Comparative Efficiency of Manual Dynamic Agitation and Passive Irrigation in Root Canal Disinfection Through Dye Penetration: An In Vitro Study

Running Title - *Comparative Evaluation of Manual Dynamic Agitation and Passive Irrigation in Root Canal Disinfection*

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ABSTRACT

Aim:

This study aimed to assess and compare the disinfection efficacy of active versus passive irrigation strategies in root canal systems using an in vitro approach.

Materials and Methodology:

Thirty human single-rooted premolar teeth were decoronated and standardized for canal instrumentation. The specimens were randomly divided into three groups (n = 10 per group). Group A underwent passive ultrasonic irrigation using the Ultra X system (Eighteenth, India); Group B received sonic activation with the EndoActivator (Dentsply Sirona); and Group C was treated using MDA with gutta-percha cones. All samples were irrigated using 3% sodium hypochlorite under a standardized protocol. Canal disinfection and cleanliness were evaluated using iohexol dye, assessed radiographically.

Results:

The ANOVA test indicated a statistically significant difference in dye penetration between the irrigation strategies ($P < 0.05$). However, when comparing Profit S3 and ProTaper Gold, no significant variation was observed with Manual Dynamic Agitation ($P = 0.210$), Passive Sonic Irrigation ($P = 0.245$), or Passive Ultrasonic Irrigation ($P = 0.538$), suggesting that both rotary systems demonstrated similar effectiveness across all irrigation techniques.

Conclusion:

Passive Ultrasonic Activation and Passive Sonic Activation based irrigation methods demonstrated superior effectiveness in root canal decontamination compared to MDA. Passive Ultrasonic and sonic activation techniques improved irrigant distribution and canal cleanliness, indicating their clinical value in enhancing endodontic disinfection.

Keywords: Iohexol dye, MDA, Passive Irrigation, Root Canal Therapy, Sonic Activation, Ultrasonic Irrigation

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INTRODUCTION

The success of endodontic treatment depends on effective disinfection procedures which require complete disinfection of root canal systems because persistent microorganisms represent the main reason for treatment failures according to studies.[1,2]The process of mechanical instrumentation enables dental professionals to create canal shapes while removing infected materials from canals, yet this method fails to achieve proper cleaning in complex areas that contain isthmuses and fins and lateral canals The mechanical preparation process requires chemical irrigation because it effectively removes both microorganisms and leftover debris which remains after the process[3]. Irrigation can be performed through passive or active techniques. Passive irrigation, usually syringe-based, relies on solution delivery without additional energy. Active methods employ agitation to improve irrigant penetration and effectiveness. Among these, sonic and ultrasonic activation are widely used, while manual dynamic agitation (MDA), performed with gutta-percha cones, is considered a simple and economical alternative[4].

Chemomechanical preparation, which combines instrumentation with irrigation, is the foundation of root canal therapy [5]. Under ultrasonic-driven natural conditions, the ultrasonic streaming, cavitation, and acoustic streaming within the aqueous environment are primarily created by the action; they present forces of shear that aid in the deep penetration of irrigant and removal of the smear layer.6 Sonic devices, though operating at lower frequencies, promote fluid movement through vibration.7 MDA improves the exchange of fluid but its performance vis-à-vis sonic and ultrasonic applications remains unclear[1,2].

The studies done to test these procedures have been inconsistent based on the results obtained[7,8]. The study indicates that some studies showed better results in terms of reduction of microbes using agitation, while other studies showed that syringe irrigation done well could achieve similar results.[9] Active procedures have been seen to achieve better results when used with the combination of sodium hypochlorite/EDTA with passive ultrasonic irrigation since they have special advantages for the coronal and middle thirds of root canals[10,11].

The study was done to test the effectiveness of three different disinfection procedures: MDA and passive sonic irrigation, as well as PUI. The study was done to see which of these procedures could achieve better results in the disinfection of the root canal using a test for the penetration of dyes[12,13]. The results obtained from the study show which of these procedures could achieve better penetration of the irrigating solution, which would help doctors choose the right procedure for better results[14,15].

