One of the main advantages of these instruments is the capacity to remove dentin and debris in a coronal direction, resulting in less debris extrusion through the apical foramen. Therefore, several studies have evaluated the action of rotary instruments in removing gutta-percha, which has been shown to be effective, safe, and time-saving. [(2)]

Usually, root canal retreatment results in apical extrusion of dentinal debris and obturating material. Furthermore, necrotic pulp tissue remnants, irrigants, microorganisms and their byproducts may be pushed into the peri-radicular tissues, which is undesirable as it could be associated with post-operative pain and/or edema, symptomatic apical periodontitis and delayed peri-apical healing. As a result, efforts must be made to reduce debris extrusion through the apical foramen [(3)].

Against this background, this study intended to estimate the efficacy of three Nickel-Titanium rotary retreatment systems regarding the terms of: amount of remaining obturating material on root canal walls, debris extruded during retreatment, time taken to reach full working length and number of fractured files during the procedure.

The null hypothesis was that there are no significant differences between the three retreatment systems regarding their efficacy in removal of obturation material.

MATERIALS AND METHODS

Retreatment rotary systems:

Protaper universal retreatment system consists of 3 instruments: D1 (#30.09), has an active tip, and is used for re-preparation of the coronal third. Both D2 (#25.08) and D3 (#20.07) have inactive tips and are used for re-preparation of the middle and apical thirds, respectively [(4)].

Mpro retreatment file system consists of five files: Orifice opener (# 22 0.11) used for coronal flaring and three files (R1, R2, and R3); size 25 with 0.08, 0.06, and 0.04 tapers, respectively. R4 (30.04) is also available.

RT GOLD Perfect files consists of 3 instruments comparable to the Protaper system: D1 (#30.09) has

an active tip, and is used for re-preparation of the coronal third. D2 (#25.08), and D3 (#20.07) have inactive tips and are used for re-preparation of the middle and apical thirds, respectively.

Sample selection: Sixty permanent lower first molars were used in this study. Roots of the selected teeth were free from any caries, cracks or fracture. Teeth having immature root apices, external/internal root resorption, previous endodontic treatment, double curvatures or calcification were discarded. The teeth were verified radiographically of having two patent separate root canals (Type III) with no evidence of internal resorption and having moderate curvature of 5˚ to 20˚ according to Schneider method.

Sample preparation: For standardization of the working length to 16 mm for each specimen, crowns were decoronated using a low speed diamond disc with water coolant. Access cavity was done using high-speed Endo access bur with copious water coolant. A K-type file size 10 was inserted in the two mesial canals until it was visualized at the two apical foramina to ensure the patency of the canal. Working length was taken 1 mm short of this length. Canal preparation was accomplished using K-type files to master apical file size 25 and stepping back with size 30, 35, 40 files 1 mm for each file. Patency of the canal was maintained with #10 K-type file. At each instrument change, canals were irrigated using 2 ml of 5.25% sodium hypochlorite to remove debris followed by removal of smear layer using 1 ml of 17% (EDTA) for 1 minute. Matching gutta-percha cones of 25/0.02 with Endo-seal zinc oxide and eugenol sealer (Prevest Denpro Limited, Jammu, India) were used for lateral compaction.

Sample Classification: All samples were one hundred and twenty canals in sixty mesial roots of lower mandibular first molars type III (n=120) that were divided randomly into three groups of forty canals each (n=40) according to the system used for retreatment.

Retreatment Procedures:

Group (I) Protaper universal retreatment: As specified by the manufacturer, ProTaper retreatment files were used in crown-down manner in a brushing motion at constant speed of 500 rpm and a torque of 2.5 N/cm. D1 was used in the coronal third without engaging dentin, D2 in the middle third and D3 in the apical third.

Group (II) Mpro retreatment files: The opener file was used for making straight access of the root canal and for coronal flaring. Then R1 is used for removal of the coronal 1/3 of the obturation material, R2 for the middle 1/3, R3 for the apical 1/3 and R4 is used for final root canal preparation. As per manufacturer's recommendation the files are used with torque 2.5N/cm and speed 300-400 rpm in a circumferential motion.

