ORIGINAL RESEARCH

Retreatment Efficacy of Hand vs Rotary Instrumentation in Oval-shaped Root Canals: An *In Vitro* Study

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Abstract

Aim: To evaluate and compare the efficacy of the ProTaper Universal Retreatment system (PTUS) and R-Endo rotary instruments with Hedström files (H-files) for the removal of gutta-percha (GP) in Retreatment of oval-shaped root canals.

Methods: Sixty mandibular premolars with one single straight canal were selected. These were instrumented with K-type files and filled using cold lateral compaction and sealer. Further, they were randomly divided into three groups of 20 each. Specimens were retreated with GP solvent and were split longitudinally. Root canal walls were examined using a stereomicroscope attached to Image Analyzer Software (MVIG 2005, Chroma Systems, India) to evaluate the cleanliness of root canal walls. Moreover, separated instruments during Retreatment and time required to remove obturating material were noted.

Results: Residue percentage was lesser (Tukey's test, $p < 0.01$) when the PTUS was used than when the R-Endo and H-files were used. Most of the residue in all specimens was in the apical one-third [analysis of variance (ANOVA), $p < 0.01$]. However, the time for removal of the root canal filling was lower with rotary files as compared with H-files. There was one fractured instrument in the PTUS group.

Conclusion: In this *in vitro* study, leftover residual filling material was found inside the root canal system, mainly in the apical third. The PTUS proved to be an efficient method of removing GP and sealer from mandibular premolars. More studies should be carried out using another endodontic Retreatment system to evaluate the efficacy in oval-shaped canals.

Clinical significance: For the success of endodontic Retreatment complete removal of previous endodontic material is required for the elimination of endodontic microflora from the root canal system. Many techniques and instruments have been advocated in endodontic Retreatment to remove obturating materials. However, residues of filling materials and iatrogenic errors have been observed. Removal of GP is always challenging in oval-shaped root canals. The findings of this study will enable clinicians to select the endodontic file system to provide optimal patient care.

Keywords: Endodontic Retreatment, Gutta-percha, Hedström files, Oval-shaped canal, ProTaper, R-Endo.

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Introduction

One of the primary goals of endodontic treatment is the elimination of microorganisms from the root canal. However, root canal treatment may fail even when the treatment is carried out with the highest standard and the most meticulous treatment procedure. In most cases, the endodontic failure results from persistent or secondary intraradicular infection.[1,2] Initial root canal treatment failure rate is about 14–16%.[3] Previously treated teeth with persistent periapical infection might be retained with nonsurgical Retreatment or endodontic surgery, assuming the tooth is restorable, periodontally sound, and the patient desires to retain the tooth.

An epidemiological study was done by Kvist and Reit to know the success of nonsurgical Retreatment and surgical Retreatment. There was no statistically significant difference between the success rate of surgical and nonsurgical Retreatment; the most commonly selected treatment for failed endodontic cases is nonsurgical Retreatment as surgical Retreatment resulted in more postoperative discomfort, trauma to the normal oral tissues, and postsurgical complications.[3] A nonsurgical Retreatment showed a higher success rate of 83.0% compared with 71.8% for endodontic surgery. An endodontic surgery offers more favorable initial success, but nonsurgical Retreatment offers a more favorable long-term outcome.[4]

Nonsurgical endodontic Retreatment aims to eliminate previous obturating material which is followed by complete mechanical as well as chemical disinfection and in the end a three-dimensional obturation of the root canal complex.[5]

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Complete removal of obturating material exposes the necrotic tissue remnant that may be accountable for the posttreatment disease. Removal of GP and root canal sealers would assist in maximizing the ability to disinfect the root canal system.

Gutta-percha in conjunction with different sealers is the most commonly used obturation material. Different techniques have been used to remove GP from the root canal which includes use of K-type or H-files along with solvents such as, chloroform,

xylene, eucalyptol, halothane, or orange solvents. Furthermore, Gates–Glidden drills and heated pluggers are used for removal of coronal third material followed by hand instrumentation, rotary Retreatment files, reciprocating files[6] such as Reciproc, Reciproc Blue, Wave One, and Wave One Gold, ultrasonic instruments, and lasers among others.[7] Hedström files, various rotary Retreatment files with or without solvents are used commonly in practice.[8]

