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EFFECTIVENESS AND CLEANING ABILITY OF ORANGE OIL SOLVENT COUPLED WITH ROTARY VERSUS MANUAL INSTRUMENTS DURING ENDODONTIC RETREATMENT PROCEDURE (AN IN-VITRO STUDY)

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ABSTRACT

The objective of this study is to assess and compare the effectiveness and cleaning capability of Hedstrom manual files, Pro-Taper and Mtwo retreatment instruments in retreatment of single rooted teeth with and without orange oil as solvent. Forty- two teeth with single root were extracted, decoronated, and shaped up to file 45 and sealed with gutta percha and resin sealer utilizing lateral condensation technique. The teeth were split into six equal groups (n=7) depending on retreatment procedure. Pro-Taper, Mtwo retreatment files, and H-files were applied to eliminate the gutta percha with and without orange oil gutta percha solvent after two weeks. Retreatment time was calculated using stopwatch. The quantity of root canal filler material remaining in the apical, middle, and coronal thirds was assessed utilizing a scanning electron microscope at 1000X magnification. Retreatment time was evaluated via Welch one-way ANOVA accompanied by the post hoc test. Cleaning ability scores were analyzed using two-way cumulative link mixed models and simple effects comparisons. Pro-Taper retreatment files combined with orange oil gutta percha solvent was significantly the fastest method for complete retreatment procedure. Substantial variation was identified between the examined groups for cleaning ability in different canal thirds($p<0.001$). The highest cleaning ability scores in apical third was found in group (V), among middle and cervical thirds the highest cleaning score was found in group (I). After all of the retreatment procedures were completed, the sealer and the gutta-percha were noticed inside the root canal, particularly at the apical and middle thirds of the canal. Overall, the study indicating better debridement were predominantly associated with rotary systems used without solvents, particularly Pro-Taper retreatment files. The use of solvents, while potentially beneficial in softening gutta-percha, did not consistently translate into improved cleaning outcomes in this experimental setting.

KEYWORDS: Endodontic retreatment, Pro-Taper retreatment files, Mtwo retreatment files, H-file, orange oil, time, cleaning ability.

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INTRODUCTION

Endodontic errors are not uncommon and would require retreatment. It is characterized by the presence of symptoms in the treated tooth and the development of a periapical lesion obvious radiographically following endodontic treatment [1]. Post-treatment endodontic disease may arise from the resistant bacteria in the root canal system, resulting from scarce cleaning, neglected canals, insufficient filling, or leakage at the coronal or apical regions [2].

Aim of retreatment is to thoroughly sterilize the root canals to facilitate peri-radicular healing. For the accomplishment of this goal, it is mandatory to entirely eliminate root canal filler material, since any residues serve as a mechanical obstacle between disinfectants and microorganisms in unreachable regions, such as isthmuses and dentinal tubules [3]. There are two methods for endodontic retreatment: apical surgery (retrograde) and nonsurgical retreatment (orthograde).

Retreatment methods are more difficult to implement than those being used in initial treatment as they require innovative instrumentation and magnification systems as well as special training. [4]

The diverse methodologies utilized for eliminating the obturating material encompass chemical approaches (orange oil, xylene, chloroform, tetrachloroethylene, eucalyptol), mechanical techniques (hand and rotary files), physical modalities (laser and ultrasonic), and combinatorial strategies (endodontic files with chemicals or heat and paper points with chemicals). [5]

Orange oil is a naturally derived solvent extracted from citrus fruit peels, primarily composed of d-limonene. Owing to its low toxicity and pleasing aroma, orange oil has gained popularity as an alternative to traditional chemical solvents such as chloroform and xylene in endodontic retreatment procedures [6]. Additionally, it has been reported that orange oil does not harmfully influence dentin microhardness, which is advantageous in preserving tooth structure during retreatment [7].

Retreatment is an arduous and time-consuming operation that results in several procedural inaccuracies. [8]. The residual filling debris has been evaluated through multiple techniques in endodontic research, including longitudinal tooth splitting, transparency methods, radiography, stereomicroscopy, scanning electron microscopy, digitized image analysis via scanners, micro-computed tomography, and computed tomography [9].

Multiple studies have shown the effectiveness, cleaning capacity, and safety of rotating nickel-titanium tools. The predominant Ni-Ti retreatment systems utilized are Pro-Taper retreatment, R-Endo, and MTwo retreatment files [5]. Disagreement has arisen regarding the efficiency of these files in eradicating gutta-percha from root canal systems.

Researchers found that no retreatment procedure can entirely eliminate residue from the root canal walls where microorganisms typically remain specially in the apical third [10]. The integration of various techniques often verified to be the most effective approach, despite being time-consuming and resulting in a loss of standardization [11].

