ORIGINAL RESEARCH

Comparative Evaluation of Different Irrigant Agitating Devices for Debris Removal from the Mesial Roots of Mandibular Molars: An *In Vitro* Study

Priyanka Reddy Chinta[1], Nagalakshmi Kalla[2], Padma Chaitanya Dhavala[3], Damarla Poorna Samudra Satyavathi[4], Sanjay Adarsh Rolla[5], Pragnya Uppalapati[6]

Abstract

Aim: To evaluate the efficiency of debris removal from the mesial root canals and isthmus of mesial roots of mandibular molars after final irrigant agitation with XP-endo Shaper, EndoVac (EV), plastic finishing file, and conventional needle irrigation.

Methods and materials: Forty extracted human mandibular first molar teeth with the isthmus between the mesial roots were selected, access cavities were prepared and distal roots were decoronated. All the mesial root specimens were mounted in acrylic, sectioned at the coronal, middle, and apical thirds, along with the resin block, and examined for debris in the canals and isthmus before the start of the procedure using a stereomicroscope and were mounted back in a custom-made jig. After determination of the working length, they were allocated to the following four different irrigant activation groups ($n = 10$): Group I—XP-endo Finisher; group II—EndoVac; group III—plastic finishing file; and group IV—standard needle irrigation. After biomechanical preparation (BMP) till F3, final agitation was done for debris removal with the respective agitating devices, and all the samples were examined under a stereomicroscope for the amount of debris in the canal after final agitation.

Results: Of all the irrigation devices used, the XP-endo Finisher and EV showed more debris removal when compared to other groups ($p < 0.05$). The plastic finishing file in continuous rotation was more efficient in cleaning debris compared with conventional needle irrigation ($p < 0.05$).

Conclusion: The XP-endo Finisher and EV showed a significant difference in cleaning efficacy than the plastic finishing files. So, these can be used as adjunctive for agitating the final irrigant.

Clinical significance: The irrigant agitation devices promote the penetration of irrigants into the intricate root canal anatomy and increase their antibacterial and tissue-dissolving effectiveness thereby improving the success rate and treatment outcome.

Keywords: Agitation, Debris, EndoVac, Irrigation, Mandibular molars, Plastic finishing file, Smear layer, XP-endo Finisher.

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Introduction

Complete debridement of the root canal system is important for endodontic success. Cleaning and shaping of root canals eliminate vital or necrotic tissues, microorganisms, and dentin debris resulting from instrumentation. However, complete elimination of debris is difficult to achieve, in anatomically complex areas of the root canal system, such as the isthmus and lateral canals. Isthmuses are narrow extensions between two canals that are capable of harboring microorganisms and dentin debris, making them challenging for cleaning and shaping. So, for the cleaning of the main canal and isthmus, irrigation plays an important role.[1]

Numerous irrigating solutions and delivery systems have been used in root canal preparation. The most commonly used method for irrigation is conventional needle irrigation where various needle types are adapted to a disposable plastic syringe associated with apical positive pressure. The use of flexible irrigation needles, which should be inserted in the canal as close as possible to the working length, associated with large volumes of irrigants and frequent exchanges is strategies to enhance the cleaning and disinfecting effects of conventional irrigation. However, it has the disadvantage of having limited cleaning efficiency at the apical portion and isthmuses.[1] To overcome the limitations of conventional needle irrigation, several irrigation devices and techniques have been proposed.

[1,2,5,6]Department of Conservative Dentistry and Endodontics, GSL Dental College & Hospital, Rajanagaram, Andhra Pradesh, India

[3,4]Master of Dental Surgery in Department of Conservative Dentistry and Endodontics, Drs Sudha & Nageswara rao Siddhartha institute of dental sciences, Gannavaram, Andhra Pradesh, India

Corresponding Author: Priyanka Reddy Chinta, Department of Conservative Dentistry and Endodontics, GSL Dental College & Hospital, Rajanagaram, Andhra Pradesh, India, Phone: +91 9493672455, e-mail: saipriyanka.chinta@gmail.com

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The XP endo finisher, which is made of a proprietary alloy (matensite–austenite electropolish), reacts at different temperatures. The XP-endo Finisher is an ISO 25/.00 instrument that is straight (M phase) at room temperature and changes its shape when exposed to body temperature (A phase), which allows the instrument to expand when the file is in rotation. It has a length of 10 mm from the tip and a depth of 1.5 mm because of its

molecular memory. Because of this inherent feature, the instrument is highly flexible and helps in effectively removing debris and microorganisms from root canals and anatomical complexities.[2,3]

The EndoVac (EV) system is based on apical negative pressure, which removes debris from the apical third of the canal. The EV system is composed of three components: a master delivery tip, a plastic macrocannula, and a stainless steel microcannula. It has the advantage of increased flow of irrigant and better debridement at 1mm from the working length. Because of its negative pressure, apical extrusion of irrigant is less frequent, resulting in a lower risk of a sodium hypochlorite accident.[4,5]

Recently, plastic rotary finishing files have been introduced. This file is unique because it has a diamond abrasive embedded in a nontoxic polymer and is for single use. This file removes the dentinal wall debris and agitates the irrigant without further enlarging the canal.[6] There is limited literature available regarding the cleaning efficiency of plastic finishing files.