ProTaper Universal Retreatment system has three different lengths, unique tapers, and diameters to sequentially remove obturating materials. These files are D1 (cutting tip, size 30, 9% taper) used for coronal third has a length of 16 mm, D2 (noncutting tip, size 25, 8% taper) used in middle third has a length of 18 mm, and D3 (noncutting tip, size 20, 7% taper) of 22 mm length is used till the apical third. R-Endo system has a noncutting tip design and is available in various tip sizes and taper as R1 (size 25, 8% taper) used in the coronal third, R2 (size 25, 6% taper) used in middle third, and R3 (size 25, 4% taper) aids in the removal of obturating material from the apical third.[9]

Retreatment is a tedious and time-consuming process leading to many procedural errors. Selecting the case for Retreatment is a meticulous process where the pros and cons of tooth prognosis have to be weighed. So, the duration of time plays an important role in selecting the case.

The rationale for this study is root canal sealers and filling materials are difficult to eliminate from the oval canal and ramifications during Retreatment procedure and to date, there are very few studies that have evaluated the effectiveness of hand and rotary systems in oval-shaped canals. However, there is still no consensus as to which is the best technique.

Nevertheless, GP removal from oval-shaped canal cases is a tedious and time-consuming operation, especially when the filling material is well compacted. Therefore, the aim of the study was to evaluate the effectiveness of H-files (Mani Dental Inc., Japan), R-Endo (Micro Mega, France), and PTUS (Dentsply Maillefer, Ballaigues, Switzerland) in the removal of GP from oval root canals. Time taken for removal and procedural errors, such as separation of instruments was assessed. The null hypothesis had shown no difference in the efficacy of removal of root canal filling material with PTUS, R-Endo, and H-files.

Methods

An experimental study was conducted at the dental institute and the study protocol was approved by the institutional review board and institutional ethics committee (ethical clearance number: MGM/DCH/IERC/39/17). The sample size was arrived at using the PASS sample size calculating software PASS 15 Power analysis and sample size software.

Inclusion and Exclusion Criteria

Sixty freshly extracted human single-rooted oval-shaped mandibular premolar teeth were used based on the inclusion criteria (stored in saline and used within 3 months of extraction) and exclusion criteria (fractured teeth, more than one root canal, resorption, open apices, caries, obturated teeth, and curved rooted teeth). Preoperative buccolingual and mesiodistal radiographs were taken for each tooth, to verify a single patent canal of curvature less than 20° without any cracks, calcification, internal resorption, or any previous root canal treatment. Metrically, Jou et al. defined "oval" as having a maximum diameter of about two times greater than the minimum diameter.[10]

The teeth were cleaned with an ultrasonic scaler and stored in the saline solution until ready for use.

Root Canal Treatment

Access cavity preparation was made on each tooth using diamond points (Diaburs, Prime Dental Products, Mumbai, India) and pulp tissues were removed with barbed broaches (Mani Dental Inc., Japan). Further, 10 K-type files (Mani Dental Inc., Japan) were passed 1 mm beyond the apical foramen to ensure the patency of the canal. After the access opening, to standardize the specimens, teeth were decoronated using a diamond disc (SS White, NJ, USA) using low-speed straight handpiece under water spray, which helped in establishing the working length of all specimens at 15 mm.

In addition, biomechanical preparation was carried out with a modified step-back flare method, whereas, Gates–Glidden drills size 1–3 (Mani Dental Inc., Japan) was used in coronal enlargement. Root canal preparation was carried out, by use of K-type endodontic files sequentially till size #30 at working length. Moreover, a step-back procedure with the increment of 1 mm to a file size 60 was carried out. However, 2 mL of 3% sodium hypochlorite (NaOCl) (Condent Corporation, India) and 17% ethylenediaminetetraacetic acid (RC Help, Prime Dental Products, Mumbai, India) were used for root canal irrigation. Teeth were then stored in saline solution (Nirlife Healthcare, Nirmala Pvt Ltd, India).

The root canal of each tooth was dried with absorbent points (Dentsply Maillefer, Ballaigues, Switzerland). A size 30 GP cone (Dentsply Maillefer, Ballaigues, Switzerland) was selected, and apical tug back was confirmed. The AH Plus sealer (Dentsply Maillefer, Ballaigues, Switzerland) was manipulated according to the manufacturer's instruction and Lentulo spiral (Mani Dental Inc., Japan) with a contra-angle handpiece rotated clockwise used for initial sealer placement. The selected GP master cone coated with sealer was placed into the canal and obturated with cold lateral compaction and temporized with IRM (Dentsply Maillefer, Ballaigues, Switzerland).

