Auto irrigate - The continuous irrigant delivery and intracanal aspiration system

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ABSTRACT

Aims: To compare the delivery of irrigant to the apical third of the root canals using an ingeniously designed continuous irrigation and intracanal aspiration system to standard irrigation techniques.

Methods: Sixty-six freshly extracted single-rooted mandibular second premolars of similar dimensions with a single straight canal, confirmed radiographically, were selected and divided into three groups ($n = 22$) based on irrigation techniques employed: (i) manual dynamic activation, (ii) passive ultrasonic activation, and (iii) the system designed by the authors. Standard oval-shaped access cavities were prepared and the working length was determined radiographically. Instrumentation with ProTaper F2 rotary files was followed by irrigation with 2.5% NaOCl and saline using a 2.5 ml syringe and needle for Groups 1 and 2, and the irrigant delivery system for Group 3. A prefinal rinse with EDTA and a final rinse with saline was also carried out. Apical delivery of irrigant was evaluated by flooding the root canals with 1% toluidine blue dye for 30 seconds. The specimens were decoronated and split vertically and labiolingually and visualized under a stereomicroscope (5 magnification) and photographed. The images were analyzed using ImageJ software to measure the unstained apical region. One-way ANOVA with Tukey's *post hoc* test was used to statistically analyze the results ($P < 0.05$).

Results: The ingeniously devised irrigation delivery and intracanal aspiration system showed a significantly higher apical delivery of irrigant as compared to the other methods studied ($P < 0.001$).

Conclusions: The proposed simple root canal irrigating device can be made with materials readily available. Comparing the same to standard techniques showed better irrigant delivery to the apical region. With further studies planned to evaluate smear layer removal and canal disinfection, we hope that this can serve as an efficient, cost-effective novel device that can be easily incorporated into clinical practice.

Keywords: Continuous irrigation, endodontics, irrigation, root canal treatment

INTRODUCTION

Safe and effective root canal irrigation is considered to be of an utmost importance to successful endodontic treatment. An ideal irrigant should provide mechanical, chemical, and microbiological functions.[1] Without effective irrigation in place, the accumulation of generated debris affects the functional effectiveness of the instruments.[1] Research also showed that several irrigating solutions reported antimicrobial activity against bacteria and yeasts.[2] A bigger challenge in the selection of a particular irrigation system depends on the areas untouched by instrumentation such as fins, isthmuses, large lateral canals, and the apical delta.

Submitted: 30-Mar-2022 **Revised:** 18-Apr-2022
Accepted: 31-May-2022 **Available Online:** 28-Dec-2022

Access this article online	
Website: www.endodontologyonweb.org	Quick Response Code
DOI: 10.4103/endo.endo_86_22	

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How to cite this article: Garain R, Pai VS, Krishnakumar GR, Bharathi M, Vedavathi B, Karim J. Auto irrigate - The continuous irrigant delivery and intracanal aspiration system. Endodontology 2022;34:248-53.

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The mechanical and chemical advantages of irrigation cannot take place without contact with the targeted microorganisms and tissue remnants.[3,4] This depends on the concentration of the active component (s) of the irrigant, the areas of contact, and the duration of interaction with the targeted material.

Access to the irrigant can be enhanced by mechanical activation techniques. The fluid motion helps the chemically active particles to be transported quickly and efficiently facilitating its flushing action. In inaccessible areas of the root canal system, irrigant action may still take place by diffusion although slowly and less effectively.

In the present scenario, sodium hypochlorite (NaOCl) is considered to be the gold standard.[5] However, in order to be effective, NaOCl should be used in large quantity,[6] stay in contact with the tissues,[7] remain mechanically agitated,[8] and be continuously replenished.[9] Besides, NaOCl should reach even the apical third of the root canal system where exchange and delivery does not take place readily, resulting in incomplete elimination of bacteria from the apical third.[10,11] Unless the needle of a positive-pressure delivery system is placed close to the apex, the portion of the canal from the apex to the end of the needle may not be reached by the irrigant.[12] When the needle is placed to a depth that allows the irrigant to reach the apex, it may be extruded beyond the apex.[13] Various manual and machine-assisted irrigation and activation techniques have been developed to address these challenges, some of which are manual dynamic agitation (MDA), ultrasonic activation, and negative apical pressure systems. However, these systems are at times tedious (MDA being tiring and taking 3-4 min)[14] to use or require additional investment (negative apical pressure systems) on part of the clinicians and thus may hinder adoption of such techniques.