So, the aim of this study was to compare and evaluate the debris removal in the canals and isthmus using three different irrigation agitating devices with standard needle irrigation. The null hypothesis tested was that there was no significant difference between different irrigant agitating devices and conventional needle irrigation in removing the debris from the canals and isthmus after the final agitation of the irrigant.

Materials and Methods

The protocol of the present study was approved by the research ethics committee of the GSL Dental College & Hospital (EC/2023). The study was conducted in the Department of conservative dentistry and endodontics, GSL Dental College, Rajanagaram, Andhra Pradesh, India. Forty mandibular molars extracted due to periodontal problems were collected from the Department of Oral and Maxillofacial Surgery in GSL Dental College, Rajanagaram, Andhra Pradesh, India. All the teeth were cleaned of debris and soft tissue remnants and stored in 0.1% thymol solution. The mandibular molars without caries extending onto the mesial root, teeth with closed apex, and teeth without vertical root fracture and root resorption were included in the study.

After standard access cavity preparation, the distal root was sectioned at the cementoenamel junction (CEJ), and the sectioned part of the remaining tooth was sealed with glass ionomer cement. Mesial roots with two canals were confirmed radiographically and used in this study. Working length was determined using a 10-K file, (Dentsply Maillefer), and the final working length was obtained by subtracting 1 mm from the observed length. Canals were enlarged using a 15-K file (Dentsply Maillefer). A custom-made jig was designed for mounting tooth specimens. All the samples were mounted in self-curing acrylic using a custom-made jig. To allow precise visualization of roots during sectioning, three markings were made at the coronal, middle, and apical thirds of roots. The mesial root was sectioned at the coronal, middle, and apical thirds and viewed under a stereomicroscope to evaluate the isthmus and the amount of debris present within the canals before the start of agitation within the canals and the intergroup mean values of debris were calculated to avoid bias. The sections were reassembled in the jig, and the bolts were tightened. After reassembling the sections in the jig, coronal flaring was done, and the canal preparation was done using Protaper universal rotary files (Dentsply Maillefer, Ballaigues, Switzerland) up to size F_3. During instrumentation, irrigation was done with 5 mL of 5.25% sodium hypochlorite (Vishal Dentocare, Ahmedabad, India), followed by 2 mL of 17% ethylenediamine tetraacetic acid (EDTA), (Ammdent Canalarge, India) and a final rinse with physiological saline solution.

Distribution of Specimens

All the specimens were divided into four groups based on the final irrigation protocol as follows:

- Group I ($n = 10$): The irrigant was agitated with XP-endo Finisher (FKG Dentaire SA, La Chaux-de-Fonds, Switzerland).
- Group II ($n = 10$): The irrigant was agitated with EV (Discus Dental Smart Endodontics, USA).
- Group III ($n = 10$): The irrigant was agitated with plastic finishing file (Easy Dental Equipment, Belo Horizonte, MG, Brazil).
- Group IV ($n = 10$): The irrigation was done with standard needle irrigation (Romo Jet, Agra, India).

Irrigation Protocol

Three cycles of irrigation were performed. The first and third cycles were irrigated with 5 mL of 5.25% hypochlorite, and the second cycle with 2 mL of 17% EDTA. The irrigant agitation during each cycle was performed with the following agitating devices:

- *Group I—XP-endo Finisher:* The XP-endo Finisher was activated (at 800 rpm) for 1 minute using slow and gentle 7–8 mm length-wise partial movements to contact the full length of the canal.
- *Group II—EndoVac:* The canals were irrigated with NaOCl for 30 seconds with macrocannula using the EV delivery tip, the canal was left undisturbed with the same irrigant for 60 seconds. The irrigation with the microcannula was done as mentioned in the irrigation protocol by positioning the tip 2 mm short of the working length for 2 seconds and at the working length for 6 seconds. This movement was done for 30 seconds after which the canal was left with irrigant for 60 seconds.
- *Group III—Plastic Finishing File:* In this group, a plastic endodontic finishing file was used in continuous rotation. It was used to agitate the irrigation solution. The size used was F1-4% taper, which has a parallel offset flute design for maximum agitation and debris removal.
- *Group IV—Conventional needle irrigation (CNI):* The canals were irrigated with a 5 mL, 30-gauge side-vented syringe with a 1 mm short of the working length.