This research seeks to assess and compare the effectiveness and duration required for total eradication of filling material by utilizing the Pro-Taper universal retreatment, MTwo retreatment and H file with and without orange oil as a gutta percha solvent. The tested hypotheses were: (1) There were no significant variance among the test groups to remove obturating material in regards to cleaning ability; and (2) There is no significant variance in the duration needed for retreatment with or without using orange oil.

MATERIAL AND METHODS

The current in vitro study was executed in the Endodontic department, faculty of dentistry, Minia University. An ethical clearance obtained used for the proposal of the research from the ethics and postgraduate committee of the faculty of Dentistry, Minia University. Also, an informed permission document completed by the patient whose teeth were used for the study before extraction.

Sample size

The total sample size (n) was settled to be 42, with 7 samples allocated to each group. The computation of sample size was conducted using G*Power version 3.1.9.7.[12]

Forty-two single rooted recently extracted human permanent teeth were chosen for this study. To ensure that every tooth had one straight canal, radiographs were obtained prior to the procedure buccolingually and mesiodistally.

Endodontic treatment

All selected specimens' lengths were standardized to 15 mm through the decoronization of each one by a water-cooled high-speed disc. To check the patency of each canal, a size #10 K-file (MANI, INC, Japanese) was passively inserted till the file tip was apparent from the apex. The root canal was prepared using a crown down method with the six files E- Flex Gold rotary system (Eighteeth, Changzhou China) with E-connect Endo motor. According to manufacturing instructions torque and speed were adjusted to each instrument. The patency was preserved using size #10 K-file throughout all processes. Then followed by manual K- file size # 40 and K- file size #45 (MANI, INC, Japanese) to complete apical canal preparation. During canal treatment, the canals were rinsed with two ml of a full concentration NaOCl (Clorox, Egypt) solution after each file. As the final rinse of the canals, two ml of seventeen percent EDTA (Prevest, Denpro, India) was administered, then two ml of a full concentration NaOCl solution.

By using size 45 paper points (Meta Biomed, Korea), canals were dried and then obturated with the lateral condensation technique with size 45 gutta percha (Meta Biomed, Korea) as the master cone, auxiliary sizes 25 and 20, and resin sealer (Adseal, Meta Biomed, Korea). Then the excess of gutta percha removed with ultrasonic tip below level of orifice 1mm to create space for sealing the access and to create reservoir for Gutta percha solvent at retreatment stage. Teeth were radiographed to verify the appropriateness of obturation, employing the following principles: consistent radiopacity, achieving working length, and absence of voids. To allow maximal set of the canal sealer, samples were placed in a hundred percent humidity at 37°C for two weeks after being restored with a temporary filling material (Orafil G, Prevest, India). [13]

Endodontic retreatment

All samples were randomly assigned into equal six groups regarding to methods of retreatment (n = 7); *group 1*:H file with gutta percha solvent, *group2*: H file without solvent, *group 3*: Pro-Taper file accompanied by solvent, *group 4*: Pro-Taper file in absence of solvent, *group 5*: Mtwo files accompanied by solvent, and *group 6*: Mtwo files in absence of solvent.

Group 1; H file with gutta percha solvent

Using H-files and orange oil gutta percha solvent, the samples were retreated. Hedstrom files (MANI, INC, Japanese) of sizes 35–15 were utilized in descending sequence to the full length utilizing a circumferential quarter-turn push-pull motion. Single drop of the orange oil solvent (Cerkamed, Poland) was administered in the canal with each instrument change [14]. After achieving

the working length with a size 15 file, sizes 20 to 45 were utilized to the full length. Irrigation with one mL of full concentrated NaOCl was carried out between each file during the retreatment. When neither the sealer nor the gutta percha was visible on the instrument and the canal looked clear upon inspection with a 5X dental loupe, the retreatment was considered complete [15].

Group 2; H file without Gutta percha solvent

The samples were retreated using H-files only without gutta percha solvent. The Hedström files were utilized as outlined in Group 1, but in the absence of a solvent.

Group 3; Pro-Taper file with solvent

The samples in these groups were retreated with Pro-Taper Universal retreatment files (Dentsply, Maillefer, Ballaigues, Switzerland) accompanied by orange oil gutta percha solvent. At a speed of 500 rpm and torque of 2.5 N.cm, the obturating material from the coronal part was removed using a Pro-Taper universal retreatment file D1 size 30, which has a 0.09 taper. The file was utilized without engaging the coronal dentin. Pro-Taper universal retreatment file D2 size 25 with 0.08 taper was used at same torque and speed to the middle third. Finally, Pro-Taper universal retreatment file D3 size 20 with 0.07 taper was used same torque and speed in the apical third, advancing till the working length was achieved. Progressive progression to the apex, incorporating in-and-out motion alongside brushing, regular withdrawal of the file for inspection, and elimination of debris from the propellers before proceeding. [16, 17]. Single drop of the orange oil solvent was dispensed into the canal during every instrument change. Irrigation was achieved with one mL of full-concentrated NaOCl between each instrument during the retreatment. The canal preparation was considered finished when the D3 file achieved the full length, with no further filler material retrieved by the file [18].

