



Efficacy of Handpiece Mounted Continuous Irrigation System for the Removal of Residual Pulpal Debris During Root Canal Preparation

Huma Sarwar¹ Fazal Qazi¹ Shahbaz Ahmed¹ Yawar Abidi² Meshal Naeem³ Juzer Shabbir⁴ Zohaib Khurshid⁵

¹Department of Operative Dentistry and Endodontics, Dr Ishrat-ul-Ibad Khan Institute of Oral Health Sciences, Dow University of Health Sciences, Karachi, Pakistan

²Department of Operative Dentistry and Endodontics, Sindh Institute of Oral Health Sciences, Jinnah Sindh Medical University, Karachi, Pakistan

³Department of Periodontology, Dr Ishrat-ul-Ibad Khan Institute of Oral Health Sciences, Dow University of Health Sciences, Karachi, Pakistan

⁴Department of Operative Dentistry and Endodontics, Liaquat College of Medicine and Dentistry, Karachi, Pakistan

⁵Department of Prosthodontics and Dental Implantology, College of Dentistry, King Faisal University, Al Ahsa, Saudi Arabia

Address for correspondence Juzer Shabbir, MDS, BDS, Department of Operative Dentistry and Endodontics, Qamar Dental Hospital, Liaquat College of Medicine and Dentistry, Street 19, KDA Scheme-Abul Asar Hafeez Jalandhari Road, Block 15 Gulistan-e-Johar, Karachi, Sindh, Pakistan (e-mail: dr.juzer.shabbir@gmail.com).

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Abstract

Objective The removal of residual pulpal debris (RPD) from the root canal walls, especially in necrotic teeth is important for successful endodontic outcome. The aim of this study was to evaluate the RPD removal efficacy of handpiece mounted continuous irrigation with simultaneous root canal preparation from the apical third of root canals as compared to conventional syringe irrigation (SI).

Materials and Methods Ninety extracted teeth were randomly divided into three groups: SI; handpiece mounted continuous irrigation (CI); and both syringe and continuous irrigation (CI+SI). After root canal preparation, roots were sectioned at 1 (a), 3 (b) and 5 (c) mm from apex and prepared for Hematoxylin-Eosin staining. Sections were microscopically examined for presence of RPD.

Statistical Analysis Intergroup difference in average percentage of RPD at different root levels was calculated by using analysis of variance test (ANOVA). Tuckey test was used for pairwise comparison.

Results ANOVA showed significant difference between all three groups ($p < 0.05$). SI group showed a significantly higher percentage of RPD as compared with CI and CI+ SI groups at all root levels ($p < 0.01$). At root level a, CI showed a significantly higher percentage of RPD as compared with CI+SI ($p < 0.01$).

Conclusion Handpiece mounted CI during rotary instrumentation showed a significant reduction in RPD as compared with conventional syringe irrigation. This technique was found to be an effective method for an enhanced root canal debridement.

Keywords

- ▶ continuous irrigation
- ▶ debridement
- ▶ dentin debris
- ▶ root canal
- ▶ sodium hypochlorite
- ▶ syringe irrigation

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Introduction

A crucial factor influencing the successful outcome of a nonsurgical endodontic treatment is the implementation of a thorough chemomechanical debridement and disinfection of the root canal system, especially of the apical third region.^{1,2} The apical region consists of wide anatomic variation and acts as a reservoir of microbes and dentino-pulpal debris (DPD) formed during root canal preparation. The DPD may jeopardize the seal created by the obturating materials. The mechanical instrumentation of the root canal system alone is insufficient for the complete removal of DPD, especially from the areas inaccessible to the instrumentation.³ Therefore, chemo-mechanical preparation with copious sodium hypochlorite (NaOCl) irrigation is required for effective root canal debridement. Several irrigation methods and devices are available for this purpose.⁴⁻⁸ The goal of these irrigation systems is to evenly spread irrigating solution throughout the root canal system. However, the penetration of irrigating solution in the apical area is dependent on the factors such as internal canal anatomy, amount of DPD present, the method of agitation, and the delivery of irrigant.^{9,10}