After final irrigation protocol, each specimen was disassembled, and images were made with a digital camera attached to a stereomicroscope at the highest magnification (20×) to allow a complete view of the canals and isthmus.

The scoring criteria were given as follows: Hülsmann et al.;[7] Peters and Barbakow[8]

- Score 1—No debris
- Score 2—25% of the canal is covered with clumps of debris
- Score 3—25–50% of the canal is covered with clumps of debris
- Score 4—50–75% of the canal is covered with clumps of debris
- Score 5—More than 75% of canals is covered with debris

The scoring of debris was evaluated by three experienced investigators.

Statistical Analysis

Data were entered in Microsoft Excel and analyzed in statistical package for the social sciences (SPSS), Version 22.0. Descriptive statistics are represented with the mean and standard deviation

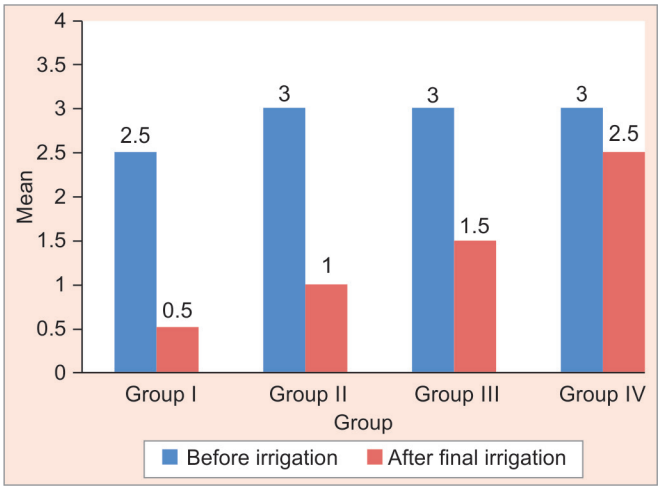

Fig. 1: Representing that the auxiliary methods in irrigation had improved the debris removal in the canal

Table 1: The mean values of the debris present before the irrigation with no statistically significant difference between the groups ($p = 0.54$)

Group	*Mean*	*SD*	*Mean*	*Intergroup comparison of p-value*
Group I	2.50	0.53	2.50	0.54
Group II	2.60	0.52	3.00	
Group III	2.80	0.42	3.00	
Group IV	2.70	0.48	3.00	

Table 2: The mean values of the debris present before the irrigation with a statistically significant difference between the groups ($p < 0.05$)

Group	*Mean*	*SD*	*Mean*	*Intergroup comparison of p-value*
Group I	0.50	0.53	0.50	0.005
Group II	1.30	0.48	1.00	0.004
Group III	1.50	0.53	1.50	0.004
Group IV	2.50	0.53	2.50	0.32

(SD). An analysis of variance (ANOVA) test was applied to compare the mean debris removal between groups. *Post hoc* tests (Dunnett's test and Tukey test) were applied to compare mean debris removal between the groups; $p < 0.05$ was considered statistically significant.

Results

Figure 1 represents the mean values of debris present in the canals pre- and postirrigant agitation in all the groups, that is, before agitation all the groups are showing the mean value of 2.5–3 and the highest mean value of debris present within the canal after agitation was recorded in the standard needle irrigation group, that is, 2.5 and the lowest debris scoring was recorded in XP-endo Shaper, EV, and plastic finishing file, that is, 0.5, 1, and 1.5, respectively. Table 1 represents the intergroup comparison of mean values for debris present within the canal before irrigation which shows that there was no statistically significant difference between the groups to avoid bias ($p = 0.54$). Table 2 shows the mean values of the debris present after irrigation which depicts that there was a significant difference in the debris removal in the canals after agitating the irrigants with various devices $p < 0.05$). Table 3 shows the intergroup comparison of debris which shows that XP-endo Shaper and EV showed a greater significant difference in the debris compared with the other groups ($p < 0.05$). The ascending order of debris remaining in the canals was XP-endo Finisher, EV, plastic endodontic finishing file, and standard needle irrigation.

Table 3: The intergroup comparison of debris which shows that XP-endo Shaper and EV showed greater significant difference in the debris compared with the other groups ($p < 0.05$)

Intergroup comparison	*p-value*
1 vs 2	0.01
1 vs 3	0.003
1 vs 4	<0.001
2 vs 3	0.004
2 vs 4	<0.001
3 vs 4	0.003

Discussion

The present study evaluated the debris removal in the canal and isthmus by different final irrigation devices, that is, the XP-endo Finisher, EV, plastic finishing file, and standard needle irrigation. Based on the results of the present study the null hypothesis was rejected as there was a significant difference in the debris present in the groups after agitation. The agitation has improved the debridement of the canals.

