Original Article

Innovative *ex vivo* exploration: A comparative study of novel approaches of root canal filling material removal efficiency

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Abstract

Introduction: Retention of the natural tooth without any symptoms in the oral cavity is one of the prime desires of endodontic treatment. Root canal therapy usually leads to failure when treatment is not up to the mark of acceptable standards. To address these deficiencies, non-surgical endodontic retreatment is the most accepted option with the success rate ranging from 65% to 83%. Forty-five single-rooted mandibular premolars with undeviated canals (as per Schneider's criteria) were obtained and divided further into three groups with 15 specimens along with resin-based sealer solvent in each group: Group 1 - Retreatment rotary file system, Group 2 - Ultrasonics, and Group 3 - Diode laser. Specimens were then evaluated under a stereomicroscope at ×10 after cutting in two halves followed by evaluation of the remaining filling material using Hulsmann and Bluhm criteria.

Context: Nonsurgical retreatment.

Aims: The aim of the study was to evaluate and compare the efficacy of various retreatment techniques for the elimination of root canal filling material.

Settings and Design: The sample size was determined using the formula $n = (Z_{\alpha/2})^2 s^2/d^2$. The design of the study is *in vitro* experimental study.

Subjects and Methods: A sum of 45 single-rooted extracted human permanent mandibular premolars were included in this study. All teeth were biomechanically prepared and obturated followed by decoronating the samples. All specimens were randomly divided into 3 groups comprising 15 specimens along with solvent based on the technique for the filling material elimination from the root canal, i.e. Group I: retreatment rotary files, Group II: ultrasonics, and Group III: diode laser.

Statistical Analysis Used: The Tukey's *post hoc* tests and one-way analysis of variance were used for comparison of the study parameters among the groups.

Results: Results revealed that ultrasonics showed the least amount of remaining filling material within the root canal which had a significant difference from other groups, i.e. retreatment rotary files and diode laser.

Conclusions: Ultrasonics with a resin-based sealer solvent can be considered a preferred option for nonsurgical retreatment. However, none of the groups shows complete elimination of filling material inside the root canal system.

Keywords: Diode laser; nonsurgical retreatment; retreatment rotary files; stereomicroscope; ultrasonics

INTRODUCTION

Endodontic therapy is the part and parcel of dentistry but the success of endodontic therapy has been reported to vary between 86% and 98%. The reported rate of healing after

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nonsurgical retreatment ranges between 74% and 98%[1] but with periradicular surgery, only 59% heal completely.[2]

For the proper three-dimensional (3D) obturation, a coalition of gutta-percha and root canal sealers is the most widely accepted to provide an adequate hermetic seal.[3] Therefore, a successful nonsurgical retreatment will depend on complete removal of both the materials in its entirety from the primary root canal and its accessories to allow proper contact of the chemical irrigants and intracanal medicaments to dentin of root canal walls.[4]

Conventional methods of removing gutta-percha are reported to be less efficacious, time consuming with more apical extrusion and more chances of instrument breakage.[5] To overpower these errors, certain new modalities have been advocated for removing root canal filling material such as retreatment rotary files, ultrasonics, and diode lasers.[6] Hence, this study aims to check their efficacy in removing filling material inside the root canal that may be behind persistent periapical inflammation.

SUBJECTS AND METHODS

A sum of 45 single-rooted extracted human permanent mandibular premolars was selected for this study, involving teeth having a single and patent canal with a root curvature $<10°$ and excluding teeth having root resorption or root caries.