The objective of this study was to develop an economical continuous irrigant delivery and intracanal aspiration system (auto-irrigate [AI]), with readily available materials at little to no added cost to clinicians, and to compare its effectiveness in delivering irrigant to the apical third of the root canals with prevailing irrigation techniques.

MATERIALS AND METHODS

Considering an effective size of 0.40, a sample size of 66 was derived using G*Power version 3.1.9.2. A previous study by Galler *et al*. was taken into consideration for calculating the sample size.[15] Sixty-six freshly extracted single-rooted mandibular second premolar teeth of similar dimensions with a single straight canal were selected and divided into three groups ($n = 22$) based on the irrigation technique employed. The three groups were as follows: (1) Group 1: MDA group, (2) Group 2: passive ultrasonic activation group, and (3) Group 3: AI. Access cavities were prepared for all the samples. This was followed by working length estimation by inserting a #15 K-file to the radiographic apex. Instrumentation was completed using ProTaper F2 rotary files at working length, with a new file being used for every specimen.

The various irrigation techniques employed in the experiment were as follows:

Group 1: Manual dynamic agitation

After final instrumentation, a master cone snugly fitting 1 mm short of working length was selected and verified radiographically. The instrumented canals were then filled with 1 ml of EDTA delivered with a 30-gauge needle. Manual agitation of the master cone was performed with an up and down motion and a 2 mm amplitude at a frequency of approximately 100 strokes during 1 min. One milliliter of EDTA was then delivered with the irrigating needle to flush out debris. The canals were flushed with saline to eliminate any residual EDTA. This was followed by a flush with 1 ml of 2.5% NaOCl and repetition of the same agitation protocol using 50 in and out strokes for 30 seconds. This was followed by a final rinse of 2.5 ml of saline.

Group 2: Passive ultrasonic activation

Postinstrumentation, ultrasonic activation was carried out for 2 cycles of 30 s with an Irrisafe ultrasonic file (Acteon India Pvt. Ltd., Gujarat, India). 2 ml of 2.5% NaOCl was intermittently injected into the canal in between cycles. This was followed by a final cycle with 17% EDTA. This was followed by a final rinse of 2.5 ml of saline.

Group 3: Auto irrigate

System design

Figure 1 depicts the design of the system in use. The irrigant delivery system consists of (i) a 9-volt submersible pump, (ii) a power supply, (iii) a rate limiter (potentiometer), and (iv) a flexible tubing that connects the pump to the irrigant delivery tip. The irrigant delivery tip was developed by attaching the barrel of a 2 ml syringe to the flexible tube. Further, a small 21-gauge needle was fixed to this assembly which could then be secured into position, to deliver irrigant into the access cavity of teeth, on the bow of a suitable rubber dam clamp with the help of a composite button [Figure 2]. The intracanal aspirator was prepared by attaching the barrel of a 2 ml syringe to the end of a low volume suction tip. To this assembly, the needles of different gauges could be attached for use in intracanal aspiration, by connecting the intracanal aspirator to the low volume suction line of the dental chair.

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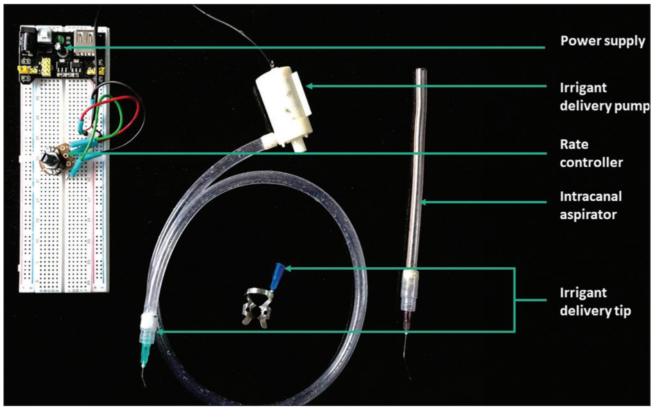