MATERIALS AND METHODS

Study Design and Sample Selection

This in vitro experimental study was conducted on 51 freshly extracted single-rooted human premolars. Teeth with a single straight root canal, without evidence of caries, fractures, or resorption, were selected for the study. The research was approved by the Institutional Scientific Review Board for Dental Research (Approval No: SRB/SDC/ENDO-2302/24/271).

Specimen Preparation

The extracted teeth were cleaned of any soft tissue remnants, stored in physiological saline solution to maintain tissue hydration, and then prepared with standardized access cavities using high-speed bur cutting with continuous water cooling. Patency of the canal was checked with a size 10 K-file (Mani, Japan).

Root Canal Instrumentation

The working length was established using a size 15 K file, where the tip was visible at the apical foramen, followed by subtraction of 1 mm. Rotary NiTi systems were used for canal preparation (ProTaper Gold and Profit S3, Dentsply Sirona) to a size 25 with a 6% taper using a crown-down technique. For irrigation during instrumentation, 3% sodium hypochlorite (NaOCl) solution (Parcan, Septodont, India) was used with a 27G side-vented needle. Following preparation, irrigation was done with 5 mL of 3% NaOCl.

Group Allocation and Irrigation Protocol

The specimens will be allocated randomly into three groups based on the irrigation activation protocol. Each group will comprise 17 specimens.

Group A (Ultrasonic Activation): 3% NaOCl will be activated using the Ultra X ultrasonic device (Orikam Eighteenth, India) for 20 seconds.

Group B (Sonic Activation): 3% NaOCl will be activated using the EndoActivator system (Dentsply Sirona). The same protocol will be applied as for Group A.

Group C (Manual Dynamic Agitation – Passive): 3% NaOCl solution was administered using a syringe, which was followed by manual agitation using a size 25 cone for 50 strokes in 30 seconds.

The total amount of the solution administered for all groups was 5 mL. The solution was administered intermittently for different cycles. Each cycle was for a duration of 20-30 seconds. The canals were later flushed with saline solution.

Assessment of Canal Cleanliness

The canal cleanliness was evaluated using Iohexol, a radiopaque contrast agent. The agent was injected into the canal to clearly indicate areas where the debris was present and where the irrigation solution had penetrated. Two blinded assessors evaluated the

digital radiographs to assess the efficiency of disinfection.

Data Collection and Statistical Analysis

Each sample was rated according to standardized criteria for disinfection and cleanliness. Data analysis was performed using one-way ANOVA, followed by a post hoc Tukey's test for intergroup comparisons. A P value < 0.05 was considered statistically significant.

RESULTS

One-way analysis of variance (ANOVA) was used to assess the difference in dye penetration between all of the irrigation methods. The results of the ANOVA analysis showed a statistically significant difference between the groups ($P < 0.05$), which indicates that the method of irrigation used did make a difference in terms of irrigant penetration and canal disinfection as shown in Fig 1.

The study also compared the effectiveness of two rotary instruments, Profit S3 and ProTaper Gold, using three methods of irrigation, which are Manual Dynamic Agitation (MDA), Passive Sonic Irrigation (PSI), and Passive Ultrasonic Irrigation (PUI). The results of each method are presented in Table 1.

Manual Dynamic Agitation (MDA)

The mean score of debris removal for the Profit S3 system under manual agitation was found to be 2.581 ± 0.055, whereas the mean score of the ProTaper Gold system was slightly higher at 2.622 ± 0.091. Statistical analysis of the results showed no significant difference between the systems ($P = 0.210$).

Passive Sonic Irrigation (PSI)

When sonic activation was used, the Profit S3 group resulted in a mean smear layer score of 0.475 ± 0.041, compared to 0.542 ± 0.129 of the ProTaper Gold. Although a slightly higher smear index was observed in the ProTaper Gold, it was not statistically significant ($P = 0.245$), which indicates that both instruments were effective in removing the smear layer when sonic activation was used.