Preparation of samples

Forty-five single-rooted premolars were selected for the study. After cleaning, all the teeth were radiographed preoperatively. Access cavity preparation was done with Endo Access Bur number EA10 (MANI) followed by refinement with Endo-Z bur (Dentsply). The working length was determined 0.5 mm short of the major diameter of the root tip. All teeth were biomechanically prepared till 30/6% using Neoendo Flex rotary files at a speed of 350 rpm and 1.5Ncm torque. Each root canal was introduced with 2 mL of 5.25% sodium hypochlorite (Prevest DenPro Ltd., India) solution after each instrumentation. Last irrigation with 10 mL of 17% EDTA (Meta Biomed Co. Ltd., Korea) was done to eliminate the smear layer after which rinsed with 10 mL of normal saline solution (IVES Drugs Pvt. Ltd). Paper points (Diadent Group International, Korea) were used to dry the root canal and obturated with gutta-percha (Diadent) cones of size 30 and 6% taper and AH Plus sealer (Dentsply Maillefer, Switzerland). All samples were stored in an incubator at 37°C for 24 h for the complete setting of sealer. After 24 h, the teeth were radiographed to detect any shortcomings in the obturation. Coronal portions of all the teeth were sectioned using a sectioning disk (Toboom) to a determined root length of 15 mm measured using a vernier caliper (INSIZE).

Solvent placement

In all the groups, removal of approximately 2 mm coronal gutta-percha was done using number 2 GatesGlidden drill (MANI) to create a cenote for the solvent, and 0.1 mL of Endosolv (Septodont, France) was placed inside the root canal by measuring with the aid of 31 G insulin syringe (DISPO VAN).

Retreatment technique

The decoronated samples were randomly distributed into three groups comprising 15 specimens along with solvent based on a technique for the filling material removal from the root canal:

- Group 1 (15 teeth): Root canal filling material was eliminated using Neoendo retreatment rotary files for 20 s. followed by cleaning of debris with normal saline and placement of solvent, again a cycle of 20 s. This process continues till we reach 0.5 mm short of working length
- Group 2 (15 teeth): Root canal filling material was eliminated using an ultrasonic handpiece with without irrigation for 20 s followed by cleaning of debris and placement of solvent, again a cycle of 20 s. This process continues till we reach 1–2 mm short of working length
- Group 3 (15 teeth): Root canal filling material was eliminated using a Diode laser in contact mode for 20 s followed by cleaning of debris and placement of solvent, again a cycle of 20 s. This process continues till we reach 2–3 mm short of working length.

Evaluation

The teeth were then sectioned longitudinally [Figure 1] after grooving buccolingually with a diamond disk (Toboom). The canals in both the sectioned halves were captured with a camera (Canon S 120, Canon Inc., Japan) attached to a stereomicroscope (GOKO® MIAMB, ISO 9001:2008) under 10x magnification [Figure 2]. To assess the remaining filling material, data were then transferred to a special software tool (Windows v. 3.00, San Antonio, USA) which was used to calculate the area of filling material remaining and root