NaOCl is the irrigant of choice for chemo-mechanical root canal preparation. The most distinguished property of NaOCl is its ability to dissolve organic pulpal tissue. This property is often dependent on the factors including its concentration, volume, pH, temperature, replenishment, agitation, contact duration, and area of the tissue covered.¹¹ Upon contact of NaOCl with the organic tissue, a local consumption of NaOCl occurs through a series of reactions such as saponification, neutralization, and chloramination. As a result, there is a decline in the availability of active NaOCl requiring frequent replenishment.^{11,12}

The root canals are enclosed in a bony socket which emulates a closed channel; and the organic decomposition of pulpal tissue by NaOCl results in liberation of carbon dioxide and ammonia in the form of bubbles. The combination of these two features promote gas entrapment during chemo-mechanical preparation, resulting in the formation of "apical vapor lock" effect.¹³⁻¹⁵ The vapor lock effect restricts the irrigant penetration into the apical region of root canal system, making the debridement suboptimum and challenging.

Syringe irrigation (SI) is the most commonly used irrigation method.^{10,14,16,17} The exchange of irrigant apical to the needle tip is dependent on the needle type, design, and gauge,^{10,13,14} and it is usually limited to 1 to 1.5 mm beyond the needle tip,¹³ which depicts that its effectiveness is limited by its depth of insertion. Therefore, to deliver active NaOCl apically, the needle is required to be inserted near the working length (WL).¹⁸ Other limitations of SI include weak mechanical flushing, incomplete dentinal debris removal, the requirement of wider canal preparation, and potential of irrigant extrusion.^{8,10,13,14}

Ideally, the NaOCl must be continuously agitated and refreshed within the root canals because the NaOCl that seeps into the apical area is readily inactivated. Therefore, there is only a limited active NaOCl available at the apical area when intermittent irrigation with SI is used.¹⁹ This limitation

necessitates the use of an auxiliary method to remove the DPD from the anatomically complex areas. In the current *in vitro* study, we used an innovative method of simultaneous (or continuous) irrigation during root canal preparation in roots with sealed apices to replicate vapor lock effect. The aim of the present study was to evaluate the remaining pulpal debris (RPD) removal efficacy of handpiece mounted continuous irrigation system (HMCIS) with simultaneous root canal preparation compared with conventional syringe irrigation from the apical third region in a closed channel model. The null hypothesis of the study was that there would be no difference in RPD removal efficacy at the apical third between experimental groups.

Materials and Methods

The current study was an *in vitro* experimental (comparative) research. It was approved by institutional review board (ref no. IRB-797/DUHS/Approval/2-16/326), Dow University of Health Sciences (DUHS). The inclusion criteria consisted of permanent, mature, and single-rooted teeth (Vertucci type-1) extracted due to orthodontic reasons. The exclusion criteria were teeth with caries or fracture below cementoenamel junction, developmental defects, and previously endodontically treated teeth. The Sample size was determined as 84 (which was increased up to 90) with 80% power of the test and 95% confidence level using PASS v11 software (Microsoft, Redmond, Washington, DC, United States). It was calculated with the help of mean percentage (\pm standard deviation) of remaining dentinal debris within three groups from a previous study.⁷ Level of significance was kept <5%.

Fabrication of Handpiece Mounted Continuous Irrigation System

Before the start of the study, HMCIS was assembled (and tested) by attaching one side of a 90-cm long silicone tube (with 2 mm internal diameter) to a 10-mL disposable leu-



Fig. 1 Rotary/endomotor handpiece with attached irrigation apparatus.

lock plastic disposable syringe. The other side of the tube was attached beneath the head of the rotary handpiece endomotor (► Fig. 1). A trained dental assistant pushed the plunger of the syringe at 10 mL/min during the root canal preparation. Prior training was given to the endodontist on the use of the manually designed HMCIS.

In Vitro Endodontic Procedures

The endodontic procedure was performed on extracted teeth (stored in a solution of 0.2% thymol/0.9% saline until used) in endodontics departments, DUHS. The histological processing was performed in histopathological laboratory, DUHS. The apices of the teeth were sealed with the help of two layers of nail varnish to simulate a closed channel, opened at one end. Root canal preparation was performed by an independent, experienced endodontist. Endodontic access and WL were achieved with 4 round bur and ISO 10 k-file, respectively. WL was kept 0.5 mm short of the apex. Canals were instrumented up to 20 k-hand file (20/0.02 taper). Afterward, the rotary NiTi file system (Protaper universal; Dentsply Maillefer, Ballaigues, Switzerland) was used for endodontic preparation till F3 (30/0.09) at manufacturer recommended torque and speed.