Figure 1: System Design

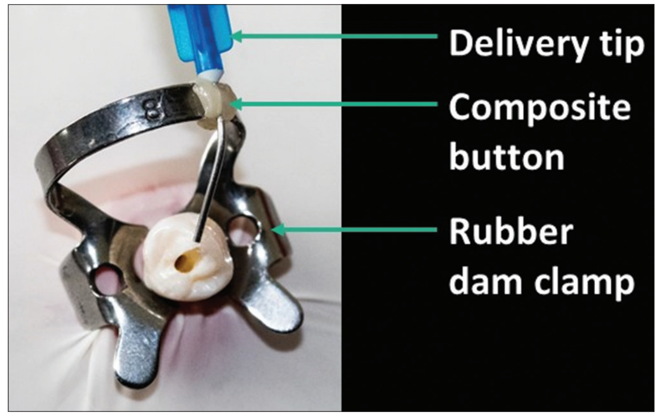

Figure 2: Irrigant Delivery Tip Attached to Rubber Dam Clamp

Irrigation protocol

The designed system was used to ensure continuous delivery of irrigant to the access cavities of the teeth and to permit aspiration of irrigant and debris from inside the canal. Continuous irrigation with 2.5% NaOCl was carried out during instrumentation. The irrigation between instruments was accomplished using 2.5% NaOCl with ultrasonic activation for 25 seconds. This was followed by intracanal aspiration, with a 27-gauge end vented nonbeveled needle that was inserted to a passive fit for 5 seconds. This process was repeated after final instrumentation. Thereafter, the same procedure was carried out with a saline rinse and the intracanal aspiration for 30 seconds. The 17% EDTA solution was used as a prefinal rinse with ultrasonic activation for 25 seconds and also as intracanal aspiration for 5 seconds. Subsequently, this was followed by a saline rinse and intracanal aspiration for 30 seconds. The aspiration after completion of the instrumentation was executed with a needle matching with the final file size (31 gauge) that was 1 mm short of working length.

In this study, apical delivery of irrigant for each group was evaluated by flooding the root canals with 1% toluidine blue dye for 30 seconds, at a time. The specimens were then sectioned vertically in a labiolingual direction with the use of a diamond disc. These sections were subsequently visualized under a stereo microscope at 5x magnification and then photographed. These digital images were scrutinized using ImageJ software to measure the unstained apical region, in the area of operation [Figure 3a-c]. One-way ANOVA with Tukey's *post hoc* test was applied for statistical analysis of the results ($P < 0.05$).

RESULTS

Table 1 shows the comparison of the mean unstained apical region using one-way ANOVA. Figure 3a-c is a representative image of the stained regions of groups 1, 2, and 3 analyzed by ImageJ software. F-value for the one-way ANOVA for comparing the unstained apical region among MDA, US, and AI ($F = 244.068$) was found to be significant and $P < 0.001$. There was a significant difference between different treatments, and pair-wise comparison using the Tukey's *post hoc* test showed $P < 0.001$ for every pair. Apical delivery of irrigant was found to be significantly higher in case of AI as compared to US followed by MDA.

DISCUSSION

A dental surgeon is always on the lookout for better activation techniques and devices for root canal cleaning, disinfection, and elimination of microbial biofilm. This is achieved by a combination of instrumentation and adequate irrigation. In this context, several different instruments and instrumentation techniques have been studied.[16] Nickel-titanium rotary instruments such as the ProTaper system have shown reduced apical transportation, deviation from canal anatomy along with better centralization in the root canals, and adequate debridement.[17,18] An increase in the apical root canal preparation and taper as a result of different instrumentation techniques has also shown improved irrigation efficacy.[19-21] Several studies on instrumentation coupled with various irrigation/activation techniques using ProTaper rotary instruments have shown satisfactory cleaning of the root canal walls when the ProTaper F2 rotary file was used as the final finishing file.[22-24] Some of the contemporarily available root canal irrigation techniques include manual dynamic activation (MDA), intermittent passive ultrasonic irrigation, continuous ultrasonic irrigation (CUI), passive ultrasonic irrigation, sonic irrigation, hydrodynamic activation, use of plastic finishing file, self-adjusting file, photoactivated disinfection, and laser activation, among others (Er:YAG, PIPS).