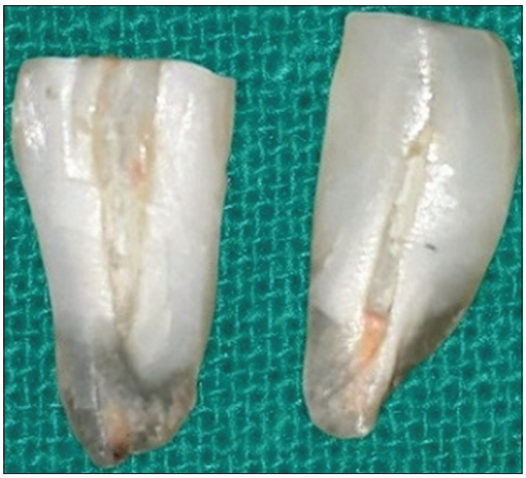


Figure 1: Sectioned halves

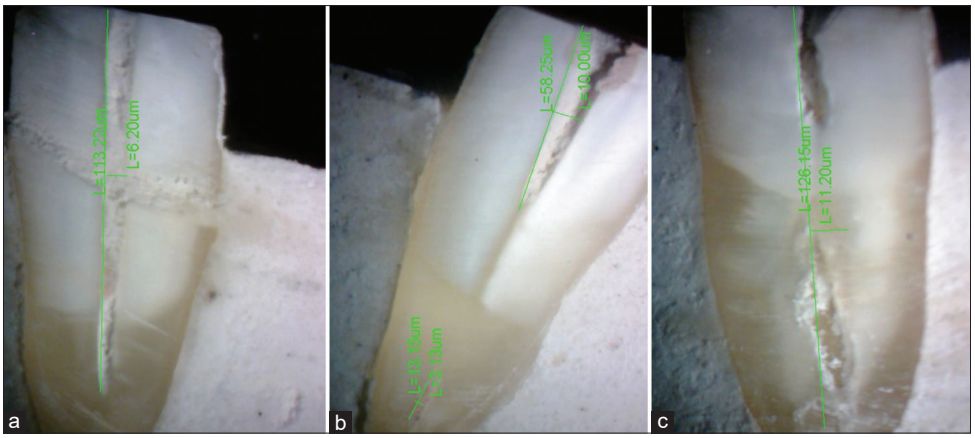


Figure 2: Specimens' evaluation under stereomicroscope at ×10 magnification, (a) Specimen treated with retreatment rotary files, (b) Specimen treated with ultrasonics, (c) Specimen treated with diode laser

Figure 3: Stereomicroscope

canal surroundings that was formulated and expressed using a stereomicroscope [Figure 3]. A score was given to the sample based on Hulsmann and Bluhm criteria.[7] Mean values were calculated and compared.

RESULTS

The results showed that some amount of filling material remains inside the root canal in all the groups with mean values described [Table 1]. Tukey's multiple *post hoc* tests were used to reveal the greatest dimension [Table 2]. Supplementary Tables 1-3 showing data obtained from each sample of each group were used to calculate the amount of filling material remaining. This test is used when there is an equal number of subjects present in each group for which pairwise comparisons of the data are being made.

Table 1: Summary of variables

Summary for variables: The greatest dimension of filling material remaining by categories of: Serial number			
Serial number	*n*	Mean	SD
Group 1	15	1.636	0.5475373
Group 2	15	0.9433333	0.4311557
Group 3	15	1.373333	0.467343
Total	45	1.317556	0.5544414

SD: Standard deviation

In the first intergroup comparison between Groups 2 and 1, Group 2 showed a difference which is statistically significant as compared to Group 1 ($P \leq 0.001$) with a confidence interval of −1.122, −0.262.

In the second intergroup comparison between 3 and 1, Group 3 showed a statistically insignificant difference as compared to Group 1 ($P \geq 0.001$) with a confidence interval of -.6924429, 0.16710960.

In the third intergroup comparison between 3 and 2, Group 3 showed a significant difference in relation to Group 1 ($P \leq 0.001$) with a confidence interval of 0.000223, 0.859.

The analysis of variance (ANOVA) statistical technique was used to evaluate the means of two or more groups to see whether they vary significantly from each other. However, when the groups were compared using one-way ANOVA, there was a statistically significant difference among Groups 1 and 2; and Groups 2 and 3 as ($P = 0.0013$) but when Groups 1 and 3 were compared, results were not statistically significant [Table 3]. The results are considered as statistically significant at $P \leq 0.01$.

Table 2: Comparison of the greatest dimension of remaining filling material among the groups

Serial number	Contrast	SE	Tukey		
			t	*P*>*t*	95% CI
2 versus 1	−0.6926667	0.1768995	−3.92	0.001	−1.122443–−0.2628904
3 versus 1	−0.2626667	0.1768995	−1.48	0.050	−0.6924429–0.1671096
3 versus 2	0.43	0.1768995	2.43	0.001	0.0002238–0.8597762

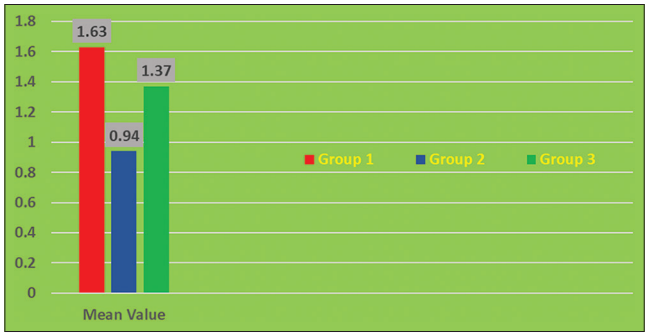
SE: Standard error, CI: Confidence interval