Passive Ultrasonic Irrigation (PUI)

When ultrasonic activation was used, the results of both systems were almost identical. The results of the Profit S3 system were a mean of 0.349 ± 0.073, whereas the results of the ProTaper Gold system were 0.355 ± 0.061. The difference was not statistically significant ($P = 0.538$), showing that ultrasonic irrigation was equally effective for canal debridement with both systems.

DISCUSSION

The procedure is inherently difficult because of the limited access for endodontic instruments, the presence of microbial contamination, and the complex root canal anatomy. In the present study, the efficiency of three different irrigation techniques, Manual Dynamic Agitation, Passive Sonic Irrigation, and Passive Ultrasonic Irrigation, was evaluated along with two different file systems, Profit S3 and ProTaper Gold. By using two-way ANOVA, significant differences between the groups were observed at the level of $P < 0.05$.

Among MDA systems, similar values in removing debris were observed for both rotary systems ($P = 0.210$). PSI systems did not demonstrate significant differences in smear removal for either rotary system ($P = 0.245$), although higher values were observed for ProTaper Gold systems. The most consistent values were observed for PUI systems, with negligible differences observed for the systems ($P = 0.538$) as shown in Fig 2. These observations indicate that the irrigation method is more important in canal decontamination compared to the choice of rotary systems for use in endodontic treatment.

These observations are supported by previous studies. Khademi et al. showed that using a larger size 30 with a 0.06 taper increases the removal of debris and the smear layer in the apical third significantly[16]. In the present study, the greater the taper used, the greater the depth of penetration of the needles. According to Mochizuki et al., minimally invasive endodontic treatment modalities not only maintain the tooth structure but may also compromise the removal of infected material in the canal[17].

The dual importance of instrumentation and irrigation was emphasized by De-Deus et al., stating that irrigants are critical for tissue dissolution and antimicrobial activity[11]. The use of fine side-vented needles or negative pressure irrigation is also safer and more efficient in the apical region, which is consistent with the reduced dye penetration observed with 26-gauge needles in the present study[16].

Ballal et al. showed that conventional instrumentation can leave up to 35 to 53% of canal surfaces unprepared, particularly in anatomically complex areas such as isthmus and lateral canals[18]. This points to the need for using adjunctive irrigation for the removal of biofilms.

With regard to activation methods, it is ranked third after syringe and ultrasonic activation methods[17]. In this study, sonic and ultrasonic activation methods were performed following standardised protocols as outlined by Ramamoorthi et al.[1].Various studies have shown that sonic activation, such as the EndoActivator, increases irrigant flow compared with conventional syringe systems[19]. Iandolo et al. found that activation increases flow dynamics, thus facilitating the removal of endodontic tissues and microorganisms[20].

Ultrasonic irrigation is also advantageous due to the superior removal of the biofilm through the mechanisms of acoustic microstreaming and cavitation, which generate a high degree of shear and turbulent flow, enabling the irrigating fluid to access the lateral canal and apical deltas[21]. The above findings are consistent with previous evidence supporting the effectiveness of active irrigation techniques on canal cleaning due to anatomical complexities[4,6]. Although the advantages of the passive system include ease of use and cost-effectiveness, the low degree of mechanical activity may interfere with the irrigating fluid flow[13,22,23]. The development of nanoparticle irrigants is one of the recent advancements in overcoming the above-mentioned problems[24].

However, despite the advantages, active irrigation systems do have some risks. If the system is misused, procedural errors may occur. Such errors may result in canal transportation/extrusion. Moreover, the increased costs may be a barrier to the implementation of active irrigation systems.

The limitation of the study is that it is an in vitro study. Therefore, the study has not taken into consideration the actual clinical situations. In addition, the study has only taken a few irrigation methods into consideration. Furthermore, the study has only taken into consideration the immediate effects. However, the long-term results have not been taken into consideration.

In conclusion, active and passive irrigation methods have been effective in the disinfection of the root canal. However, active irrigation methods, such as sonic and ultrasonic activation, have been found to be effective in complex root canal systems.