A total of 90 teeth were randomly divided into three groups (group I, II, and III; $n = 30/\text{group}$) according to the employed irrigation method by using MS Excel software. In group I, conventional SI (with 1 mL of 3% NaOCl through

handpiece mounted CI was done. In group III, the combination of SI and CI (CI+SI) was used. In this group, SI was performed between each file used during CI. After completion of chemo-mechanical preparation, a final irrigation with 1 mL of saline solution was done to neutralize the NaOCl activity. The root canals were dried with ISO standard paper points and subjected to histological processing.

Histological Processing and Sectioning

In this study, we evaluated and defined RPD as soft tissue debris remaining after chemo-mechanical root canal preparation in the root canal lumen, observed under microscope. For tissue processing, root canals were filled with 1 mL of 10% buffered formalin for 24 hours to fix RPD. Later, the crowns of the teeth were separated from the roots with the help of a diamond disc (NTI, Kahla, Germany). The roots were immersed in 10% formalin for 96 hours. The specimens were then washed in running water for about an hour. Afterward, the specimens were decalcified for 10 days in a solution containing <15% (by wt.) hydrochloric acid/<5% EDTA at 40°C in an oven. For standard histological processing, samples were dehydrated in ascending grades of ethanol, cleared in xylene, and finally infiltrated with paraffin. Roots were marked and sectioned at 1 mm (root level "a"), 3 mm (root level "b"), and 5 mm (root level "c") from the apex using a microtome. The sections were then stained with hematoxylin-eosin, and the slides were examined under a stereomicroscope.

Microscopic Assessment and Data Analysis

Stereomicroscope (Nikon microscope Eclipse 80i; Nikon Instech Co. Ltd; Minato-ku, Tokyo, Japan) was used to observe the slides at $\times 100$ magnification. Images were digitalized for morphological analysis. The scans of microscopic slides were uploaded to ImageJ software (U.S. National Institute of Health, Bethesda, Maryland, United States) and two regions of interest, RO1 and RO2 were drawn. RO1 was characterized as the region in the canal space that contained RPD, and RO2 as the total canal space. Following equation was used to calculate the percentage of RPD in each image:

$$\text{Percentage of RPD} = \frac{\text{RO1}}{\text{RO2}} \times 100\%$$

Mean percentages of RPD were calculated for the three sections of the root. The principal investigator performed histological processing of teeth and evaluation of RPD.

The data were analyzed by using SPSS version 21.0. Percentages were reported for the prevalence of tooth type in the study. Descriptive statistics like percentages were reported for RPD at root levels a, b, and c in each group. Analysis of variance (ANOVA) test was used to identify the existence of a significant difference in the average RPD between the groups. Post hoc Tuckey's test and independent-sample *t*-test were applied for pairwise comparison to specify the significant difference between the two irrigation groups at different root levels and between the two root levels in different irrigation groups. The significance level was kept at <5%.

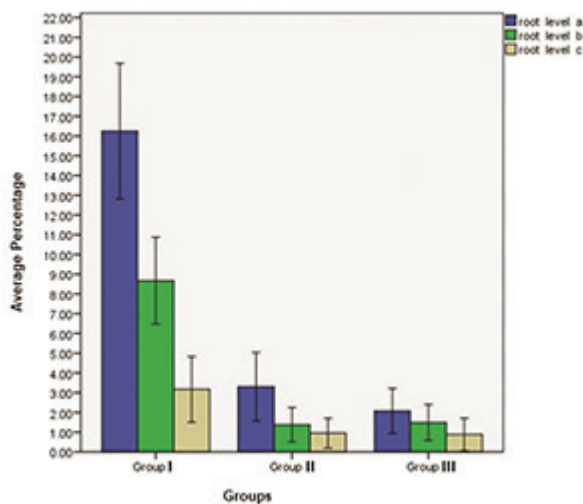


Fig. 2 Average percentage of remaining dental debris in different irrigation groups at different root levels. Group I (SI), Group II (CI), Group III (CI+SI); root_level_a (1 mm from apex), root_level_b (3 mm from apex), and root_level_c (5 mm from apex). CI, continuous irrigation; SI, syringe irrigation.