Group 4; Pro-Taper file without Gutta percha solvent:

The samples in these groups were retreated with Pro-Taper Universal retreatment files without gutta percha solvent. Pro-Taper Universal retreatment files were utilized as outlined in Group 3, however without a solvent.

Group 5; Mtwo files with Gutta percha solvent

The samples in these groups were retreated with Mtwo retreatment files (VDW, Germany) and orange oil gutta percha solvent. Mtwo retreatment file size 15 with 0.05 taper (white coded) was utilized to the working length at speed 300 rpm and torque of 1.5 N.cm. Followed by MTwo file size 25 with 0.05 taper (red coded) until the WL, at same torque and speed. Both files used with brushing motion with lateral pressing movement [5]. Regularly remove the file for inspection and clear the propellers of debris before proceeding [19]. A single drop of solvent was administered to the root canal with each instrument change. Irrigation was made with one mL of full concentrated NaOCl after every file during the retreatment.

Group 6; Mtwo files without Gutta percha solvent

The samples in these groups were retreated with MTwo retreatment files without gutta percha solvent. MTwo retreatment files were utilized as described in Group 5 but in absence a solvent.

Each specimen in all groups underwent final irrigation with five mL of half-concentrated NaOCl.

Each file was utilized a maximum of five times and subsequently discarded upon noticing any sign of distortion.

Methods of Evaluation

Time recorded

Stop watch was utilized to measure the duration of retreatment. Upon reaching the full length **(T1)**

was noted. The duration needed for instrument change was excluded. The duration necessary for effective gutta-percha eradication was documented as **(T2)**. The summation of T1 and T2 was the total duration for retreatment. A single operator performed all processes in order to ensure no bias. [5]

Cleaning ability assessment

All samples were grooved with a diamond disk then longitudinally bisected with a mallet and chisel. The half exhibiting the greatest quantity of noticeable filling was chosen and placed beneath the Scanning Electron Microscope (JEOL, India), attached to a SEM support following gold plating [20]. At 1000x magnification, the presence of residue in the apical, middle, and cervical parts was evaluated in locations placed centrally at 3, 6, and 9 mm from the apex, respectively.

The quantity of residue was evaluated based on the criteria established by Ezzie et al. [4] **Table 1**

TABLE (1) Ezzie et al.'s criteria

Score	Criteria
1	Negligible or minimal presence of filler material leftovers (0%-25%).
2	Low to moderate presence of filler material leftovers (25%-50%)
3	Moderate to great presence of filler material leftovers (50%-75%)
4	Great presence of filler material leftovers (75%–100%).

Three examiners separately assessed the existence of residue on the walls of the root canal. The approaches of retreatment employed for each specimen were obscured, and scoring was conducted. [5]

Statistical analysis

Numerical data were presented as mean values accompanied with standard deviation (SD). The distribution of data was examined for normality utilizing the Shapiro-Wilk test, and variance homogeneity was evaluated with Levene's test. The retreatment time data exhibited a normal distribution; however, the assumption of homogeneity was violated, necessitating analysis employing Welch one-way ANOVA, accompanied by the post hoc test. Cleaning ability scores were analyzed using two-way cumulative link mixed models and simple effects comparisons. P-values were adjusted for multiple comparisons utilizing the False Discovery Rate approach. The significance level was set at $p<0.05$. Statistical analysis was accomplished with R statistical analysis software version 4.4.2.

RESULTS

Regarding the time needed for retreatment, there was a substantial variance among different groups ($p<0.001$). The highest retreatment time (9.97±1.61) (minutes) was recorded during using H file without Gutta percha solvent, while the lowest retreatment time (2.33±0.55) (minutes) was recorded during using Pro-Taper file with solvent. As showed in table (2), figure (1).

TABLE (2) Intergroup comparisons and summary statistics of retreatment time (min).

Time	Retreatment time (min) (Mean±SD)						p-value
	Group (I)	Group (II)	Group (III)	Group (IV)	Group (V)	Group (VI)	
T1	3.64 ± 0.83^{AB}	4.62 ± 1.02^{A}	1.04 ± 0.22^{D}	1.32 ± 0.23^{D}	2.08 ± 0.39^{C}	2.67 ± 0.71^{BC}	**<0.001***
T2	4.22 ± 0.74^{AB}	5.35 ± 0.70^{A}	1.29 ± 0.33^{D}	1.56 ± 0.34^{D}	2.27 ± 0.39^{C}	3.69 ± 0.84^{B}	**<0.001***
Tt	7.86 ± 1.55^{AB}	9.97 ± 1.61^{A}	2.33 ± 0.55^{D}	2.88 ± 0.48^{D}	4.35 ± 0.77^{C}	6.36 ± 1.45^{BC}	**<0.001***

Values with different superscripts within the same horizontal row are significantly different, * significant (p<0.05).

