Original Article

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Dentistry Section

Efficacy of Rotary Retreatment Techniques Assisted with Passive Ultrasonic Activation of Resin Solvent in Removal of Gutta-percha with Epoxy Resin and MTA based Root Canal Sealers: An In-vitro Study

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ABSTRACT

Introduction: Endodontic retreatment is indicated in cases of failed primary endodontic treatment. The main goal of retreatment is to establish conditions that will enable the healing of the periapical tissue.

Aim: To evaluate the efficacy of rotary retreatment with the ProTaper Universal Retreatment system supplemented with passive ultrasonic activation of solvent in retreatment of single-rooted mandibular premolar teeth obturated with gutta-percha and two different root canal sealers {AH Plus and Mineral Trioxide Aggregate (MTA) Fillapex}.

Materials and Methods: This in-vitro study was conducted in the Department of Conservative Dentistry and Endodontics at Mahatma Gandhi Mission's Dental College and Hospital, Navi Mumbai, Maharashtra, India, from January 2019 to April 2019. Total 66 freshly extracted human single rooted mandibular premolars were used in this study. Root canal preparation was done using ProTaper Next (PTN) rotary files. Teeth were decoronated to get a uniform length of 18 mm and were divided into three retreatment groups based on the technique used for retreatment. Group I included rotary retreatment, group II involved rotary retreatment with solvent and paper point wicking, and group III involved rotary retreatment with passive ultrasonic activation of solvent and paper point wicking. Based on the sealer used for obturation, teeth in each group were further divided into two subgroups, subgroup A with AH Plus sealer and subgroup B with MTA Fillapex sealer. Teeth were stored in an incubator for 30 days to allow sealer to set after which sectioning of the specimens were done buccolingually for examination under the stereomicroscope and photographed. Statistical analysis was done by using parametric Analysis of Variance (ANOVA) followed by Posthoc tests and Unpaired t-test.

Results: No statistically significant difference in percentage area of residual root canal filling material noted between the group I and II and when obturated with gutta-percha and AH Plus sealer (subgroup A) as p-value=0.215. Whereas, it revealed a statistically significant difference between the group I, II, and III when obturated with gutta-percha and MTA Fillapex sealer (subgroup B) as p-value <0.001.

Conclusion: Passive ultrasonic activation of solvent after gutta-percha removal using ProTaper Universal rotary files could improve the quality of endodontic retreatment.

Keywords: AH plus sealer, Endosolv R, Mineral trioxide aggregate fillapex root canal sealer, ProTaper universal retreatment file, Stereomicroscope

INTRODUCTION

A successful outcome of the retreatment procedure depends on the effective removal of filling material from the root canal system [1]. An effectively performed procedure promotes better cleaning and disinfection because instruments and irrigating solutions reach the entire root canal system [2]. There are several techniques for removing Gutta-percha (GP) and sealer from filled root canals including hand files, burs, automated devices, rotary, reciprocating instruments, and sonic or ultrasonic irrigation which are generally preceded by softening of the filling material with different solvents or heat [1]. Different rotary instrumentation systems have been developed specifically such as XP-endo finisher, RaCe, FlexMaster, and ProTaper Universal Retreatment (PTUR) system for removal of gutta-percha and sealer.

However, a small amount of residual gutta-percha and sealer was observed to be left on canal walls post retreatment as observed in stereomicroscopic studies [3]. All retreatment techniques leave residual debris in the canal walls after reinstrumentation [4]. Necrotic tissue or bacteria, covered by the remaining GP or sealer may be responsible for periapical inflammation or pain and complete removal of it is necessary for a successful outcome. This enables thorough chemomechanical reinstrumentation and disinfection of the root canal system [3]. The primary goal of root canal retreatment is to stop the infectious process through the removal of filling material, debris, and microorganisms that cause apical periodontitis [5]. To remove residual obturating material, passive ultrasonic activation has been suggested as a supplemental technique in addition to the routine retreatment methods. During root canal retreatment, a solvent can be used to facilitate the removal of gutta-percha by softening it. Gutta-percha and most sealers are miscible in chloroform, xylene, and endosolv and once in the solution can be absorbed and removed with appropriately sized absorbent points [6]. Passive Ultrasonic Activation (PUA) involves ultrasonically activating a file inside a root canal filled with an endodontic irrigant [7].