Table 3: Comparison of means of groups

Analysis of variance					
Source	SS	df	MS	*F*	*P*>*F*
Between groups	3.66840444	2	1.83420222	7.82	0.0013
Within groups	9.85742667	42	0.234700635		
Total	13.5258311	44	0.307400635		

Bartlett's test for equal variances: χ^2 (2)=0.8178, $P>\chi^2$=0.664. SS: Sum of squares MS: Mean square

Results revealed that ultrasonics showed the least amount of remaining filling material within the root canal which had a significant difference from other groups, i.e. retreatment rotary files and ultrasonics [Graph 1]. However, there was an insignificant difference in the retreatment rotary files and diode laser groups, respectively.



Graph 1: Comparison of a mean dimension of filling material remaining among the groups

DISCUSSION

Endodontics is a matter of strategy and tactics, and this is especially true in the case of retreatment. According to various reports, 15%–17% of endodontic treatments result in a failure.[8]

To judge the success or failure of primary endodontic treatment, a criterion was given by Strindberg, based on the existence or nonexistence of clinical symptoms such as pain, sinus tract, or sensitivity to hot and cold.[9]

On radiographical examination, if periapical radiolucency decreases in size, it is considered complete healing while if there is an increase or persistence of rarefaction it is considered a failure.[10]

Out of all treatment options available nonsurgical retreatment is considered the first option as surgical retreatment involves excessive loss of periradicular structures, medical conditions, and anatomical factors. For periradicular surgery, the success rate found at 2–3 years (78.2%) was comparable with nonsurgical retreatment for the same period of follow-up (71.2%). However, at 3–5 years, this relationship was completely opposite, with nonsurgical retreatment having a higher success rate (82.7%) compared with periradicular surgery (72.4%).[11] The success rate of nonsurgical endodontic retreatment and implant is 85.1%–89.3% and 97.8%, respectively.[12]

Root canal filling material comprises core material and a sealer to provide a hermetic seal.[13] Contemporary procedures such as the single cone obturation technique make resin-based sealers the sealers of choice.[14] The setting of epoxy resin sealers includes monomer cross-linking, resulting in a 3D lattice.[15] This cross-linked polymer shows the least microleakage. Adequate elimination of filling material is necessary to provide good accessibility to microbes resulting in periapical infection.[16]

Newer techniques such as retreatment rotary files, sealer solvents, ultrasonics, and lasers have been introduced to facilitate better removal of root canal filling material. Solvents facilitate removal therefore resin-based sealer solvents can act as an adjunct along with contemporary retreatment techniques.

The application of Endosolv for the elimination of resin-based sealer has been advocated by Duncan, Cohen, and Chong.[17] According to the manufacturer, it contains ethyl acetate, amyl acetate, and thymol for its action. Ethyl acetate presents a high resin-based sealer dissolving ability. Endosolv can penetrate this 3D lattice resulting in distension of the lattice and decrease in its strength and hardness.

In a modern era of Ni-Ti file systems, retreatment file systems have revealed a higher success rate.[18] In the present study, the Neoendo retreatment rotary files system was used because of its easy availability, good economics, and a paucity of studies comparing its efficacy with other systems. A study[19] reported that the Neoendo group (Orikam) displayed a significantly lesser amount of residual root canal filling material compared to ProTaper Universal retreatment rotary files (Dentsply Maillefer), R-Endo (Micro-Mega), and the H-Files (Dentsply Maillefer).

These files work at a speed of 350 rpm and a torque value of 1.5Ncm (according to the manufacturer's instruction) and are available as N1 (30/9%) for the coronal third, N2 (25/8%) for the middle third, and N3 (20/7%) for apical third.

Parallelogram cross-section limits the contact of file at any given cross-section. This will decrease less screwing in and binding, thus, improving the safety and cutting efficiency.[20] Moreover, a positive rake angle with sharp cutting edges engages the filling material very effectively and reduces the cutting forces required.

However, Neoendo retreatment rotary files showed the greatest amount of residual filling material. This could be attributed to the fact that the rotary retreatment files may have been less efficacious in accessory canals as they do not come in contact with ramifications leading to no mechanical action on them. In addition, there may have been less or no activation of sealer solvent.