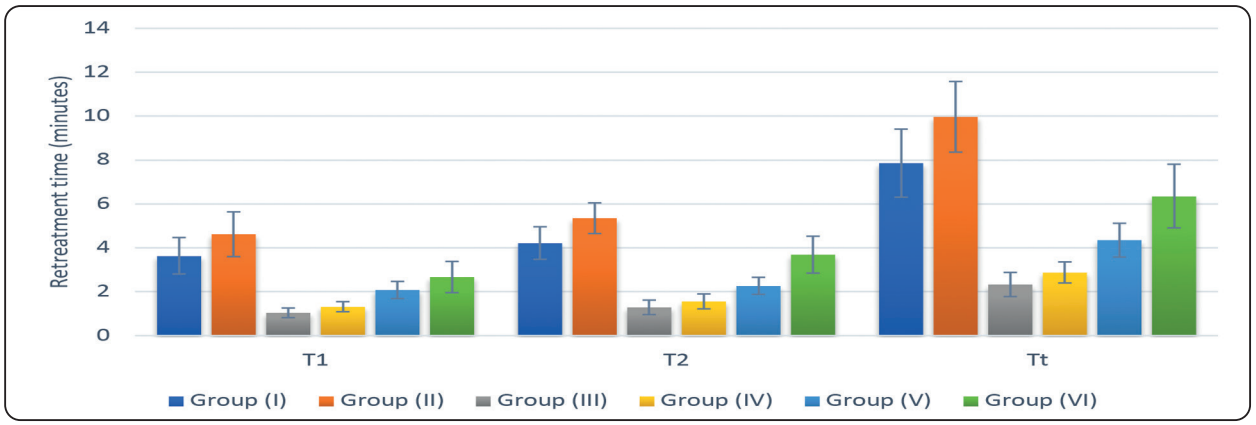

Fig. (1) Bar chart showing mean of retreatment time (min) for different groups.

Regarding the cleaning ability assessment, there was a substantial difference among different groups ($p<0.001$). The highest cleaning score at apical third was found in group (V) while at middle third was found in group (I). At cervical third the highest cleaning score was found in group (I). As showed in table (3), figure (2).

TABLE (3) Intragroup comparisons and summary statistics of cleaning ability score.

Group	Cleaning ability score (Mean±SD)			p-value
	Apical	Middle	Cervical	
Group (I)	3.43±0.53^{A}	3.57±0.53^{A}	3.14±0.69^{A}	**0.391ns**
Group (II)	1.86±0.69^{A}	1.86±0.38^{A}	1.71±0.49^{A}	**0.829ns**
Group (III)	2.57±0.53^{A}	2.71±0.49^{A}	2.29±0.49^{A}	**0.327ns**
Group (IV)	2.00±0.58^{A}	1.86±0.38^{A}	1.57±0.53^{A}	**0.268ns**
Group (V)	3.57±0.79^{A}	3.14±0.69^{A}	3.00±0.58^{A}	**0.110ns**
Group (VI)	2.43±0.53^{A}	2.00±0.82^{A}	1.86±0.38^{A}	**0.092ns**

Values with different superscripts within the same horizontal row are significantly different, ns not significant.

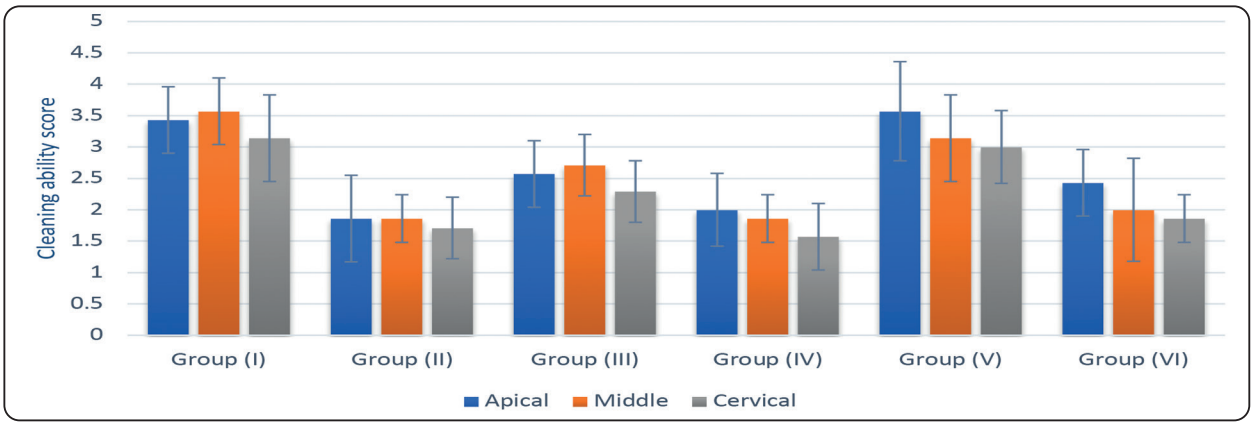

Fig. (2) Bar chart showing mean of cleaning ability score in different root sections.