Group (III) RT GOLD files: They are designed to be used in sequence to remove filling materials. As per manufacturer's recommendation they are used in a brushing motion with torque 2-3N/cm and speed 250-360 rpm. The working tip on the D1 file facilitates initial penetration. Without engaging dentin, D1 is gently pressed into the gutta-percha to remove the obturation material from the coronal 1/3, then D2 progressively remove material from the middle 1/3 and D3 is used in removal of obturation material from the apical 1/3.

Root canals were irrigated by 2ml of 2.5% NaOCl at each change of instruments. Retreatment of all samples was considered complete when the last file reaches the working length, with no obturating material covering the instrument, and the canal walls are smooth and free of observable debris. One set of retreatment files was used for re-preparing eight root canals.

Evaluation of the remaining obturation material

All samples were grooved bucco-lingually with a diamond disc until the shadow of the canal appeared through a thin layer of dentin, then teeth

were split longitudinally using a chisel and mallet into mesial and distal halves. Stereomicroscope was used to scan the half of the root with the largest area of remaining obturating material then analyzed at the coronal, middle and apical thirds, using a fixed magnification of x40. Images were captured using a digital camera fitted on the microscope then moved to the desktop and saved as JPEG format. Remaining obturating material was calculated using image J software (1.53t/ java 1.8.0_345 image analyzer software). Percentage of the remaining material to the total canal area was measured without any attempt to differentiate between residual gutta-percha and sealer.

Debris extrusion

Any debris or irrigants extruded during the procedure were collected in an Eppendorf tube. For measuring the weight of each tube, pre weighing was done using a digital microbalance with a precision of 0.0001grams. Three successive readings were taken for calculating the mean weight for each Eppendorf tube. Then each sample was securely inserted into the hole of the modified cap up to the cemento-enamel junction level. Additionally, a 27-gauge needle was placed along with the stopper to act as a drainage cannula and for balancing the air pressure outside and inside the tubes. After retreatment the Eppendorf tubes were stored in an incubator at 37°C for 15 days to allow NaOCl desiccation. Then the tubes were weighted again using the same digital microbalance to obtain the final weight of the tube containing the collected debris. To calculate the mean value, three successive readings were taken for each tube. Then the initial weight was subtracted from the final weight of the extruded debris.

Time taken to reach the full working length

The total time was recorded (in minutes) using a stopwatch including the time taken to reach the full working length from the first file used and until no obturating material can be observed on the last file used. Time taken for changing files and irrigation was excluded.

File breakage

Total number of fractured files was recorded. Any file had been broken was discarded and additional sample was added to the group.

Statistical Analysis

Data were checked for normality using Shapiro-Wilk test. They were distributed and analyzed normally using one-way ANOVA followed by Tukey's post hoc test for intergroup comparisons and repeated measures ANOVA followed by Bonferroni post hoc test for intragroup comparisons. The significance level was set at $p \leq 0.05$ within all tests.

RESULTS

Regarding amount of filling material on canal walls, RT files showed the highest amount of remaining obturating material (39.90 ±3.13) followed by Mpro (33.02 ±2.78) while Protaper showed the least amount of remaining gutta percha (31.74 ±3.26). There was a statistically significant difference between Protaper and the other two systems. (Table 1)

TABLE (1) Mean ± standard deviation (SD) of remaining GP (%) for different retreatment rotary systems.

Root section	Remaining filling material (%) (mean±SD)			P-value
	Protaper	Mpro	RT	
Coronal	31.54±2.66^{B}	31.67±2.11^{B}	38.21±2.16^{A}	<0.001*
Middle	31.59±3.41^{B}	33.17±3.18^{B}	40.25±3.51^{A}	<0.001*
Apical	32.10±3.73^{C}	34.22±3.05^{B}	41.25±3.73^{A}	<0.001*

Means with different superscript letters within the same horizontal row are significantly different *; significant (p ≤ 0.05) ns; non-significant (p>0.05)

TABLE (2) Intergroup comparisons and mean ± standard deviation (SD) values of weight of apically extruded debris (mg) for different files

Weight of apically extruded debris (mg) (mean±SD)			p-value
Protaper	Mpro	RT	
0.0068±0.0025^{A}	0.0054±0.0021^{A}	0.0058±0.0019^{A}	0.181ns

Means with different superscript letters within the same horizontal row are significantly different *; significant (p ≤ 0.05) ns; non-significant (p>0.05)

Regarding weight of apically extruded debris (mg*10^4) for different files, there was no significant difference between different groups (p=0.181). The highest value was found in Protaper (0.0068±0.0025), followed by RT (0.0058±0.0019), while the lowest value was found in Mpro (0.0054±0.0021) (Table 2).