CONCLUSION

In this study, it was found that ProFit S3 and ProTaper Gold rotary file systems have shown similar efficacy in terms of removal of debris, reduction of smear layers, and efficacy of passive ultrasonic irrigation. There were no statistically significant differences found in using ProFit S3 and ProTaper Gold systems, which indicates that ProFit S3 can be used as a potential alternative to ProTaper Gold in dental practice. However, more studies with larger sample sizes in in vivo conditions are required to determine the efficacy of ProFit S3 and ProTaper Gold systems in dental practice to evaluate their long-term effects in endodontic treatment.

Declarations:

Ethics Approval: The present in vitro study was conducted after obtaining approval from the Institutional Review Board (Approval No.SRB/SDC/ENDO-2302/24/271). The research was carried out in September 2024 at the White Lab, SIMATS University, Chennai, India, in collaboration with Saveetha Dental College & Hospital.

Competing Interest: No conflict of interest

Data Availability: All data generated or analyzed during this study are included in this published article.

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antibiofilm efficacy. Endodontology. 2025 Jan 1;37(1):61-8.

Irrigation Activation	ProFit S3	Protaper Gold	One way ANOVA
Manual Dynamic	2.58 ± .055	2.62 ± .091	0.002
Sonic Irrigation	0.43 ± .156	0.54 ± .128	
Passive Ultrasonic	0.17 ± .328	.033 ± .377	

Table 1:Comparative analysis of PROFIT S3 and PROTAPER GOLD rotary systems across three irrigation techniques: MDA (MDA), Passive Sonic Irrigation (PSI), and Passive Ultrasonic Irrigation (PUI)

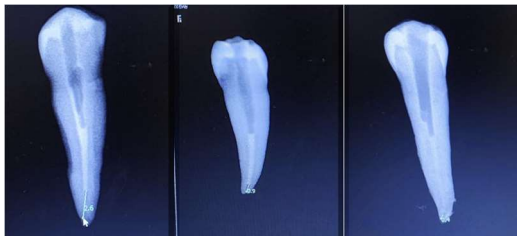

Figure 1 - Dye Penetration Seen In Rvg Using MDA, Sonic , Ultrasonic Passive Irrigation, A. MDA B. Sonic Passive Irrigation C. Ultrasonic Passive Irrigation

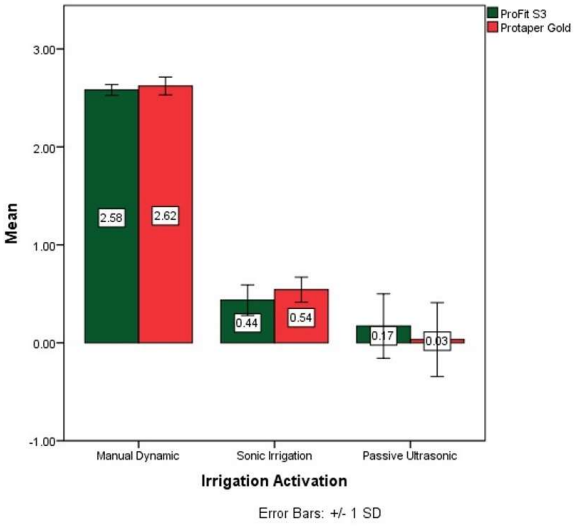

Figure 2 - Graph Showing Dye Penetration Using Different Irrigation Methods

Table Legend

Table 1:Comparative analysis of PROFIT S3 and PROTAPER GOLD rotary systems across three irrigation techniques: MDA (MDA), Passive Sonic Irrigation (PSI), and Passive Ultrasonic Irrigation (PUI)

Figure Legends

Figure 1 - Dye Penetration Seen In Rvg Using MDA, Sonic , Ultrasonic Passive Irrigation, A. MDA B. Sonic Passive Irrigation C. Ultrasonic Passive Irrigation

Figure 2 - Graph Showing Dye Penetration Using Different Irrigation Methods