Isthmus and accessory canals filled with gutta-percha and sealer are very difficult to remove during retreatment as these endodontic sealers penetrate deep in dentinal tubules leaving back residual filling materials [8]. To date, few reports have studied the effectiveness of rotary systems supplemented with passive ultrasonic activation of solvent while removing root canal filling material [8-10]. None of the studies have evaluated the effect of PUA in the removal of MTA Fillapex root canal sealer.

The aim of this study was to evaluate whether passive ultrasonic activation of solvent will enhance the removal of gutta-percha and root canal sealer. The null hypothesis states that there will be no improvement in the efficacy of rotary retreatment when supplemented with passive ultrasonic activation of solvent in the removal of gutta-percha in epoxy resin-based sealer or gutta-percha in MTA based sealer from the root canal treated teeth.

MATERIALS AND METHODS

This in-vitro study was conducted in the Department of Conservative Dentistry and Endodontics at Mahatma Gandhi Mission's Dental College and Hospital, Navi Mumbai, Maharashtra, India, from January 2019 to April 2019. Ethical approval was obtained from Institutional Ethics Committee (MGM/DCH/IERC/492/17). A total of 66 freshly extracted human single rooted mandibular premolar teeth were chosen for the study.

Inclusion criteria: Permanent human single rooted mandibular premolars with a single root canal extracted for periodontal and orthodontic reasons, intact teeth with no cracks or defects, teeth with similar crown-root dimensions, without caries, having a single root canal with closed or mature apices, with a patent root canal and teeth with a straight canal with minimal curvature (0 to 10 degrees) were included in the study.

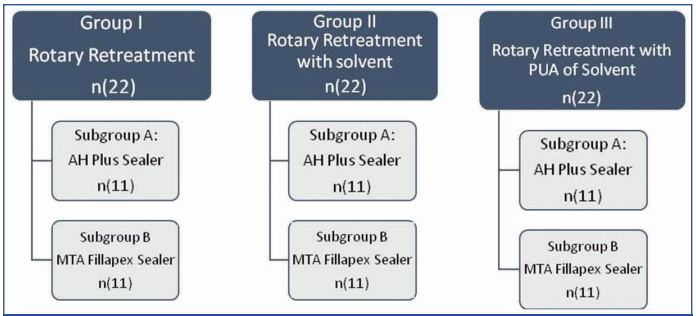
Exclusion criteria: Deciduous teeth, permanent human teeth with multiple roots and canals, teeth with pre-existing dentinal cracks or microcracks or fracture defects, teeth with caries, hypoplastic defects, external and internal root resorption, restorations, anatomic malformations, root canals with calcifications and the root canal treated teeth were excluded from the study.

Endodontic Treatment

The selected teeth were immersed in 5% Sodium Hypochlorite (NaOCl, Trifarma, India) for an hour to remove any organic debris. All 66 teeth were decoronated with a diamond disc to get a uniform length of 18 mm. All the root canals were instrumented by the same operator using ProTaper Next (PTN) (Dentsply, Tulsa Dental, Switzerland) rotary system. Canal preparation was done using a crown down approach till instrument size X3 (#30, 0.07) followed by circumferential filing with the Master Apical File (MAF). Throughout instrumentation, 25 mL 5% sodium hypochlorite (Trifarma, India) was delivered from a 30-gauge irrigation side venting needle (Neo Endo, London United Kingdom) between each file. Once instrumentation was completed, Passive Ultrasonic Irrigation (PUI) was performed in all the teeth using a No. 25 Irrisafe ultrasonic tip (Acteon, Satelec United Kingdom) kept 2 mm short of working length at a power setting of 3 with 5% sodium hypochlorite solution for three cycles of 20 seconds for a total volume of 6 mL. This was followed by 17% Ethylenediamine Tetra Acetic acid (EDTA, META BIOMED, Korea) and similarly for three cycles of 20 seconds for a total volume of 6 mL of 17% EDTA. This was followed by flushing the canals with 6 mL of 5% sodium hypochlorite and would be finalised with irrigation using 20 mL distilled water (Nir life, India).