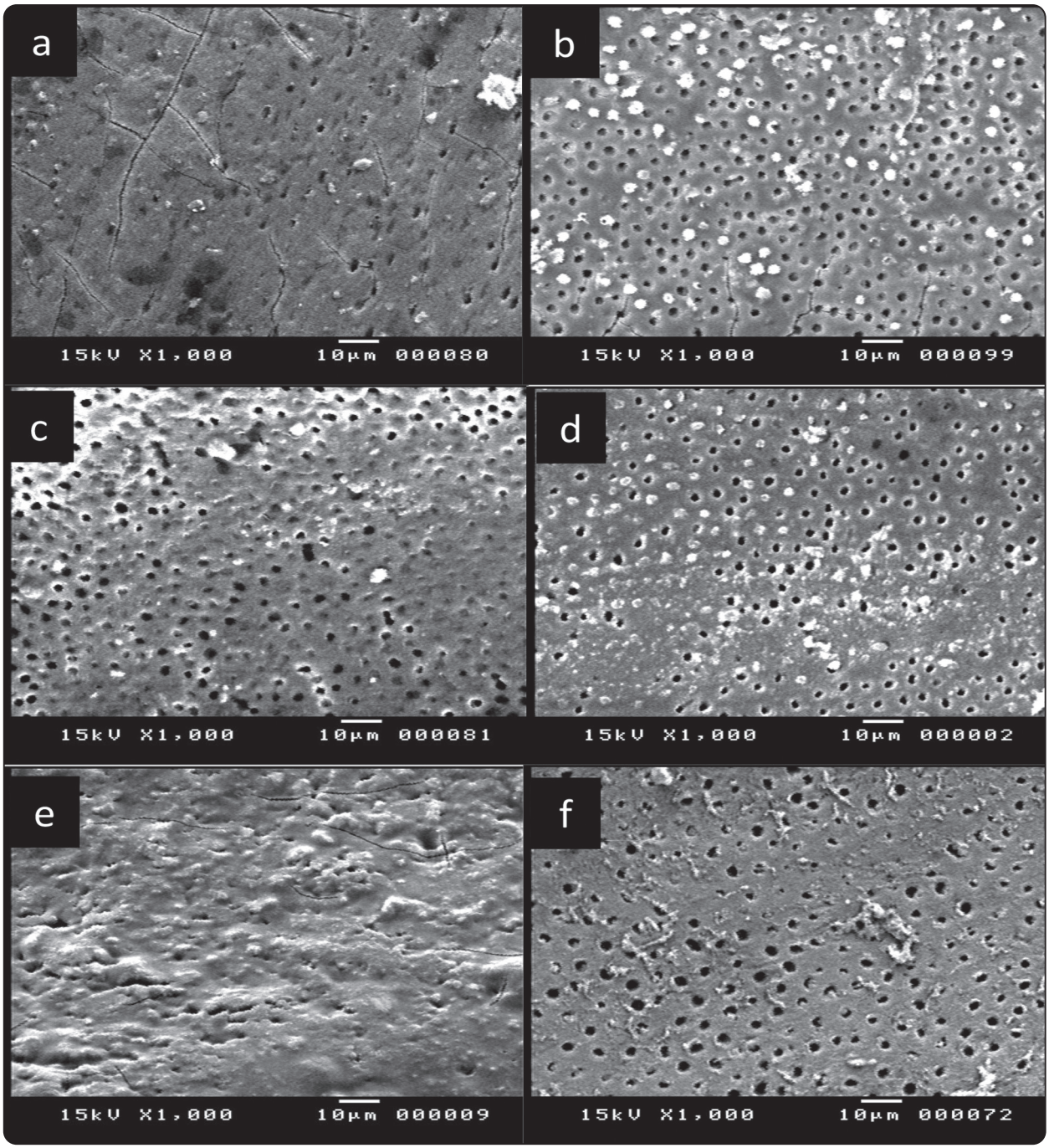

Fig. (3) SEM micrographs showing cleaning ability at apical third for the groups (a: group I) (b: group II) (c: group III) (d: group IV) (e: group V) (f: group VI)

DISCUSSION

The effective removal of gutta-percha and sealer, accompanied by suitable chemico-mechanical porotcol, is essential for accessing necrotic pulp remnants and residual bacteria [21]. According to previous studies, no procedure currently in use can guarantee the total eradication of old filler materials from the root canal [22,23].