a 30-gauge Max i-Probe needle (Dentsply Maillefer) was performed between each file used during root canal preparation. It was kept 1.5 mm short of the WL, and was moved up and down during irrigation to prevent binding. In group II,

Results

A total of 90 single-rooted teeth were included in the study out of which 40.5% of the included teeth were maxillary second premolars, 25.5% were mandibular first premolars, 13.5% were mandibular second premolars, and 1.8% were maxillary first premolars. ►Fig. 2 shows a general graphical representation of the RPD in each irrigation group at different root levels. It revealed that the average percentages of RPD were highest in the SI group at all the root levels (a, 16.25 ± 1.71 ; b, 8.67 ± 1 ; c, 3.16 ± 0.83). Moreover, the mean difference in RPD between the three groups I (SI), II (CI), and III (CI+SI) at all root levels was found to be statistically significant ($p < 0.05$; ►Fig. 2).

Further analysis using pairwise comparison of the irrigation groups (I vs. II, II vs. III, III vs. I) at different root levels showed a significant increase of RPD in SI group as compared with CI and CI+SI group at all the root levels ($p < 0.0001$). Whereas at root level b and c, no significant difference could be observed between the CI group and CI+SI group. Only at root level a, group II showed a significant increase in the mean percentage of RPD as compared with group III ($p < 0.0001$; ►Table 1; ►Fig. 2).

Another pairwise comparison between the different root levels (a vs. b, b vs. c, c vs. a) in each irrigation group showed a statistically significant difference ($p < 0.01$) in RPD between all root levels in all the irrigation groups (►Table 2). The analysis showed that root level a had significantly higher amount of RPD as compared with root level b and c in all the irrigation groups ($p < 0.01$), and root level b had significantly more RPD as compared with root level c in all irrigation groups. The mean irrigation time recorded for groups I, II, and III was recorded to be 8.41 ± 2.32 , 6.36 ± 2.13 , and 12.64

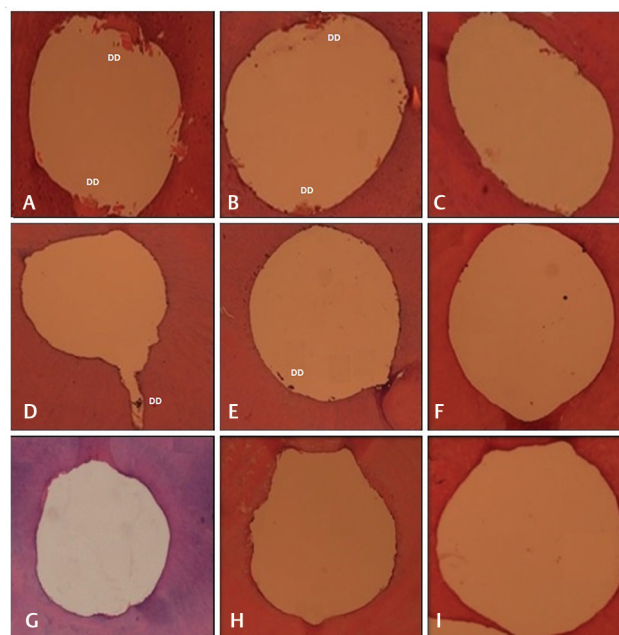


Fig. 3 Photomicrographic images of root canal lumen at different levels and irrigation groups. DD, residual pulp debris; SI (A, 1 mm; B, 3 mm; c, 5 mm from apex), CI (D, 1 mm; e, 3 mm; f, 5 mm from apex), CI+SI (G, 1 mm; h, 3 mm; i, 5 mm from apex). CI, continuous irrigation; SI, syringe irrigation.

± 1.48 minutes, respectively. The photomicrographic images of the root sections and associated RPD in the canal after root canal preparation in SI, CI, and CI+SI groups are shown in ►Fig. 3. The presence of RPD can be clearly observed in the SI group, especially at 1 mm (a) and 3 mm (c) from the apex.