The selected teeth were randomly assigned into three groups based on the retreatment technique to be carried out with 22 teeth in each group. Each group was divided into two subgroups based on the sealer used along with gutta-percha for obturation. Teeth belonging to subgroup A were obturated with GP and epoxy resin-based sealer (AH Plus) (Dentsply, Tulsa Dental, Switzerland) while those in subgroup B were obturated with GP and Mineral Trioxide Aggregate (MTA) based sealer (MTA Fillapex) (Angelus, Londrina, Parana, Brazil) [Table/Fig-1]. The sealers were manipulated as per the manufacturer's instructions.

The quality of root filling was deemed adequate when no voids were seen on radiographs and obturation appeared dense [11]. Access opening was temporised with Intermediate Restorative Material (IRM)



[Table/Fig-1]: Flowchart showing the distribution of teeth in Groups I, II, and III, and each group is further divided into two subgroups based on the sealer used for obturation.

(Dentsply, Tulsa Dental, Switzerland). The specimens were stored under 100% humidity at 37°C for 30 days to allow the sealer to set completely in an incubator (Dolphin, India) [12].

Rotary retreatment was carried out using ProTaper Universal Rotary Retreatment system (PTUR, Dentsply, Tulsa Dental, Switzerland). Endosolv R was used as a solvent during the retreatment procedure. #25 Irrisafe ultrasonic tip (Irrisafe tips, Acteon, Merignac, France) was used for Passive Ultrasonic Activation of solvent.

Endodontic Retreatment

Group I: Gates Glidden drill (Mani Inc, Japan) sizes 2 and 3 were used in the first 3 mm of the root canal coronally. Root fillings were removed with PTUR instruments (Dentsply, Tulsa Dental, Switzerland) following the manufacturer's instructions. Rotary retreatment files D1, D2, and D3 were sequentially used in a crown-down manner at a speed of 500 rpm and torque of 3N/cm to reach the pre-established working length; they were manipulated in a brushing action. A single operator performed all filling removal protocols. The rotary instruments were used for five teeth and then discarded.

Group II: Rotary retreatment was supplemented with Endosolv R solvent and the procedure was carried out similar to the technique described in group I. A 0.1 mL of Endosolv R was introduced in the root canal to soften the gutta-percha for 30 seconds before instrumentation. The solvent-filled canal was then dried with absorbent points called 'wicking'; this is the final stage in GP removal [12]. The canal was flooded with 1 mL of Endosolv R and the solution was absorbed and removed with appropriately sized absorbent points [12]. The canal was replenished with 1 mL of solvent and the above procedure was repeated till the absorbent points came out dry. Absorbent points aided in the removal of GP by drawing dissolved materials into and then out of the shaped canal. Even when absorbent points came out of the canal clean, white, and dry, it was assumed that residual GP and sealer might be still present [13].

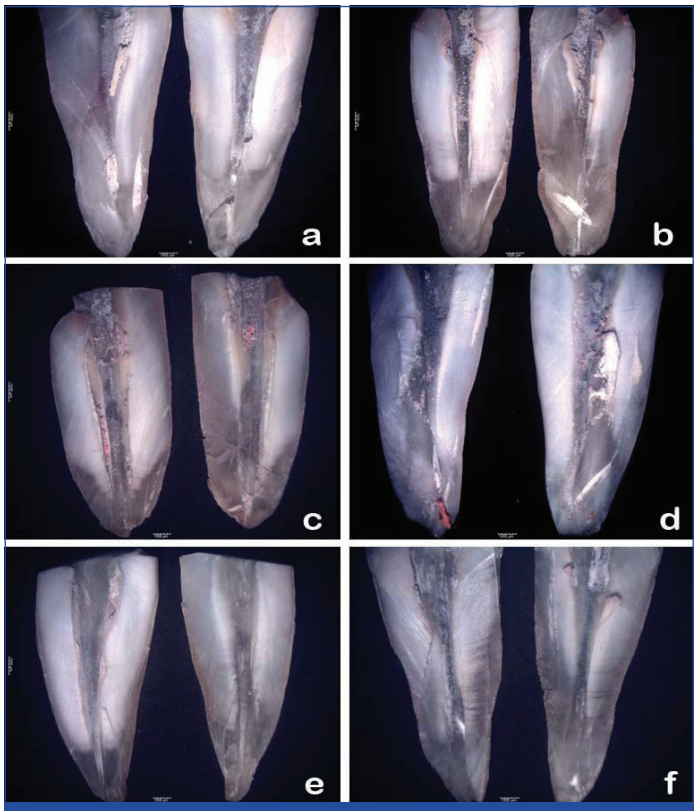
Group III: Rotary retreatment was done according to the technique described in group I. The canal was flooded with 1 mL of Endosolv R and passive ultrasonic activation of it was performed for one minute in three cycles of 20 seconds, with a No 25 Irri safe ultrasonic tip at 1 mm short of the working length, in an up-and-down motion. The ultrasonic handpiece (Satelac, Acteon, Merignac, France) was set to operate at a power setting of 3. The solvent solution was replenished after each cycle of 20 seconds. The solution was then absorbed and removed with appropriately sized absorbent points. Paper point wicking was done according to the technique described in group II.