DISCUSSION

One of the primary reasons for a negative outcome following the endodontic treatment is the persistent bacteria within the root canal system. Nonsurgical retreatment is commonly considered the first line of treatment to remove the infected intra-canal filling material, disinfect and re-obturate the root canal system [5].

An appropriate retreatment technique should be designated to remove as much filling material as possible from the root canal system in order to eradicate or to reduce the microbial load which may be responsible for failure and periapical inflammation, while decreasing the amount of extruded debris, to prevent inflammation and pain [6].

In the last few decades, several rotary retreatment systems have been presented to the market which endure to develop in different aspects as cutting and shaping efficiency, cutting blade design and varying tapers. Furthermore, improvements in manufacturing technologies and thermo-mechanical treatment have resulted in the advancement of the NiTi alloys microstructure.

The Protaper Universal system was used as a comparative system because it is frequently used as a gold standard against which new file systems are evaluated. The selection of Mpro retreatment files and RT gold files was due to the fact that they were presented into the market recently and there was no sufficient information about their performance in the canal. As a result, we needed to shed a light on their retreatment ability and extrusion of debris apically.

In numerous studies, micro-CT scans have been used to measure the residual intra-canal filling material following retreatment [7]. This approach allows accurate, nondestructive, 3D quantitative assessment of residual obturating material, sealer and dentin separately on the canal wall before and after retreatment.

Due to the scarcity of micro CT scans, the quantity of residual filling material in the present study was determined by longitudinal cleavage followed by quantitative analysis. The roots were meticulously sectioned to prevent dislodgment of gutta-percha from the canal walls. Then evaluation of remaining filling material was performed by measuring the percentage of debris inside the canal [8]. Three distinct aspects of the tooth were assessed: the coronal, middle, and apical thirds in one half of a split root sample. Each segment was inspected individually as they are morphologically distinct from one another, which would influence our results.

Stereomicroscope was used to assess the leftovers of root canal filling material, this maneuver is simple as the object-device distance remains constant which enables image standardization. Furthermore, the assessment using qualitative digitalized Image J software is better than manual qualitative recording used in other studies to reduce subjectivity [9].

Under the circumstances of the present study, our results came in accordance with the literature

in that none of the retreatment techniques or instruments assured full clearance of the root canal from obturating material [10&11]. The vast majority of remnants on the canal walls appeared to be sealer, which is consistent with other studies done by ***Barrieshi*** [12] and ***Wilcox et al.*** [13].

In the current study, the retreatment procedure was considered complete when the last file in sequence reached the full working length with no obvious filling material distinguished on the flutes, though all canals had residual filling material, as shown in other studies done by ***Taşdemir*** [14] and ***Ezzie*** [15]. According to our results, the absence of filling material on instruments is not a reliable method for ensuring complete removal of gutta-percha from the canal walls, which came in accordance with ***Schirrmeister*** and colleagues [16].

Regarding removal of obturation material, it is worth mentioning that there are some characteristics which influence the removal of gutta-percha such as metallurgy, cross section and taper. In our study the three file systems had progressively increasing pitch along their blades with convex triangular cross section. Regarding metallurgy, two file systems are austenitic which are Protaper and Mpro, while RT file is M-Wire which contains austenite, martensite and R-phases.

The findings of our study revealed favorable outcome for Protaper retreatment system which presented less amount of residual filling material left inside the canal compared to the other systems, similar to the findings of ***Takahashi et al.***[17] and ***Guiliani et al.*** [18] who accredited the ability of Protaper universal retreatment instruments for gutta-percha removal to the spirals running around the instruments and the negative cutting angle which provides cutting action instead of planning the gutta-percha against the root canal walls, also ***Bramante et al.*** [19&20] who accredited the rapid and effective performance of Protaper retreatment instruments to their high taper and more metallic core. Such a design leads to greater heat release and rapid gutta-percha plasticization.