Chloroform has historically served as a prevalent solvent for the quick eradication of gutta-percha due to its rapid dissolving properties. Agency for Research on Cancer has classified chloroform as carcinogenic, resulting in cessation of its use [3]. To eliminate gutta-percha, further solvents such as halothane, tetrachloroethylene, xylene, and orange oil have been recommended. Tetrachloroethylene exhibits the lowest dissolving effectiveness, whereas xylene and orange oil have superior performance due to their pronounced lipophilic properties. Xylene, an aromatic hydrocarbon, exhibits a high capacity to dissolve organic substances, thereby facilitating the breakdown of gutta-percha. Orange oil, which contains d-limonene, is a natural solvent known for its biocompatibility and effectiveness in softening gutta-percha [24].

It is possible that the file morphology and design of Pro-Taper retreatment files make them more effective. There are three pro-taper retreatment instruments available, each with a different length and taper: D1, D2, and D3. Because of these characteristics, the retreatment files can remove both the canal filler materials and the superficial dentin in the root. In addition, the obturation material is drew into the flutes and guided to the orifice by the particular design of the flutes and rotary motion of the Pro-Taper retreatment instruments [25]. Mtwo retreatment files do not have radial land relief and have a positive rake angle. A positive rake angle makes the file more efficient at cutting gutta percha, which makes it easier to remove it. The Pro-Taper and Mtwo retreatment files have a constantly shifting helical pitch, that encourages material eradication to the coronal part [26].

In our study, teeth were decoronated, leaving 15 mm of root to facilitates the process of standardizing the samples by regulating variables like morphology of the crown and root canal access, despite not simulating retreatment in clinical environments. This enables a more accurate comparison of retreatment procedures in endodontics. [27]

A SEM was utilized to capture images of the root canal after eradication of filler material, utilizing a significant magnification of 1,000 x. This method allows for the observation and identification of the remaining obturation material through the acquisition of high-resolution images [28]. Debris scores were evaluated based on the criteria established by Ezzie et al [29]. where higher scores indicated more remaining filling material and hence poorer canal cleanliness. This strategy was selected due to its simplicity. Hulsmann and Bluhm (2004) proposed an alternative scoring system in which sealer and gutta-percha were assessed in millimeters, with scoring conducted on a scale from 1 to 7 [30].

Before SEM procedure, the specimens were grooved and halved longitudinally with diamond discs and a chisel to ensures the split is done without contaminating the root canal or damaging the dentinal tubules. [9,31]

The findings indicated that Group 2 (H-files without solvent) had the longest retreatment time, whereas Group 5 (MTwo with solvent) and Group 3 (ProTaper with solvent) exhibited significantly shorter times. This highlights the combined effect of rotary instrumentation and gutta-percha solvent in reducing retreatment time. Solvent application clearly enhanced the dissolution and softening of the filling material, facilitating faster removal. Another study indicated that hand files were more efficient throughout the retreatment operation, a conclusion that may be ascribed to the change of rotary

files [32]. Also, other research indicated that rotary files in absence of solvent accelerated the retreatment duration [33]. The application of solvents resulted in a thin coating of soft gutta-percha adhering to the walls of the canal through retreatment, thus increasing the duration to remove it.

The result of our study in accordance to most previously published studies [30,34]. This observation is attributed to the plasticization of gutta-percha caused by rotating instrumentation [30], facilitating the rapid penetration and retrieval of softened gutta-percha.

In contrast, H-files, particularly without solvent (Group 2), required more time likely due to limited cutting efficiency and increased manual effort. Although solvent usage in Group 1 improved their performance, the overall time remained higher than that of rotary systems.

Among all tested groups, Group V (MTwo with solvent) consistently presented the highest residual scores, particularly in the apical third (3.57±0.79), followed by the middle (3.14±0.69) and cervical thirds (3.00±0.58). These results suggest that, despite the theoretical advantage of solvent-assisted gutta-percha softening, the MTwo system may have struggled to efficiently engage and eliminate the softened material. The reduced efficacy of the Mtwo retreatment files may be attributed to their smaller tapers (0.05) compared to the Pro-Taper retreatment files (0.07, 0.08, and 0.09). [35]

Conversely, Group IV (Pro-Taper without solvent) achieved the lowest cleaning scores across the apical, middle, and cervical thirds, indicating superior canal cleanliness among all tested groups. This suggests that mechanical action alone when delivered through efficient file design and controlled rotary motion may be more effective in gutta-percha removal than relying on chemical assistance. [18]

Consistent with Takahashi et al. [31] we discovered that solvent had no substantial impact on root canal wall cleanliness. Also, Dadresanfar et al. [36] demonstrated that application of solvent had negative effect on retreatment capability of Mtwo retreatment files. Solvents should be utilized exclusively in specific circumstances where the prior working length could not be achieved without them [37].