Irrigation protocol during retreatment: Irrigation during filling removal was performed using a total of 25 mL of 5% NaOCl solution per tooth in each group. The smear layer in each tooth was removed by irrigation with 5 mL 17% EDTA for 3 minutes [14]. This was followed by flushing the canals with 5 mL of 5% sodium hypochlorite and was finally irrigated using 5 mL distilled water. Distilled water acts as an inert solution that does not possess damaging properties to dentinal structure [15]. The filling removal procedure was considered

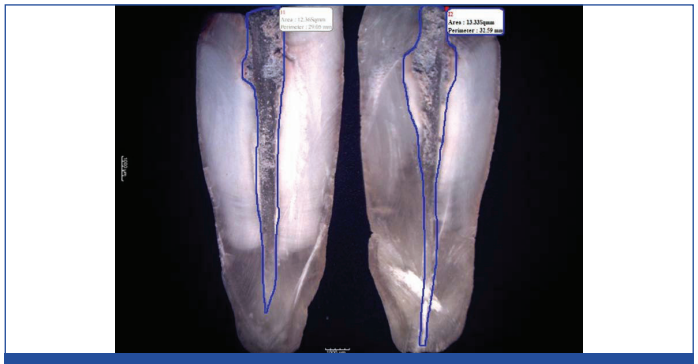
complete when no further filling material was evident adhering to the instrument used during retreatment [16].

Coding of specimens and assessment of obturation removal: Coding of the specimens were done by an independent observer to remove operator bias before the evaluation of residual filling material. To evaluate the residual filling material along the root canal wall, the teeth were grooved buccolingually using a high-speed diamond disk and sectioned longitudinally using a chisel. Digital images were obtained using the stereomicroscope (Moticam, Hongkong) and Motic camera (Moticam, Hongkong) by placing the sectioned tooth on a black platform under 1X magnification and were transferred to a computer. The photographs of the specimens obtained were captured as JPEG images [Table/Fig-2a-f]. The residual filling material was assessed by loading the images into motic imaging software (Moticam, Hongkong) and measuring the area of the remaining filling material (by tracing the residual filling material inside the root canal) relative to the total root canal area (by tracing the root canal outline) [9] [Table/Fig-3,4]. Three readings were taken and amongst them, the average value was considered. The percentage of the remaining filling material on the canal walls were calculated with the following equation [9].

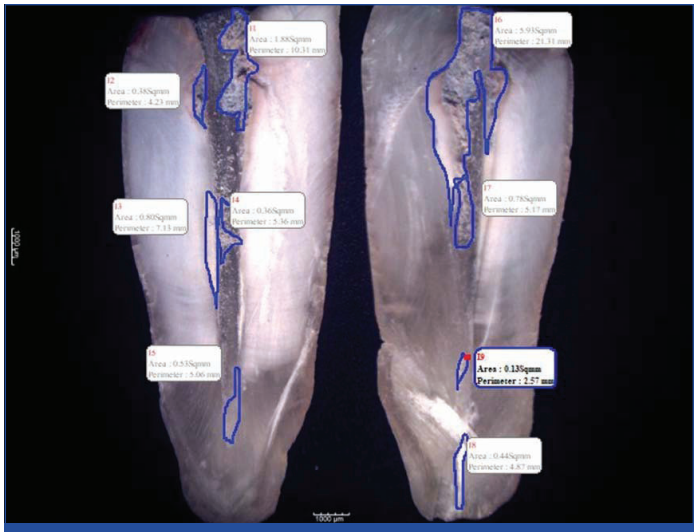
$$\% \text{ Area of remaining filling material} = \frac{\text{Area of remaining filling material}}{\text{Area of canal space}} \times 100$$