Many previous studies used a variety of methodologies to investigate the efficacy of different irrigation systems in cleaning the root canal systems. In the present study, the procedure for preparing the specimens was adapted from a method used by Howard et al. and Klyn et al.[9,10] A custom-made jig was used for the assembly of sectioned specimens. The custom-made jig, which was specially created for this work was based on a Bramante et al.[11] approach but with the inclusion of a compression component. Within each specimen, compressing the parallel sections eliminated the 0.3-mm space with each cut of the saw. The custom-made jig enables the sectioning and subsequent reassembling of a tooth to rebuild a complete root canal system. This gives the chance to assess the anatomy of the canal and isthmus as well as the impact of irrigation on leftover debris, each tooth acting as its own control.

The mesial roots of mandibular first molars were selected and sectioned at three levels because of the higher incidence of canal isthmus (54–89%)[6] which was found to be maximum between 2 and 4 mm from the apex.

In the present study, the highest percentage reduction of debris was observed in the XP-endo Finisher (80%) group, followed by EV (67%), plastic endodontic files (50%), and conventional needle irrigation (17%).

Conventional needle irrigation techniques have limited ability to remove dentin debris, mostly in anatomically complex areas; this makes it necessary to use an auxiliary method in the cleaning process.[1]

The plastic finishing file has a diamond abrasive coating that effectively removes the smear layer from the dentinal walls without further enlarging the canal. Singh et al. reported that the plastic

finishing file can be used as an adjunctive for conventional needle irrigation for the better removal of debris from the root canals which was evaluated using scanning electron microscopy.[12]

In the present study, it was observed that the XP-endo Finisher was the most effective device for the removal of debris from the canal and isthmus. This may be explained by the highly flexible proprietary alloy combined with the small core size and zero taper of the instrument, which allowed it to expand and reach difficult areas when in rotation.[13] Bao et al. concluded that the XP-endo Finisher presented the best biofilm reduction (99.18%) when compared to passive ultrasonic irrigation when examined with scanning electron microscope, which indicated that the XP-endo Finisher has the ability to eliminate bacteria from anatomical complexities such as fins and isthmuses.[14] Chatterjee et al. and Baumeier et al. concluded that the XP-endo Finisher presented the best smear layer removal compared with the other groups in their studies using scanning electron microscope (SEM). This might be because of its unique manufacturing material (Max Wire; FKG Dentaire SA, La Chaux-de-Fonds, Switzerland), which allows the file to expand at body temperature and compress its elliptical parts due to the resistance of root canal anatomy, which enables it to remove debris from the walls of the canal.[15,16]

The EV system is a negative pressure irrigation system that uses a master tip to deliver and evacuate the irrigant simultaneously at the pulp chamber level, whereas microcannula are used deeply in the canal, showing promising results in disinfection, debris removal, and smear layer removal.[17,18] It introduces a higher flow of irrigant and produces better debridement at 1mm from working length.[19–24] In the previous studies, it was concluded that the EV system was capable of achieving penetration of irrigant solution up to the working length and lateral canals.[25,26] In the present study, EV showed a greater amount of debris removal when compared to standard needle irrigation, which was in accordance with a study done by Haapasalo et al., who concluded that EV achieved a higher percentage of debris removal when compared to standard needle irrigation.[27]

Susin et al. concluded in their study that the use of the apical negative pressure technique resulted in a considerably cleaner isthmus when compared with standard needle irrigation by digitizing the canals and isthmus using National Institutes of Health (NIH) Image J software.[28]

The plastic finishing file showed the least amount of debris removal when compared to the XP endo finisher and EV, and showed better debris removal when compared to standard needle irrigation. It was found that XP-endo Finisher was more efficient in removing canal debris when compared to the other groups, overcoming the limited ability to remove debris in the isthmus.

In the present study, evaluation with the stereomicroscope analysis has shortcomings compared with the SEM analysis or cone beam computed tomography (CBCT) evaluation. So further studies should be done using SEM and CBCT.

Conclusion

Within the limitations of the present *in vitro* study, it was concluded that the XP-endo Finisher and EV showed a significant difference in cleaning efficacy, when compared to plastic finishing files, and standard needle irrigation. Hence, the XP-endo Finisher and EV can be used as an adjunctive irrigation approach for the removal of debris from the canal and isthmus.

Orcid

Priyanka Reddy Chinta https://orcid.org/0000-0002-7463-9443

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