Contemporary Irrigant Agitation Techniques

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Abstract:

Introduction: **Introduction:** Effective irrigant delivery and agitation are prerequisites for successful endodontic treatment.

Methods: This article presents an overview of the irrigant agitation methods currently available and their debridement efficacy.

Results:Technological advances during the last decade have brought to fruition new agitation devices that rely on various mechanisms of irrigant transfer, soft tissue debridement, and, depending on treatment philosophy, removal of smear layers. These devices might be divided into the manual and machineassisted agitation systems. Overall, they appear to have resulted in improved canal cleanliness when compared with conventional syringe needle irrigation. Despite the plethora of in vitro studies, no well-controlled study is available. This raises imperative concerns on the need for studies that could more effectively evaluate specific irrigation methods by using standardized debris or biofilm models. In addition, no evidence-based study is available to date that attempts to correlate the clinical efficacy of these devices with improved treatment outcomes. Thus, the question of whether these devices are really necessary remains unresolved. There also appears to be the need to refocus from a practice management perspective on how these devices are perceived by clinicians in terms of their practicality and ease of use.

Conclusions: Understanding these fundamental issues is crucial for clinical scientists to improve the design and user-friendliness of future generations of irrigant agitation systems and for manufacturers' contentions that these systems play a pivotal role in contemporary endodontics.

Introduction

Throughout the history of endodontics, continuous efforts have been made to develop more effective irrigation and agitation methods for root canal irrigation. These systems could be divided into two broad categories, manual agitation techniques and machine-assisted agitation devices. The aim of this review was to provide an overview of contemporary methods of irrigant agitation available in endodontics and provide a critique of their debridement efficacy.

The delivery and activation of irrigant solutions

Irrigant solutions have traditionally been delivered to root canals with a syringe and some form of needle. The depth of insertion of the irrigant needle has an impact on the exchange of irrigant solution, and the design of its tip has an impact on irrigant hydrodynamics.[1–7]

Syringe delivery

Irrigant is delivered most commonly by the application of positive pressure to a disposable syringe with a side-ported needle.[8] A recognised risk is the possibility of introducing irrigant into the periapical tissues, causing tissue damage and postoperative pain.[3,8–13]Mercifully, such events occur rarely, and limiting factors include the closed system in which irrigation takes place and the effects of tissue pressure at the periapex. Investigations and discussions of root canal irrigation must recognise the effects of closed-systems, and the limitations this may impose on fluid exchange beyond the tip of the irrigating needle.[14–18]Vapour lock, caused by gas entrapment is also recognised to limit irrigant penetration.[19–21,22,23]*In vitro*, studies have sought to simulate the clinical scenario by closing the apex of the root. Apices may for example be embedded in polyvinysiloxane impression material, and studies in which this is undertaken are associated with less effective irrigant exchange than those conducted open systems.[24–26]

This was confirmed recently by **Tay*et al.***[27] who found that there was a difference in root canal cleanliness between closed and open root canal systems in apical, middle and coronal thirds, using conventional syringe irrigation with side-vented needles.

Irrigant replacement in a positive-pressure conventional syringe system may be limited to 1-1.5 mm beyond the needle tip and may require a high flow rate to generate turbulent fluid flow for effective agitation.[17,18,28,29] The position of the tip of the needle could be either slightly coronally to the binding point or at the point of resistance felt by the operator. In addition, this position can be estimated when a needle with known external diameter (DN) is inserted in a root canal with known apical preparation size (A) and taper (T) using the equation (L= (DN - A) / T), where L represents the distance from the working length (WL).[30] Irrigation needle size is measured according to the ISO 9626:1991/ Amd.1:2001 specifications (ISO 9626 2001), and usually falls within the range of 21-30 G, with external diameters of 0.8-0.3 mm respectively.[3,30,31] The apical part of the root canal is often recommended to be enlarged to at least size 35-40 (0.35-0.4mm diameter) in order to facilitate needle placement to within 1-2 mm of working length.[14,32–35] Use of a small diameter needle may logically allow penetration to within 1 mm of working length, but the problem of vapour lock is still not solved and may limit exchange in the apical third.[27] Irrigation with chelating agents results in demineralisation and a mesh of collagen (fibrillar network of collagen) could form in the apical part of root dentine surface which could trap debris during root canal irrigation, if the irrigation could not produce adequate turbulent flow.[27,36] Although syringe irrigation represents normal practice for most dentists, the limitations of fluid exchange in closed systems and heightened awareness of canal ramifications have encouraged the pursuit of more effective methods of irrigant delivery and turnover. 'Activated' irrigation, employing a variety of methods to improve irrigant penetration, flow and hopefully effectiveness has become a strong research focus in recent years.[8,37,38] Examples will be described in the following pages.

A). Manual Agitation Techniques

1.*Brush*

Brush covered needles are designed for root canal debridement and for agitation of the root canal irrigant. Both Endobrush and the NaviTip FX belong to this category.

I. An earlier study by **Keir*et al.***[39] studied the Endobrush (C & S Microinstruments Limited, Markham, Ontario, Canada) which is a spiral brush designed for endodontic use that consists of nylon bristles set in twisted wires with an attached handle and is designed to remove debris from the root canal. It was claimed that during debridement, the bristles of the brush extended to the uninstrumented areas of the canal walls.