[Table/Fig-2]: Stereomicroscopic images under 1X magnification for specimens belonging to; a) Group I Subgroup A; b) Group I Subgroup B; c) Group II Subgroup A; d) Group II Subgroup B; e) Group III Subgroup A; f) Group III Subgroup B.



[Table/Fig-3]: Tracing done using motic imaging software to calculate total area of root canal (mm^2).



[Table/Fig-4]: Tracing done using motic imaging software to calculate area of remaining root canal filling material (mm^2).

STATISTICAL ANALYSIS

Statistical analysis was done using Statistical Package for Social Sciences software (IBM SPSS Statistics, University of Chicago) version 16.0. The data obtained was presented using descriptive statistics such as mean, standard deviation, maximum and minimum values. The mean percentage values relative to the total canal area was compared. Normality of the data was tested using Kolmogorov-Smirnov test. The data was found to be normally distributed and further analysis was done using parametric Analysis of Variance (ANOVA) followed by Posthoc tests and Unpaired t-test. All p-values <0.05 were treated as significant.

RESULTS

Mean, median, minimum and maximum values of the percentage area of remaining filling material for groups I, II, and III are shown in [Table/Fig-5]. For teeth obturated with AH Plus sealer, the mean percentage area of residual filling material ranged from 27.15 to 34.21% with the maximum amount of residual filling material seen in group I (rotary retreatment) and minimum amount seen with group III {(rotary retreatment with Passive Ultrasonic Activation (PUA) of solvent)} with a Standard Deviation (SD) of 6.94 to 10.42. For teeth obturated with MTA Fillapex sealer, the mean percentage area of residual filling material ranged from 13.33 to 29.73% with the maximum amount of residual filling material seen in group II (Rotary Retreatment with solvent) and minimum amount seen with group III (rotary retreatment with PUA of solvent) with a SD of 6.13 to 13.60 and a confidence interval of 95%.

The results of one-way ANOVA for the percentage area of canal covered with residual filling material revealed no statistically significant difference between the groups I, II, and III when root canal space was obturated with gutta-percha and AH Plus sealer (subgroup A) as p-value >0.05 which is presented in [Table/Fig-6].

The results of one-way ANOVA for the percentage area of canal covered with residual filling material revealed a statistically significant (p-value <0.001) difference between the groups I, II, and III when root canal space was obturated with gutta-percha and MTA Fillapex sealer (subgroup B) which is presented in [Table/Fig-7].

Posthoc LSD test comparison revealed there was a statistically significant difference between the three techniques used for the removal of obturating material. The percentage area of residual filling material of teeth where group I (rotary retreatment) was used was statistically significant (p-value <0.05) [Table/Fig-8] when compared with group II (rotary retreatment with solvent) and group III (rotary retreatment with passive ultrasonic activation of solvent). Group II (rotary retreatment with solvent) showed a statistically significant (p-value <0.001) difference [Table/Fig-9] when compared with group III-(rotary retreatment with passive ultrasonic activation of solvent).

Groups	Sub group	N	Mean (mm^2)	Median (mm^2)	Standard deviation	Standard error of mean	95% Confidence interval for mean		Minimum (mm^2)	Maximum (mm^2)
							Lower bound	Upper bound		
Group I Rotary Retreatment (RR)	Subgroup A (AH Plus)	11	34.21	38.70	10.42	3.14	13.78	40.37	19	45.91
	Subgroup B (MTA Fill Apex)	11	29.73	28.71	12.04	3.63	4.42	35.13	13	58.80
Group II Rotary Retreatment with solvent	Subgroup A (AH Plus)	11	28.02	29.12	6.94	2.09	13.56	31.25	12	47
	Subgroup B (MTA Fill Apex)	11	40.05	28.71	13.60	4.10	3.07	37.77	18.5	51
Group III Rotary Retreatment with Passive Ultrasonic Activation (PUA) of solvent	Subgroup A (AH Plus)	11	27.15	41.46	8.89	2.68	22.63	45.30	17	38.5
	Subgroup B (MTA Fill Apex)	11	13.33	12.05	6.13	1.85	1.32	16.95	7	16

[Table/Fig-5]: Descriptive statistics of percentage area of residual filling material in group I, II, and III.