The utilization of single-rooted teeth may limit our study, as root curvature significantly influences the efficacy of root canal instruments and cleaning efficiency. The qualitative score-based SEM analysis may exhibit subjectivity, with variations in image selection and evaluation among different examiners.

There is a high-volume percentage of residue in the apical regions because the primary treatment's preparation size remained unchanged following the removal of the obturation material. Because of this, additional research is required to determine the efficacy of re-instrumenting the canals with bigger instruments following a retreatment process in order to achieve better apical cleaning.

CONCLUSION

Overall, the study indicating better debridement were predominantly associated with rotary systems used without solvents, particularly Pro-Taper retreatment files. The use of solvents, while potentially beneficial in softening gutta-percha, did not consistently translate into improved cleaning outcomes in this experimental setting.

REFERENCES

1. Lovdahl PE. Endodontic retreatment. Dent Clin North Am. 1992; 36:473–90.
2. Siqueira JF Jr. An Etiology of root canal treatment failure: why well-treated teeth can fail. Int Endod J. 2001;34(1):1–10.
3. Schirrmeister JF, Wrbas KT, Meyer KM, Altenburger MJ, Hellwig E. Efficacy of different rotary instruments for gutta-percha removal in root canal retreatment. J Endod. 2006; 32:469–72.

4. Friedman S, Stabholz A. Endodontic retreatment case selection and technique. Part 1: Criteria for case selection Endod 1986; 12:28-33.

5. Purba R & Sonarkar SS & Podar R & Singh S & Babel S & Kulkarni G. Comparative evaluation of retreatment techniques by using different file systems from oval-shaped canals. J Conserv Dent. 2020 Jan-Feb;23(1):91-96.

6. Maria R, Dutta SD, Thete SG, AlAttas MH. Evaluation of Antibacterial Properties of Organic Gutta-percha Solvents and Synthetic Solvents Against Enterococcus faecalis. J Int Soc Prev Community Dent. 2021 Apr 15;11(2):179-183.

7. Khedmat S, Hashemi A, Dibaji F, Kharrazifard MJ. Effect of chloroform, eucalyptol and orange oil solvents on the microhardness of human root dentin. J Dent (Tehran). 2015 Jan;12(1):25-30.

8. Kasam S, Mariswamy AB. Efficacy of Different Methods for Removing Root Canal Filling Material in Retreatment - An In-vitro Study. J Clin Diagn Res. 2016;10(6): ZC06-ZC10.

9. Akhavan H, Azdadi YK, Azimi S, Dadresanfar B, Ahmadi A. Comparing the Efficacy of Mtwo and D-RaCe Retreatment Systems in Removing Residual Gutta-Percha and Sealer in the Root Canal. Iran Endod J. 2012;7(3):122–6.

10. Gergi R, Sabbagh C. Effectiveness of two nickel-titanium rotary instruments and a hand file for removing gutta-percha in severely curved root canals during retreatment: an ex vivo study. Int Endod J 2007; 40: 532-537.

11. Mollo A, Botti G, Prinicipi Goldoni N, Randellini E, Paragliola R, Chazine M. Efficacy of two Ni-Ti systems and hand files for removing gutta-percha from root canals. Int Endod J 2012; 45:1

12. Faul F & Erdfelder E & Lang AG & Buchner A. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods. 2007 May;39(2):175-91.

13. Özyürek T, Demiryürek EÖ. Comparison of the Effectiveness of Different Techniques for Supportive Removal of Root Canal Filling Material. Eur Endod J. 2016 Dec; 1:1-6.

14. Castro RF, Melo JDSS, Dias LCL, Silva EJNL, Brandão JMDS. Evaluation of the efficacy of filling material removal and re-filling after different retreatment procedures. Braz Oral Res. 2018; 32:94.

15. Chauhan R, Tikku A, Chandra A. Detection of residual obturation material after root canal retreatment with three different techniques using a dental operating microscope and a stereomicroscope: An in vitro comparative evaluation. J Conserv Dent. 2012 Jul;15(3):218-22.

16. Zongova-Adem SE, Tsenova-Ilieva IK, Dogandzhiyska VD, Topalova-Pirinska SZ, Karova EG. Pro-Taper universal retreatment potential in oval-shaped canals filled with different obturation techniques-A micro-computed tomography study. J Int Soc Prev Community Dent. 2024 Apr ;14(2):152-160.

17. Alves FR, Ribeiro TO, Moreno JO, Lopes HP. Comparison of the efficacy of nickel-titanium rotary systems with or without the retreatment instruments in the removal of gutta-percha in the apical third. BMC Oral Health. 2014; 14:102.