The quality of obturation was evaluated with buccolingual and mesiodistal radiographs. The obturation was an absence of voids considered adequate, whereas, specimens with unsatisfactory obturation were discarded. All teeth were stored in a humidor (DBK BOD, Model DTC96, Innovative Bacteriological Incubator) at 37°C for 4 weeks to permit complete hardening of the sealer.

Removal of Obturation

The specimens were randomly allotted into three groups, that is, I, II, and III consisting of 20 teeth each by simple randomization. The temporary restoration was removed and root canals were reopened. Gates–Glidden size 3 was used to remove the coronal GP and create a reservoir for GP solvent (RC Solve, Prime Dental Products, Mumbai, India). To soften the root obturation material, 0.2 mL of solvent was first placed into the access cavity for 2 minutes. A random usage sequence was performed to avoid bias.

Group I: R-Endo

- According to the manufacturer's instructions, R-Endo instruments were sequentially used with torque-controlled endo motor (X-Smart Endodontic Motor, Dentsply Maillefer, Ballaigues, Switzerland) in a gentle brushing motion at 300 rpm speed and 1.2 N cm torque.
- Rm (size 25, 4% taper) was used for initial preparation, to create a pathway thus allowing the centering and alignment of the next

instrument. Re (size 25, 12% taper) (length 15 mm) was used 1–3 mm beyond the pulp chamber to remove the initial bulk of obturation material.

- R1 (size 25, 8% taper) (length 15 mm) and R2 (size 25, 6% taper) (length 19 mm) were used coronal and middle thirds of the root canal, respectively and R3 (size 25, 4% taper) (length 23 mm) was used till working length.

Group II: PTUS

ProTaper Universal Retreatment instruments were sequentially used with torque-controlled endo motor in a gentle brushing action on canal walls. In brief, D1 (9% taper, size 30), D2 (8% taper, size 25), and D3 (7% taper, size 20) were sequentially used in a crown-down manner to reach the pre-established working length. The rotational speed was set at 500 rpm for D1, 400 rpm for D2 and D3, with a torque of 3 N cm.

In both the groups, if rotary instruments could not get to working length, stainless-steel K-type files #10 and 15 were used. After negotiation, rotary instruments were used till working length.

Group III: H-files

ISO size 15 and 20 H-files were used until they reach the working length. Hand instrumentation was carried out with the help of H-files and the sizes used were 25, 30, and 35 in the circumferential filing motion to withdraw GP and sealer from the canal wall.

Each specimen while Retreatment was irrigated with a total volume of 25 mL of 3% NaOCl. All instruments were wiped regularly with wet gauze pieces to remove the debris. One set of instruments was used for the Retreatment of four root canals and later discarded. Preparation was judged complete when the irrigating solution appeared clean without debris and Retreatment files were not coated with sealer or GP.

Evaluation

The single operator conducted all the endodontic procedures to minimize bias. Another examiner who was blind to the group allotment evaluated remnant filling materials.

For all the specimens three types of data were recorded.

Time Required to Remove Material

The stopwatch was used to evaluate the time lapsed from a first file entering the root canal until the complete reinstrumentation.

Procedural Errors

Numerous errors such as ledge formation, perforations, fractured instruments, and miscellaneous failures were reported. In case of instrument fracture, it was replaced by another specimen.

Amount of Remaining Filling Material (RFM)

The tooth was sectioned longitudinally and each half of all root was then marked into three equal thirds, that is, cervical, middle, and apical. The amount of RFM on the canal wall of each third (of 5 mm each) was measured using Image Analyzer Software (MVIG 2005, Chroma Systems, India) connected to a stereomicroscope of 10 × magnification (Vardhan, India) (Fig. 1). The arithmetical mean calculating the area of the canal wall and RFM for each specimen (in millimeters) was obtained and was used to measure the percentage of RFM for all the specimens.

RFM (%) = area of GP/sealer remnants × 100

Area of canal wall data obtained were tabulated and subjected to ANOVA and further *post hoc* test was done using Tukey's test. The level of significance applied for all the tests was set at $p < 0.05$.

Statistical Analysis

The data obtained were analyzed by using descriptive statistics, one-way ANOVA followed by Tukey–Kramer *post hoc* test through MedCalc Statistical Software Version 18.2.1 (MedCalc Software bvba, Ostend, Belgium).