Source of variation	Sum of squares (mm^2)	df	Mean square (mm^2)
Between groups (Influence factor)	325.761	2	162.881
Within groups (Other fluctuations)	3017.513	30	100.584
Total	3343.274	32	
F-ratio	1.619		
p-value	0.215		

[Table/Fig-6]: One-way ANOVA for subgroup A.

Source of variation	Sum of squares (mm^2)	df	Mean square (mm^2)
Between groups (Influence factor)	3993.395	2	1996.698
Within groups (Other fluctuations)	3015.628	30	100.521
Total	3343.274	32	
F-ratio	19.863		
p-value	<0.001*		

[Table/Fig-7]: One-way ANOVA for subgroup B.
*p-value <0.05 was considered as statistically significant

Percentage area of residual filling material MTA Fillapex sealer	Comparison	Mean difference (I-J)	Std. Error	p-value	95% Confidence interval		F
					Lower bound	Upper bound	
Group I	Group II	-10.32	4.28	0.022	-19.05	-1.59	19.863
Group I	Group III	16.40	4.28	0.001*	7.67	25.13	19.863

[Table/Fig-8]: Posthoc LSD test for Group I Subgroup B comparing the percentage area of the residual filling material with Group II and III Subgroup B.
*p-value <0.05 was considered as statistically significant

Percentage area of residual filling material MTA Fillapex sealer	Comparison	Mean difference (I-J)	Std. Error	p-value	95% Confidence interval		F
					Lower bound	Upper bound	
Group II	Group III	26.72	4.28	<0.001*	17.99	35.45	19.863

[Table/Fig-9]: Posthoc LSD test for Group II Subgroup B comparing the percentage area of the residual filling material with Group III Subgroup B.
*p-value <0.05 was considered as statistically significant

Intergroup comparison for differences in the mean percentage area values for groups I, II, and III obturated with AH Plus and MTA Fillapex sealer was done using Unpaired t-test as depicted in [Table/Fig-10]. The results of the unpaired t-test analysis revealed that there was no significant difference in the percentage of residual filling material for group I when both AH Plus and MTA Fillapex subgroups were compared. However, there was a significant difference (p-value <0.05) in the percentage of residual filling material for group II and group III when both AH Plus and MTA Fillapex subgroups were compared with t-values.

Percentage area of residual filling material	Mean difference (Subgroup A-Subgroup B)	Std. Error difference	95% CI of the difference		t	p-value (2-tailed)	df
			Lower	Upper			
Group I	4.48	5.17	-6.30	15.26	0.866	0.396	20
Group II	-12.03	4.51	-21.44	-2.62	-2.667	0.015*	20
Group III	13.82	2.79	8.00	19.64	4.952	<0.0001*	20

[Table/Fig-10]: Intragroup comparison of percentage area of residual filling material (AH plus versus MTA sealer).
Unpaired t test; *p-value <0.05 was considered as statistically significant

The percentage area of residual root canal filling material was highest in the coronal and middle 1/3rd of the root for groups I, II, and III. Rotary retreatment with passive ultrasonic activation of solvent showed the best result in the removal of root canal filling material when compared with other retreatment groups.

DISCUSSION

Inadequate cleaning, shaping, obturation, and final restoration of an endodontically diseased tooth can lead to posttreatment disease [17]. If initial endodontic therapy does not render the canal space free of bacteria, if the obturation does not adequately entomb those that may remain, or if new microorganisms are allowed to reenter the cleaned and sealed canal space, the post-treatment disease can and usually does occur [8].