Ultrasonic devices working at a frequency between 20 and 45 KHz in a linear, back-and-forth motion produces frictional heat that thermo-softens the gutta-percha, disintegrates the sealer, and breaks the bond between the sealer and the gutta-percha.[21] During the oscillation of the tip, energy is transmitted from the tip to the solvent by means of ultrasonic waves which leads to the rapid movement of fluid around the tip and the creation of bubbles which expand and contract, leading to activation of solvent.[22] In this study, the "Ultra X" (Orikam) was used as it has a specific tip (blue) with 18 mm length and 20/2%taper designated for gutta-percha removal, which is easily available and economical. All the above-mentioned factors could have contributed to ultrasonics showing the best results among the three groups.

A Biolase Diode laser operating at a wavelength of 940 nm, with a power of 5W that works through flexible optical fiber having a diameter of 200 μm was used in this study. Diode laser is well absorbed by the pigmented substances and is poorly absorbed by tooth structure. The photothermal effect of a laser beam is behind accomplishing this goal.[23] The energy is released in a continuous wave (CW mode). In the present study, the Diode laser was more effective in comparison to retreatment rotary files as along with thermo-softening the core material, it also led to indirect warming of sealer solvent which may have increased its efficacy. However, there is no mechanical action of laser and some of the plasticized filling material may have clung to the walls of root dentin, making them less efficacious than ultrasonics.

This study used vertical sectioning of the tooth and its assessment under stereomicroscope at 10x magnification. This technique is simple to employ and allows image standardization by providing a constant distance between device and the surface of the object.[24] This procedure minimizes the subjectivity errors as a scoring system based on numbers and scales is used.

Mandibular premolars are most commonly extracted for orthodontic purpose and revealed a 27% prevalence of oval-shaped canal anatomy.[25] They show anatomical discrepancy along with buccal and lingual surface extensions exist, which are hard to access.

CONCLUSIONS

Ultrasonics was the most efficacious in removing root canal filling material. Diode laser showed better results than rotary files but lacks in efficacy with respect to ultrasonics. Although, none of the technique was completely successful in eliminating the root canal filling material.

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Conflicts of interest

There are no conflicts of interest.

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Supplementary Table 1: Filling material remaining inside the root canal after using retreatment rotary files (Group I)

Greatest dimension of remaining filling material (mm)	Number of remnants	Score
1.45	2	3
0.66	1	2
2.68	1	5
1.32	2	3
1.2	2	3
2.23	1	5
1.32	3	3
1.04	5	4
1.41	2	3
1.59	4	4
1.54	3	3
1.44	2	3
1.82	4	4
1.9	3	3
1.38	3	3

The mean value of the remaining filling material after using retreatment rotary files came out to be 3.4 with a minimum score of 3 and a maximum score of 5

Supplementary Table 2: Filling material remaining inside the root canal after using ultrasonics (Group II)

Greatest dimension of remaining filling material (mm)	Number of remnants	Score
0.34	2	3
0.67	1	2
1.32	1	2
0.97	3	3
0.67	1	2
1.4	3	3
0.89	1	2
1.22	1	2
0.36	2	3
0.8	3	3
1.2	1	2
1.67	3	3
0.26	1	2
0.95	1	2
1.43	2	3

The mean value of the remaining filling material after using ultrasonics came out to be 2.4 with a minimum score of 2 and a maximum score of 3

Supplementary Table 3: Filling material remaining inside the root canal after using diode laser (Group III)

Greatest dimension of remaining filling material (mm)	Number of remnants	Score
1.06	3	3
0.63	2	3
1.03	3	3
1.42	3	3
1.98	4	4
1.75	3	3
1.91	1	2
1.75	3	3
1.43	2	3
1.44	3	3
0.78	2	3
1.93	3	3
1.76	2	3
0.79	3	3
0.94	1	2

The mean value of the remaining filling material after using diode laser came out to be 2.9 with a minimum score of 2 and a maximum score of 4