Results

The results of the study showed that the least RFM was seen in group II (PTUS) and highest in group III (H-files) (Fig. 2). Means and standard deviations (SDs) of the percentage of RFM are presented (Table 1). The highest mean value for RFM was seen for group III (H-files) where the Retreatment was done using H files followed by group I (R-Endo). The specimens in which Retreatment was done with PTUS (group II) were observed to have lesser RFM (Fig. 2). The ANOVA test

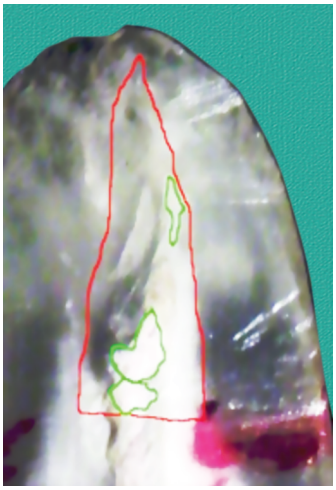

Fig. 1: Photomicrograph of root showing remaining GP under stereomicroscope attached to Image Analyzer Software. Red outline shows root canal area and green outline shows RFM

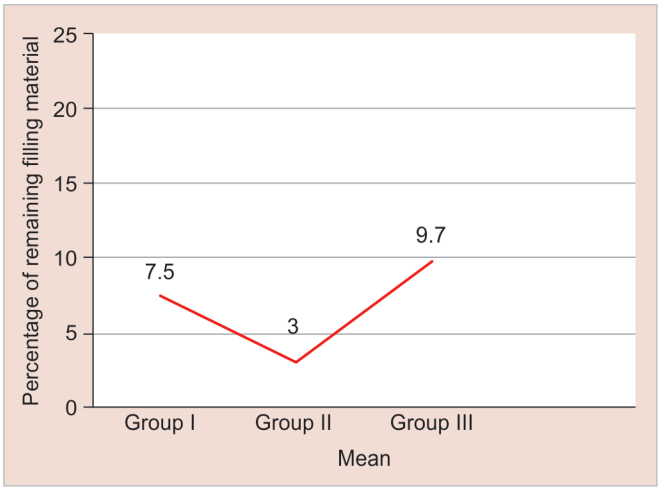

Fig. 2: Mean and SDs of the percentage of RFMs of all three groups

revealed a statistically significant difference between the groups with $p < 0.001$. Intergroup comparison by Tukey–Kramer test showed a statistically significant difference ($p < 0.05$) (Table 2). However, none of the techniques could remove obturating materials completely.

Intergroup Comparison

Comparison of the Mean % of RFM in the Cervical 1/3rd Region in All Groups

The mean scores of % RFM in the coronal 1/3rd region using R-Endo, PTUS, and H-files were 2.8, 1.3, and 3.7%, respectively (Table 1). Analysis of variance showed significant differences between the groups, that is, 0.000 (p = 0.05 or less). ProTaper Universal Retreatment system has shown the least % of GP remaining in the cervical 1/3rd region, followed by R-Endo and H-files (Fig. 3).

Comparison of the Mean % of RFM in the Middle 1/3rd Region in All Groups

The mean scores of % of RFM in the middle 1/3rd region using R-Endo, PTUS, and H-files were 6.3, 2.7, and 8.7%, respectively (Table 1). Analysis of variance showed significant differences between the groups, that is, 0.000 (p = 0.05 or less). ProTaper Universal Retreatment system has shown the least % of GP remaining in the middle 1/3rd region, followed by R-Endo and H-files (Fig. 3).

Comparison of the Mean % of RFM in the Apical 1/3rd Region in All Groups

The mean scores of % of RFM in the apical 1/3rd region using R-Endo, PTUS, and H-files were 13.5, 5.2, and 16.5, respectively (Table 1). Analysis of variance showed significant differences between the groups, that is, 0.000 (p = 0.05 or less). ProTaper Universal Retreatment system has shown the least % of GP remaining in the apical 1/3rd region, followed by R-Endo and H-files (Fig. 3).

Comparison of the Mean % of RFM in the Entire Tooth in All Groups

The mean scores of % of RFM in the total root canal using R-Endo, PTUS, and H-files were 7.5, 3.0, and 9.7%, respectively (Table 1). Analysis of variance showed significant differences between the groups, that is, 0.000 (p = 0.05 or less). ProTaper Universal Retreatment system has shown the least % of GP remaining in the total area of teeth, followed by R-Endo and H-files (Fig. 2).