ProTaper Universal Retreatment system which has three retreatment instruments was used in all three groups. D1 (size 30, 0.09 taper), D2 (size 25, 0.08 taper), and D3 (20, 0.07 taper) retreatment series have a convex cross-section with a working tip that facilitates its penetration into filling materials [18]. Further root canal refining is necessary because the apical diameter of the D3 PTUR file does not permit a complete cleaning action. The final shaping of the canal was done using X3 ProTaper Next (PTN) rotary file.

ProTaper Universal Retreatment files showing good results in the removal of root canal filling material in the apical thirds could be explained by the fact that D3 has a tip size of 20 and 7% taper which is closer to the master apical file size of X3 tip (size 30 with 7% taper) [18]. Rotary retreatment was followed by shaping the root canal with the ProTaper Next X3 file. [Table/Fig-11] is showing the comparison of the results of the present study and relevant studies conducted in the past [7-10,19-22].

Organic solvents are a chemical class of compounds that are applied during retreatment to decrease the resistance of filling materials in

Author's name and year	Place of study	Sample size	Parameters compared	Conclusion
Kumar MS et al., [19] 2012	India	30	Efficacy of ProTaper Universal rotary retreatment system with or without solvent and stainless-steel hand files for endodontic filling removal from root canals and time required for same.	All the specimens had some remnants on the root canal wall. ProTaper Universal retreatment system files alone proved to be faster than the other experimental groups.
Müller GG et al., [10] 2013	Brazil	56	Efficacy of final rinse with Endosolv R® solvent and ultrasound resulted in cleaning root canal walls during endodontic retreatment.	Passive Ultrasonic Irrigation (PUI) with Endosolv R was not effective in the removal of filling debris from root canal walls.
Shenoi PR et al., [20] 2014	India	60	Softening ability of Xylene and Endosolv-R on three different epoxy resin-based sealers within 1 to 2 minutes.	Endosolv R softens AH plus and Adseal more effectively than Xylene after two minutes, but less effectively than Xylene against AH 26.
Rios Mde A et al., [21] 2014	Brazil	60	Efficacy of two reciprocating systems (Reciproc and WaveOne compared with a nickel-titanium (NiTi) rotary system (ProTaper Universal Retreatment in the removal of root canal filling material.	The Reciproc and WaveOne reciprocating systems were as effective as the ProTaper Universal retreatment system for gutta-percha and sealer removal.
Das S et al., [22] 2017	India	60	Relative efficacy of three rotary instrumentation systems for removal of gutta-percha from root canal during endodontic retreatment.	ProTaper and Mtwo retreatment file systems were found to be effective in the removal of root canal filling material compared to R Endo. Complete removal of gutta-percha from root canals did not occur with any of the experimental groups.
Trevisan L et al., [7] 2017	Brazil	70	Dissolving efficacy of eucalyptol and orange oil solvents associated with Passive Ultrasonic Activation (PUA) in Zinc Oxide-Eugenol (ZOE) based and epoxy resin-based root canal sealers.	PUA combined with essential oils can dissolve Zinc Oxide Eugenol (ZOE)-based sealers effectively.
Margasahayam SV et al., [9] 2020	India	40	Efficacy between passive ultrasonic activation assisted hand vs. rotary retreatment files in the removal of gutta-percha and sealer during endodontic retreatment.	Root canal filling materials can be removed more efficiently with rotary instrumentation combined with passive ultrasonic activation.
Marwa M and Roshdy N, [8] 2018	Egypt	60	Efficacy of passive ultrasonic irrigation in the removal of root canal filling material using R-Endo and D-Race retreatment systems.	D-RaCe/ PUI was the fastest and most efficient technique in the removal of sealer and root canal filling material.
Present study 2019	India	66	Retreatment efficacy of ProTaper Universal Retreatment system along with passive ultrasonic activation of Endosolv R solvent in the removal of gutta-percha with AH Plus and MTA Fillapex sealer.	Passive ultrasonic activation of solvent enhanced the removal of gutta-percha and root canal sealer from root canal treated teeth more effectively.

[Table/Fig-11]: Comparison of the results of the present study and relevant previous studies.

the root canal, thus facilitating their removal without damaging the tooth [7]. Diverse chemical solvents are available, and they dissolve root canal sealers at different intensities. Endosolv R is an organic solvent that contains formamide 50 grams and phenylethylene alcohol 50 grams [20]. It has been shown to aid in fresh AH Plus removal after filling and to dissolve set AH Plus in-vitro.