The above-noted techniques and devices used by the dental surgeons are often found to have been extensively tested

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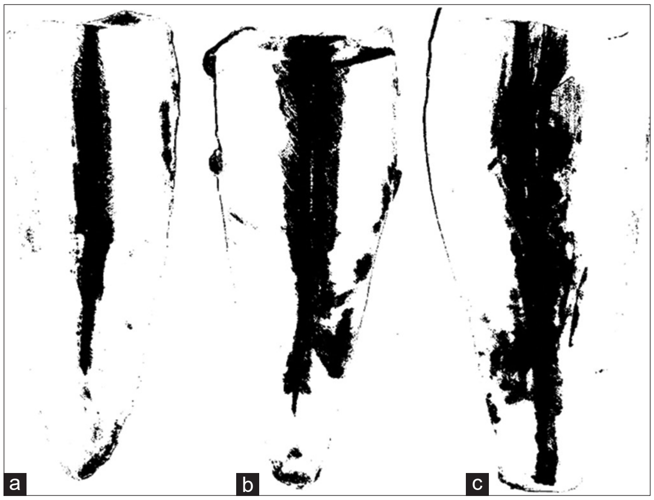

Figure 3: (a) Analysis of the stained region of the root in Group 1. (b) Analysis of the stained region of the root in Group 2. (c) Analysis of the stained region of the root in Group 3. The black and white regions in each image show the stained and unstained areas respectively

and compared. Comparison of these results is at times inconclusive due to model differences, use of plastic and extracted teeth, diverse evaluation methodologies, different preparation tapers, various apical sizes, volume variations, and time horizons.

Irrespective of the activation technique considered, it is significant to note that the agitation plays a critical role in distributing and exchanging the solution within the canal space and for enhancing antiseptic and solvent effectiveness. In this context, there is a general consensus on the benefit of using irrigant activation at the end of the canal preparation.[25]

MDA is widely accepted as a simple yet cost-effective way to help the irrigant to reach the canal intricacies, the apical portion of the canal, and to dislodge the vapor lock effect in the surrounding area. It creates higher intracanal pressure changes during the in-and-out movement of the GP cone, and further the frequency of the strokes creates turbulences and thereafter it enhances diffusion by shear stresses. Ultimately, MDA facilitates the mixing of fresh solution with the stagnant solution in the apical millimeters.[25] Parente *et al*. in 2010 conducted a series of studies to compare the efficacy of ANP (EndoVac) and MDA. In one experiment, the canal debridement efficiency was tested for both the techniques, in a closed system as well as in an open environment.[26] The findings exhibited that a sealed apical foramen adversely affected debridement while using MDA, but the same was not the case for ANP. Jiang *et al*.,[27] while comparing MDA, the safety irrigator, CUI, and the apical negative pressure (ANP), found CUI to be the most useful and effective technique. In such experiments, the researcher's main concern during irrigant activation is the risk of apical extrusion. The contemporary research and findings[28-30] support that all tested devices (including MDA) appear to extrude some irrigant. While ANP was reported to be the safest, ANP should be seen more as a delivery device rather than an activation system.

Table 1: Result of one-way ANOVA

Irrigation technique	Mean	SD	*P*
MDA	0.313	0.035	<0.001*
US	0.21	0.049	
AI	0.069	0.019	