Table 1 Pairwise comparison of irrigation groups at different root levels

Root levels	Group I–II, (mean \pm SD) ^a	AD (%) (p-Value)	Group I–III, (mean \pm SD) ^a	AD (%) (p-Value)	Group II–III, (mean \pm SD) ^a	AD (%) (p-Value)
a	(16.2 \pm 1.71)–(3.3 \pm 0.86)	12.94 (<0.0001 ^b)	(16.2 \pm 1.71)–(2.07 \pm 0.57)	14.17 (<0.0001 ^b)	(3.3 \pm 0.86)–(2.07 \pm 0.57)	1.23 (<0.0001 ^b)
b	(8.6 \pm 1.09)–(1.3 \pm 0.43)	7.30 (<0.0001 ^b)	(8.67 \pm 1.09)–(1.48 \pm 0.45)	7.18 (<0.0001 ^b)	(1.37 \pm 0.43)–(1.48 \pm 0.45)	0.11 (0.574)
c	(3.16 \pm 0.83)–(0.95 \pm 0.37)	2.21 (<0.0001 ^b)	(3.16 \pm 0.83)–(0.88 \pm 0.41)	2.28 (<0.0001 ^b)	(0.95 \pm 0.37)–(0.88 \pm 0.41)	0.06 (0.795)

Abbreviations: AD, average difference; SD, standard deviation.

^aValues are expressed in terms on percentage.

^bSignificant difference; root levels a, 1 mm from apex; b, 3 mm from apex; c, 5 mm from apex; irrigation groups ($n = 30$ /group) group I, SI; group II, SI, Group III, CI+SI.

Table 2 Pairwise comparison of different root levels within the irrigation groups

Irrigation groups	Root level a–b, (mean \pm SD) ^a	AD (%) (p-Value)	Root level a–c, (mean \pm SD) ^a	AD (%) (p-Value)	Root level b–c, (mean \pm SD) ^a	AD (%) (p-Value)
I	(16.2 \pm 1.71)–(8.6 \pm 1.09)	7.57 (<0.01 ^a)	(16.2 \pm 1.71)–(3.16 \pm 0.83)	13.08 (<0.01 ^a)	(8.6 \pm 1.09)–(3.16 \pm 0.83)	5.50 (<0.01 ^a)
II	(3.3 \pm 0.86)–(1.3 \pm 0.43)	1.93 (<0.01 ^a)	(3.3 \pm 0.86)–(0.95 \pm 0.37)	2.35 (<0.01 ^a)	(1.3 \pm 0.43)–(0.95 \pm 0.37)	0.42 (<0.01 ^a)
III	(2.07 \pm 0.57)–(1.48 \pm 0.45)	0.58 (<0.01 ^a)	(2.07 \pm 0.57)–(0.88 \pm 0.41)	1.18 (<0.01 ^a)	(1.48 \pm 0.45)–(0.88 \pm 0.41)	0.60 (<0.01 ^a)

Abbreviations: AD, average difference; SD, standard deviation.

^aSignificant difference; level a, 1 mm from apex; Level b, 3 mm from apex; level c, 5 mm from apex; group I, SI; group II, SI, group III, CI+SI.

An interesting observation was the presence of RPD in the lateral canal (► Fig. 3D). Apparently, the clearest canals were observed in CI+SI group at all root levels.

Discussion

Several methods of irrigation have been proposed in literature for effective disinfection of the root canal system and removal of RPD such as ultrasonic activation of irrigant, sonic irrigation using EndoActivator, EndoVac system, laser activated irrigation, and GentleWave system.⁵⁻⁸ The limited ability of SI to remove DPD from the apical part of root canal system^{20,21} mandated the development of these systems. In this study, we compared a new method of CI through manually designed HMCIS with the SI for removal of RPD in a closed channel environment.