It has been shown that ultrasonically driven files are effective for the irrigation of root canals. Therefore, the use of ultrasonics in canals has evolved from primary instrumentation to a passive cleaning technique [23]. Small, intense, circular fluid movement (i.e., eddy flow) around the instrument is created due to acoustic streaming. The maximum eddying effect occurs at the tip of the file compared to the coronal end, with an apically directed flow. An enlarged root canal helps the file or wire to vibrate freely in a way to enables acoustic streaming with the transfer of energy to the irrigant inside the canal [23].

To evaluate the residual filling material both root halves were photographed under a stereomicroscope. Stereomicroscopes are used to study three-dimensional objects, examine small objects, or dissect biological specimens [24]. They provide magnification upto 5X which can be used to differentiate between sealer and GP left inside the canal. It provides an attachment for a digital camera which is useful to capture images of the sectioned teeth at different magnification values. Images from a stereomicroscope can be easily transferred to a computer containing imaging software where images are analysed. In the present study percentage area of the residual root canal, filling material was assessed using image analysis software by calculating the total area of the canal in (mm^2) and the area covered by residual root canal filling material (mm^2).

The results of the present study revealed that rotary retreatment supplemented with PUA of GP solvent showed the better removal of root canal filling material when compared with other retreatment groups and was statistically significant. Hence, the null hypothesis stands rejected. Lesser residual filling material was observed in teeth with rotary retreatment followed by PUA of solvent in both MTA Fillapex and AH Plus groups. Ultrasonic agitation of organic solvents during retreatment can help to improve the chemical characteristics of these substances by boosting their dissolving capabilities for root canal sealers. The prospect of ultrasound stimulating solvent extrusion and generating adverse effects on periapical tissues calls into question the connection of ultrasound with a solvent [25].

In the present study, the retreatment for MTA Fillapex showed the least amount of residual filling material as compared with AH Plus. This may be attributed to two reasons: the low bond strength of MTA Fillapex to root dentin and the questionable biomineralisation of MTA Fillapex [26]. The low bond strength of MTA Fillapex confirms the results of recent studies that reported a low adhesion capacity of MTA Fillapex [27-29]. The superior performance widely reported by the literature for the use of MTA was attributed to its biomineralisation ability. The interaction of MTA with a phosphate-containing fluid produces calcium-deficient B-type carbonated apatite via an amorphous calcium phosphate phase [26]. However, the low bond strength of MTA Fillapex has been attributed to the low adhesion capacity of these tag-like appetites. However, this supposition is in contrast to the findings of Salles LP et al, who noted that MTA Fillapex showed increased alkaline phosphatase activity after seven days, thereby stimulating hydroxyapatite crystal nucleation. Nevertheless, a comparison of MTA Fillapex with other commercial brands of MTA is yet to be performed [30].

The efficacy of a solvent Endosolv R in dissolving a solute or softening a polymer may be explained by the concept "like dissolves like" (i.e., polar solvents are better at dissolving polar compounds) [10]. Non polar solvents typically will not dissolve polar substances and vice- versa. Epoxy resin is probably miscible with the formamide/2-phenyl ethanol cosolvents, enabling it to be dissolved by the Endosolv. Because formamide and 2-phenyl ethanol are miscible with water, this permits the dissolved epoxy resin to be rinsed away by water [20].

Limitation(s)

The limitations of this study included the in-vitro study design which makes it difficult to be compared with clinical situations and the complexity associated with it. It also lacked chemical analysis of the solvent. This would be to quantitatively verify the saturation of the solutions and the interaction pattern of root canal sealers with solvents during PUA.

CONCLUSION(S)

Within the limitations of the present study, it was observed that passive ultrasonic activation of solvent enhanced the removal of gutta-percha and root canal sealer from root canal treated teeth more effectively. The retreatment for MTA Fillapex showed the least amount of residual filling material as compared with AH Plus. However passive ultrasonic activation of solvent seems to be a promising approach for clinicians during retreatment procedures. Additional testing with alternative solvents is encouraged. Moreover, a statistically significant finding in this type of in-vitro study does not necessarily imply clinical significance.

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