**P*<0.001 for every pair. SD: Standard deviation, MDA: Manual dynamic agitation, US: Ultrasonic, AI: Auto irrigate

In the case of smear layer removal utilizing US, results are varied, with a greater number of studies indicating that US helps remove smear layer. Such variations in results could be due to the use of different types, quantity, and concentrations of irrigants. The amount of irrigant, the delivery method, and the delivery time of irrigants have also been evaluated. Intermittent flushing is considered to be a more popular method in comparison to external continuous flushing for US. However, this technique is more time-consuming due to the stop-and-go process applied. There is a need to replenish the irrigant periodically, in view of the dentin debris, tissue, bacteria, and biofilm continuously saturating the irrigating solution and increasing the viscosity of the solution. It may be noted that such a process may perpetuate to the point where no ultrasonic activity may occur in the solution. Weller *et al*.[31] and Moorer and Wesselink[8] also reported this effect. The available research supports the findings that refreshing NaOCl during PUI/UAI increases the reaction of NaOCl[32,33] and improves the cleaning of the canals. It is pertinent to note that the time taken for the technique and for the irrigant replenishment will become a consideration, since the US improves the cleanliness of root canals and canal isthmuses. Gutarts *et al*.[34] reported one of the early studies using an ultrasonically activated irrigating needle that simultaneously and successfully activated and replenished the irrigant deep within the canals. This system was subsequently designated as CUI. The outcome resulted in cleaner canals and canal isthmuses within the 3 mm of the canal apex and in the vital mandibular molar mesial roots. This occurred with irrigation duration of 1 min per canal with 5.25% NaOCl. In further study in this direction, Carver *et al*.[35] evaluated the *in vivo* removal of planktonic bacteria using the same treatment technique and the CUI in necrotic mandibular molars. Their findings reported a significant increase in negative cultures and reduction of CFUs in comparison to the canal preparation solely with needle irrigation (NaOCl). Another study by Burleson *et al*.[36] examined *in vivo* biofilm removal applying the

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same device/technique. It is pertinent to highlight that their findings reported significantly cleaner canals and isthmuses with the use of CUI as compared to needle irrigation.

The apical negative-pressure systems for irrigation have the ability to suction, thus performing the job of drawing and delivering the irrigant passively to the apex.[37] The EndoVac system is one the such systems that was developed to safely and predictably deliver irrigant to the apical terminus. The EndoVac allows a better penetration of the irrigating solution into the inherent anatomy and morphology of the root canal system. This delivers the chosen irrigant passively to the apex[12,38] and positively deal with the problem of irrigation penetration past the apex into the periapical tissue, that could otherwise result in treatment complications.[13,39,40] *In vitro* and *in vivo* studies have positively confirmed superior expulsion of debris from the apical walls. This has resulted in a statistically cleaner outcome using ANP irrigation in closed root canal systems with sealed apices. Siu and Baumgartner[41] reported less residual debris present around 1 mm working space, while using ANP compared to the use of traditional needle irrigation. Park *et al*.[42] also found that both traditional syringe irrigation and ANP technique resulted in clean root canals. However, ANP resulted in less residual debris lingering at 1.5 and 3.5 mm from working area.[41-43] The root canal debridement using MDA was also compared with the EndoVac system for final agitation in a closed system as well as in an open system. The results reported the presence of a sealed apical foramen adversely affecting debridement efficacy during the use of MDA. However, similar adverse impact on the results was not reported in the use of the EndoVac system. Thus, it can be confidently stated that the ANP irrigation is an effective method to overcome the fluid dynamic challenges inherent in a closed root canal system.[26,44] Further, both the ANP irrigation and the manual dynamic irrigation have been found to be more efficient and effective in removing the smear layer in the apical one third,[45] compared to passive ultrasonic irrigation.

Keeping these findings in mind, the current delivery system was designed (i) to ensure continuous delivery of irrigant, (ii) to permit irrigant replenishment, and (iii) to create a negative apical pressure gradient for providing flow of irrigant from the coronal to the apical region. It assumes significance to guarantee the flow of irrigant from the coronal to the apical region, while aspirating the older irrigant and debris and at the same time preventing apical extrusion of the same. The preliminary study resorted to use of dye penetration as a surrogate method for testing the irrigant action in the apical region. This method was chosen for the preliminary study for testing the hypothesis. These test results reported to be in concurrence with the findings of prevailing studies. The findings of this study showed higher irrigant action with the use of AI system in comparison with both MDA and US. Despite certain methodological limitations in this study, the findings appear to be convincing and prospective. Further studies on smear layer removal, biofilm removal/root canal disinfection, and apical extrusion would aid in validating the efficacy of this system.

CONCLUSIONS

From the findings of this study, it can be concluded:

1. This ingeniously developed continuous irrigant delivery and intracanal aspiration system showed greatest irrigant delivery to the apical third of the root canal
2. Standard passive ultrasonic activation performed better than manual dynamic activation, but poorly when compared to the continuous irrigant delivery and intracanal aspiration system
3. MDA showed the least delivery of irrigant to the apical third of the root canal.

Further research findings can evaluate and validate the efficacy of this system. This innovative and yet simple root canal irrigating device would serve as an efficient, cost-effective, and novel device that can be effortlessly incorporated into clinical practice.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

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