18. Koçak MM, Koçak S, Türker SA, Sağlam BC. Cleaning efficacy of reciprocal and rotary systems in the removal of root canal filling material. J Conserv Dent. 2016 Mar-Apr;19(2):184-8.

19. Kishore KN, Varma KM, Sajjan GS, Satish RK, Mohammad R, Dutta GS. Comparative evaluation of efficacy of three single file retreatment systems for removal of gutta percha and assessment of root canal transportation An In Vitro study. Indian J Dent Res. 2022 Oct-Dec;33(4):435-9.

20. Vidal FT, Nunes E, Horta MC, Freitas MR, Silveira FF. Evaluation of three different rotary systems during endodontic retreatment - Analysis by scanning electron microscopy. J Clin Exp Dent. 2016 Apr;8(2): e125-9.

21. Zandi H, Petronijevic N, Mdala I, Kristoffersen AK, Enersen M, Roˆ c¸as IN. Outcome of endodontic retreatment using 2 root canal irrigants and influence of infection on healing as determined by a molecular method: a randomized clinical trial. J Endod 2019; 45(9): 1089-1098

22. Zhang MM, Fang GF, Chen XT, Liang YH. Four-year outcome of nonsurgical root canal retreatment using cone-beam computed tomography: a prospective cohort study. J Endod 2021; 47(3): 382-390.

23. de Carvalho Maciel AC, Zaccaro Scelza MF. Efficacy of automated versus hand instrumentation during root canal retreatment: an ex vivo study. Int Endod J 2006; 39(10): 779-784.

24. Mushtaq M, Farooq R, Ibrahim M, Khan FY. Dissolving efficacy of different organic solvents on gutta-percha and resilon root canal obturating materials at different immersion time intervals. J Conserv Dent. 2012;15(2):141-145.

25. Iriboz E, Sazak Öveçoğlu H. Comparison of Pro-Taper and Mtwo retreatment systems in the removal of resin-based root canal obturation materials during retreatment. Aust Endod J. 2014 Apr;40(1):6-11.

26. Dioguardi M, Stellacci C, La Femina L, Spirito F, Sovereto D, Laneve E, et al. Comparison of endodontic failures between nonsurgical retreatment and endodontic surgery: Systematic review and meta-analysis with trial sequential analysis. Medicina (Kaunas) 2022; 58:894.

27. Kumar T, Mittal S, Keshav V, Kaur R, Maakhni E. A comparative evaluation of remaining dentin thickness following biomechanical preparation of teeth using different rotary file systems: an: in vitro: study. Journal of Conservative Dentistry and Endodontics 2022; 25(1): 32-36.

28. Jain M, Singhal A, Gurtu A, Vinayak V. Influence of ultrasonic irrigation and chloroform on cleanliness of dentinal tubules during endodontic retreatment – An in vitro SEM study. J Clin Diagn Res. 2015;9: ZC11–5.

29. Ezzie E, Fleury A, Solomon E, Spears R, He J. Efficacy of retreatment techniques for resin-based root canal obturating material. J Endod. 2006; 32:341–4.

30. Hülsmann M, Bluhm V. Efficacy, cleaning ability and safety of different rotary Ni-Ti instruments in root canal retreatment. Int Endod J. 2004; 37:468–76.

31. Takahashi CM, Cunha RS, de Martin AS, Fontana CE, Silveira CF, da Silveira Bueno CE. In vitro evaluation of the effectiveness of Pro-Taper universal rotary retreatment system for gutta-percha removal with or without a solvent. J Endod.2009;35(11):1580–3.

32. Barrieshi-Nusair KM. Gutta-percha retreatment: Effectiveness of Nickle titanium rotary instruments versus stainless-steel hand files. J Endod. 2002; 28:454–6.

33. Gu LS, Ling JQ, Wei X, Huang XY. Efficacy of Pro-Taper Universal rotary retreatment system for gutta-percha removal from root canals. Int Endod J. 2008; 41:288–95.

34. Kfir A, Tsesis I, Yakirevich E, Matalon S, Abramovitz I. The efficacy of five techniques for removing root filling material: microscopic versus radiographic evaluation. IntEndod J. 2012; 45:35–41.

35. Madarati AA, Al-Nazzawi AA, Sammani AMN, Alkayyal MA. The efficacy of retreatment and new reciprocating systems in removing a gutta-percha-based filling material. J Taibah Univ Med Sci. 2018 Jun 27;13(5):452-458.

36. Dadresanfar B, Iranmanesh M, Mohebbi P, Mehrvarzfar P, Vatanpour M. Efficacy of Two Rotary Ni-Ti Instruments in Removal of Resilon/Epiphany Obturants. Iran Endod J. 2012;7(4):183–8.

37. Boariu M, Nica LM, Marinescu A, et al. Efficiency of eucalyptol as organic solvent in removal of gutta-percha from root canal fillings. Rev Chim-Bucharest. 2015;66(6):907-910.