The methodology employed in the current study for evaluation of the RPD was adopted from previous studies.^{4,22} In those studies, the term “residual dentinal debris” was used for the description of the dentinopulpal debris acquired after root canal preparation. However, this term is not a true representation of the dentinal debris observed in the root canal lumen under microscope after decalcification process. Therefore, we used the term “RPD” to represent the remaining debris left after the decalcification process. A closed channel system was used to simulate a natural root canal having a closed chamber environment. SI with a 30-gauge needle in 5 cc leuc-lock syringe was used because of its verified safety and control.⁹ The open-ended needles were preferred over side vented needles for SI because of better irrigant replacement at the advancing front.⁹ The irrigation needle was kept 1.5 mm short of the WL during SI because the irrigant replacement is limited only to 1.5 mm beyond the tip.^{13,23}

The intragroup analysis showed that the apical sections of the roots irrespective of the irrigation groups had the highest amount of RPD followed by middle and coronal sections. This finding corroborated with the results of a previous study.⁸ The intergroup comparison revealed that the RPD removal efficacy of group II (CI) and Group III (CI+SI) was same in all sections (a, b, and c) except at 1 mm from the apex, where CI+SI group was found to be more efficacious than CI alone. Overall, CI and CI+SI group showed better debridement than SI group especially at the apical third, resulting in the rejection of the study's null hypothesis. Additionally, it is a known fact that by increasing the irrigant volume or prolonging the irrigant contact time, pulp tissue dissolution can be enhanced.²⁴ Even though, the current study showed that the mean irrigation time was the longest in group III and shortest in group II, both of these groups showed better RPD removal efficacy when compared with SI at all the three root levels. The enhanced debridement might be due to continuous refreshment of NaOCL along with simultaneous agitation and instrumentation to the WL, which possibly disrupted the vapor lock effect.^{14,25} Similar results were found in previous studies which used Self-Adjusting File (SAF) in conjunction with CI.^{26,27} Moreover, previous studies have highlighted the

limited ability of SI to debride apical part of root canal system.^{8,14,28} This limitation is suggested to be due to the absence of frequent replenishment of NaOCL at the apex.^{6,29} On the other hand, Walters et al found no difference in root canal debridement between a handpiece mounted Quantec E irrigation system with simultaneous root canal preparation and SI.⁴ However, the study did not use sealed root apices. Hence, the closed channel environment and the apical vapor lock effect could not be replicated.

The application of lubricants and periodic cleaning of the rotary endodontic instruments of dentinal debris during cleaning and shaping procedure is recommended to reduce the friction between the instrument and the canal walls.^{30,31} One attraction of the CI is that it provides a continuous lubrication and cleaning of the endodontic files through mechanical flushing.³¹ Additionally, irrigant present inside the canal at all times act as an effective heat sink which prolongs the fatigue life of the instrument.¹⁶ The continuous handpiece mounted irrigation system can be considered as a no-pressure irrigation method, similar to SAF, because the irrigating solution reaches the apical area of root canal through vibration and pecking motion of the endodontic file while it is delivered passively from the assembly.¹⁹

An important limitation of this study was that the irrigant volume in group III was dissimilar to group I and II (12 mL). This might have affected the outcome of our study. However, despite the difference in volume of irrigation between the groups II and III, the debridement efficacy of both groups was found to be superior than group I at all three root levels. This shows that the debridement is not just limited to the volume of irrigant, but also related to other factors like agitation, replenishment, and vapor lock disruption.^{11,32,33} Other limitations of this study were the absence of a negative control group which could have provided a baseline value of RPD affected by histological processing and presence of an unblinded endodontist who performed root canal preparation. However, this novel idea provided an in vitro evidence of the efficacy of simple handpiece mounted irrigation for removal of RPD from the apical portion during root canal preparation. Furthermore, no adjuncts to irrigation were required for activation and agitation of the irrigant. Therefore, this method of irrigation is expected to save clinicians' time and expenses without compromising the quality of endodontic treatment. This study encourages further investigation by addressing these limitations before this method can be implemented clinically.

Conclusion

Within the limitations of this study, it can be concluded that the HMCIS with simultaneous root canal preparation was found to be highly effective in removal of RPD from the apical part of the root canals as compared with syringe irrigation. This approach of irrigation is therefore suggested to be a simple, practical, and cost-effective mode of enhanced endodontic debridement during root canal preparation.

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None.

Conflict of Interest

None declared.

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