Comparison of the Retreatment Time among All Groups

The mean Retreatment time using R-Endo, PTUS, and H-files were 14.9, 11.4, and 21.4 minutes, respectively (Table 3). Analysis of variance showed significant differences between the groups, that is, p = 0.05 or less. Least time required for Retreatment was seen in PTUS and highest time required for Retreatment was seen in H-files. The hand instruments required more time to remove the filling material as compared to the PTUS and the R-Endo system (Fig. 4).

Intragroup Comparison

The mean percentage of RFM is significantly higher statistically in the apical area followed by the middle area and least in the cervical area of teeth in all the groups. All the specimens showed RFM predominantly in the apical portions, the RFM was highest in group III followed by group I and group II, which was significant statically ($p < 0.001$).

The incidence of one separated instrument was observed in group II specimens which were retreated with PTUS.

Discussion

A prerequisite of nonsurgical endodontic Retreatment is to remove entire obturating materials as it enables subsequent cleaning, shaping, and filling of the root canal system.[11] In the current study, mandibular premolars were selected because

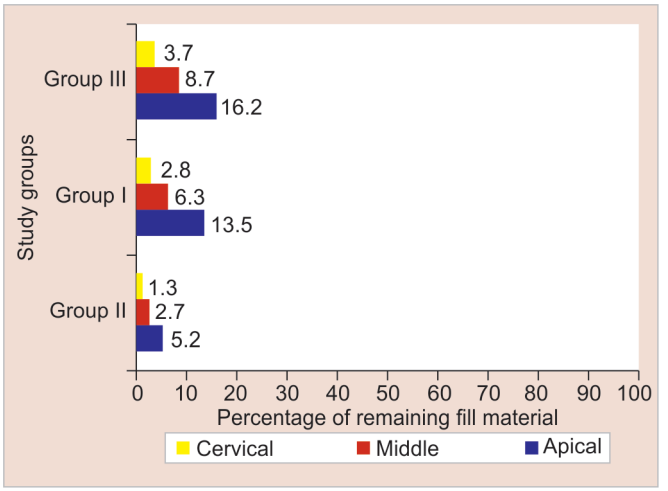

Fig. 3: Comparison of mean percentage of RFM among all three groups

Table 1: Comparison of mean percentage of RFM among all three groups

Groups	*N*	*Mean (±SD)*	*Area*	*Mean (±SD)*
Group I: R-Endo	20	7.5 (±1.6)	Apical	13.5 (±3.5)
			Middle	6.3 (±1.7)
			Cervical	2.8 (±1.3.)
Group II: PTUS	20	3.0 (±1.1)	Apical	5.2 (±2.1)
			Middle	2.7 (±1.0)
			Cervical	1.3 (±0.7)
Group III: H-files	20	9.7 (± 1.8)	Apical	16.5 (±3.7)
			Middle	8.7 (±2.9)
			Cervical	3.7 (±1.3)

Table 2: Tukey's test for intergroup comparison of percentage area of RFMs

Group	*Group*	*p-value*
I	II	0.00
	III	0.01
II	I	0.00
	III	0.00
III	I	0.02
	II	0.00

Table 3: Comparison of Retreatment time among all three groups

Area	*Mean (±SD)*	*F-value*	*p-value*	*Significance*
Group I	14.9 (±0.8)	358.2	0.00	Highly significant
Group II	11.4 (±0.8)			
Group III	21.4 (±1.7)			

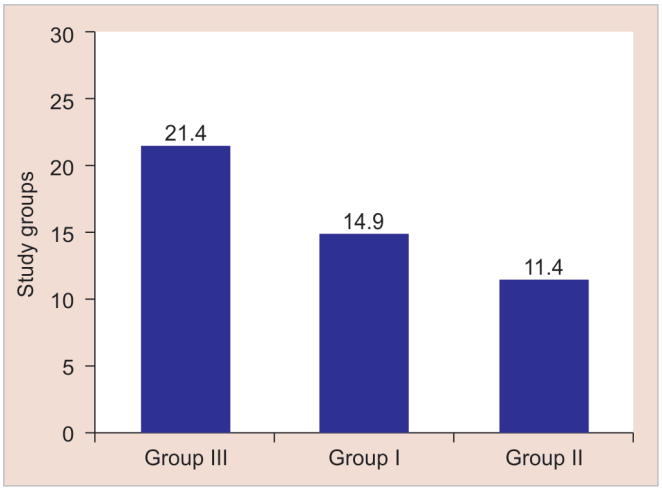

Fig. 4: Comparison of time required to Retreatment among the groups

canals are often oval (27%)[12] an important variation during their endodontic Retreatment.[13]