Although no sufficient data was found in literature about the other two systems, Mpro retreatment system has shown to be more efficient than RT gold system, this may be attributed to the presence of Mpro in the austenite phase at room temperature that justify its strength and hardness. This came in accordance with the study done by ***ElSewify*** [21] who revealed that Mpro retreatment system (E3-ReRoot) was significantly more efficient than R-Endo in removal of intracanal filling from the whole root canal.

Regarding measurement of remaining intra-canal filling material in different root sections, our results revealed that the highest amounts of remaining filling material were detected in the apical third, compared to the middle and coronal thirds, which came in full agreement with ***Fenoul*** [22] and ***Somma*** [23]. Therefore, the current study emphasizes the well-known challenge of removing gutta-percha and sealer from the entire root canal, especially the apical third of the root, which is essential to achieve apical disinfection and periapical healing. This has been accredited to the high anatomical variation in the apical third of the canal, less approachability to clean this section and the apical vapour lock, which hinders displacement during instrumentation and final irrigation, preventing irrigant flow into the apical area and satisfactory root canal system debridement [24].

Regarding extrusion of debris, the present study revealed that all instrumentation systems caused apical debris and irrigants extrusion. This came in full agreement with ***Tomer*** [25] who confirmed that no method could entirely prevent debris extrusion.

Although results presented no significant difference between the three groups, Mpro

retreatment files showed the smallest amount of extruded debris. This outcome cannot be compared directly to earlier studies because none could be found in the literature, but this could be accredited to the superior cutting efficiency of X wire used that directed the debris towards the orifice.

Meanwhile, Protaper universal retreatment system showed the highest amount of extruded debris, this could be attributed to its high rotational speed that removes more amount of gutta percha in less time and also no spillways for debris clearance that may cause debris to accumulate and extrude apically. This was in agreement with ***Clauder***[26] who stated that faster systems remove larger amount of dentin in short period, may pose the risk of increased amount of apical extrusion.

Regarding time taken for removal of gutta-percha, it is assumed that there are some characteristics which influence the penetrability of files thus affecting the time for removal of gutta-percha such as rake angle, helical angle, metallurgy of the file and geometric design. Because of their specific flute design, Protaper universal retreatment files recorded the least time to remove gutta-percha. The files cut gutta-percha as well as the superficial layer of dentin during gutta-percha removal. Other features include progressive tapers of D1, D2, and D3 files which allows to shape specific sections of a root canal with a single file. The rotary motion and flute design cut the large amount of gutta-percha surrounding the instrument and direct it toward the orifices, these results came in agreement with other studies as stated by ***Özyürek*** [27], ***Purba et al*** [28], but our results opposed ***Marfisi et al.*** [29] who concluded that Protaper requires more time to remove intra canal filling material.

RT file system consumed the longest time for gutta-percha retrieval, this system is made of M wire which is known by its high flexibility that may act as a contributing factor to its poor performance and slower action.

Though each instrument was used as stated by the manufacturer's guidelines, 1 PTUR, 4 Mpro and 6 RT files fractured. In spite of the M-Wire technology that RT file system is made of, it showed to have the highest number of fractured files. In comparison to the conventional NiTi alloy, M-Wire offers greater flexibility while preserving cutting efficiency and higher resistance to cyclic fatigue. Thus high fracture incidence of RT files may be attributed to manufacturing process that may impact the instrument's fatigue lifetime by inducing external or internal defects.

The low fracture incidence of PTUR may be attributed to its high rotational speed. It was used at 500 rpm consistent with the manufacturer's instructions. This was mentioned by ***Barrieshi*** [30] and ***Daughtery*** [31] who claimed that higher rpms showed no fractures and less deformed files during instrumentation. Another potential explanation is the flute design which allows to shape particular sectors of a root canal with single file and variable tip diameter that permit the file specific cutting action in a definite area of the canal, without stressing the instrument in other sections [32].

On the basis of these findings in the present study, the null hypothesis was therefore rejected, as PTUR showed to be significantly more efficient in removing root canal filling material, consumed less time during retreatment with less number of fractured instruments. While Mpro retreatment files showed the least amount of apical debris extrusion.

CONCLUSION

Under the conditions of this study, it can be concluded that all techniques failed to clear the canals from remaining obturating material with the highest percentage on the apical area, debris extrusion remains problematic in all systems used, Protaper file is the most speed efficient and has higher efficacy in removing intra-canal filling material than the other two groups.

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