This study investigated the effectiveness of hand and rotary systems in removing GP-based root canal filling material (RFM). Different techniques have been performed for the assessment of RFMs, such as three-dimensional radiographic techniques [cone beam computed tomography (CBCT) or micro-CT],[14] scanning electron microscopy,[15] two-dimensional radiographic image analysis,[16] clearing techniques,[17] and split teeth.[18] Every technique has its pros and cons. Radiographic interpretation failed to recognize the coverage of remaining root filling material, which could only be detected using microscopy.[19] In the present study, splitting roots longitudinally and stereomicroscopic images evaluations quantified with Image Analyzer Software were utilized for the assessment of RFM because this improves the inspection of the root canal walls.[19] Stereomicroscope shows halves of canal wall at higher magnification, that is, 10× in the present study, so easy to distinguish between remaining GP, sealer, and smear of GP adheres to canal walls.[13,20]

In this study, eucalyptus oil was used as a GP solvent. While, chloroform is proved to be the most effective GP solvent, thus, using chloroform might have dissolved the GP better than eucalyptus oil. However, the International Agency for Research of Cancer declared chloroform as a "Group 2B" carcinogen.[21] Turpentine showed higher toxicity than chloroform and halothane, xylene, eucalyptol oil, and orange oil were the least irritating.[22,23] It was found that when rotary files and solvents were used for Retreatment, it took less time for obturating material removal.[8,24] However, other studies stated that rotary files without solvent speeded up the Retreatment time.[25] When solvents were used, smear softened GP to the root canal walls during Retreatment thus taking more time for the removal.

In the present study, we compared effectiveness in removal of filling material during the Retreatment in mandibular premolars between the H-files, R-Endo, and PTUS. We found that the amount of RFM was higher in the R-Endo group when compared to the PTUS group. Residual filling material was observed in all three groups. Consistently in all the groups, the RFM was greater in the apical third. In general, there are increased anatomical complexities in the apical third.[12,13] While, R-Endo instruments have an inactive tip, no radial land, and triangular cross-section. The files were used to remove the GP and its sealer in a brushing circumferential motion.[26]

ProTaper Universal Retreatment system has a working tip, the D1 file allows easy penetration of the subsequent files D2 and D3, as averse to the PTUS, which is unable to penetrate the GP without separating the file tip. The nonactive tips of D2 and D3 had shown a reduction in the prevalence of procedural errors as compared to another Retreatment instrument system, which has active tips for all Retreatment instruments.[27] Gu et al. imputed to the innovative concept of PTUS. Furthermore, they mentioned that this concept may allow instruments to not only remove GP but also, the superficial layer of radicular dentin during Retreatment.[25] The better performance of PTUS can be attributed to their concept. The special flute design and rotary motion of PTUS tend to engage GP into flutes and pull it toward the orifice.[28] In addition, the rotary motion of files generates a certain degree of frictional heat, which plasticizes GP and thus presents less opposition while GP removal.

In the present study, instrument fracture was minimum but observed with the PTUS group may be related to the taper. According to a previous study, the taper was considered an important factor in determining fracture probability for rotary nickel–titanium instruments.[29] This can be credited to the fact that after Retreatment of four canals instrument was disposed of, thus, substantially reducing the possibility of instrument seperation.[30]

Limitations

Some of the limitations of the study include the *in vitro* study where complex intraoral conditions could not be simulated. Other factors such as canal curvatures, isthmus, and ramifications were not taken into consideration. The RFM evaluated by the split tooth method is technique sensitive, moreover residual material might be lost during the procedure.

Nonsurgical endodontic Retreatment using a rotary system helps in gaining access to infected teeth by removing obturating material from the canal and further, along with irrigants this helps to reach critical areas of the root canal system, thereby decreasing the microbial load, aids in achieving healing of periapical tissues. Further research should be directed to formulate the best instrument design and technique to retreat oval-shaped canals which can pose a challenge in failed endodontic cases.

Conclusions

In conclusion, it is observed that PTUS was an effective and less time-consuming device for the removal of GP as compared to R-Endo and H-files. All Retreatment instruments left filling material inside the root canal system. Further studies need to be carried out to investigate the canal cleanliness with different rotary file systems, different agitation devices, different solvents, and apical extrusion of GP and solvent.

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