II. **Al-Hadlaq*et al.***[40] studied the efficacy of the NaviTip FX (NaviTip FX, Ultradent Products Inc, South Jordan, UT) 30-gauge irrigating needle when covered with a brush. When compared with the same needle without a brush, they found statistically significant less debris in the coronal third of the root canal with no statistical difference in either the middle or apical thirds of the canal.

2.*Manual-Dynamic Agitation*

Irrigant volume and flow are important factors which influence the efficacy of root canal debridement.[17] Several techniques have been used in order to increase the flow and distribution of irrigants into awkward places inside the root canal system.[41] In this method, after instrumentation of the root canal, a gutta-percha point is repeatedly inserted to the full working length of the canal and pumped up and down at low amplitude and at approximately 100 cycles per minute.[37]

The unpublished experiment by Pierre Machtou in 2003 showed that agitation of irrigant by a well-fitting gutta-percha point enhanced irrigant penetration and replacement apically in comparison with static irrigation.[35] Dynamic manual agitation of irrigant with gutta-percha point could have the potential to displace the apical vapour lock (gas entrapment) from a closed system. [37,42]

B). Mechanical Agitation Techniques

1. *Rotary Brush*

Ruddle brush and CanalBrush both fit in this category.
I. A rotary handpiece–attached microbrushhas been used by Ruddle (2001) to facilitate debris and smear layer removal from instrumented root canals. The brush includes a shaft and a tapered brush section. The latter has multiple bristles extending radially from a central wire core. During the debridement phase, the microbrush rotates at about 300 rpm, causing the bristles to deform into the irregularities of the preparation. This helps to displace residual debris out of the canal in a coronal direction. However, this product has not been commercially available since the patent was approved in 2001.

II. CanalBrush is another endodontic microbrush that has recently been made commercially available. This highly flexible microbrushis molded entirely from polypropylene and might be used manually with a rotary action. **Weise *et al.***[43] showed that debris was effectively removed from simulated canal extensions and irregularities with the use of the small and flexible CanalBrush with an irrigant.

2. *XP-endo Finisher file*
A new nickel-titanium rotary finishing file has been developed called the XP-endo Finisher file (FKG Dentaire SA, La Chaux-de-Fonds, Switzerland). The XP-endo Finisher file was introduced to be used after any root canal instrumentation to accomplish an enhanced cleaning of the root canal while conserving dentin. It has been reported that XP-endo Finisher curved bulb can expand its extent 6 mm in diameter when the file tip is squeezed or 100-times of a corresponding sized file. The XP-endo Finisher has a small core size (ISO 25 in diameter and zero taper) with improved flexibility. The XPendo Finisher file is formed using a proprietary NiTi alloy (Martensite-Austenite Electropolish-FleX). The XP-endo Finisher file performs at different temperatures and is claimed to have high flexibility.[44,45,46]

3. *Continuous Irrigation during Rotary Instrumentation*

The Quantec-E irrigation system (SybronEndo, Orange, CA) is a self-contained fluid delivery unit that is attached to the Quantec-E Endo System. It uses a pump console, 2 irrigation reservoirs, and tubing to provide continuous irrigation during rotary instrumentation.[47]

4. *Sonic Irrigation*

Sonic instruments for endodontics was first reported by **Tronstad*et al.***[48] Sonic irrigation operates at a lower frequency (1–6 kHz) and produces smaller shear stresses than ultrasonic irrigation.[49] The Endoactivator (sonic activation) is a recently introduced device, consisting of a small battery operated cordless hand piece, which delivers sonic energy through disposable nylon tips. It has been shown that EndoActivator and passive ultrasonic activation of the endodontic file inside pre-shaped canals resulted in a significantly cleaner canal in comparison with hand instrumentation alone.[8,50,51] In addition, there was no difference in the cleaning efficiency between the EndoActivator and passive ultrasonic techniques.[8,50,51] One advantage of the EndoActivator is that the nylon tips do not cut dentine.[51]

5.*EDDY*

A sonic powered endodontic irrigation tip made of polyamide, EDDY (VDW Zentrale, München). EDDY is driven at a frequency of 5000 to 6000 Hz by an air-driven handpiece (Airscaler). The manufacturer claims that the high frequency vibration produced is transferred to the polyamide tip which is moved in an oscillating movement at high amplitude. This three-dimensional movement triggers cavitation and acoustic streaming that allows particularly efficient irrigation of complex root canal systems.[52,53,54,55]

6. *Ultrasonic Irrigation*

Ultrasonic devices were introduced to dentistry in the 1950s and later adopted for endodontic applications (Richman, 1957), both for cutting dentine, and activating NaOCl solutions.[56–60] Ultrasonic files oscillate at 25-30 kHz, which is beyond the limit of human hearing, and work in transverse vibration.[61] Attempts to shape canals ultrasonically have not been well reviewed, frequently resulting in damaged and irregular canal shapes and apical perforation.[62,63] Nevertheless, they are effective in root canal irrigation, and ultrasound is popularly adopted in passive ultrasonic irrigation (PUI).[64,65]In this technique, after canal shaping, the canal is flooded with irrigant. In the next step, a small file (size 15) or smooth wire is introduced into the centre of the canal until it reaches the apical region and activated ultrasonically. The file moves freely and as a result, the irrigant moves easily into the apical part of the canal, with efforts to avoid potentially damaging wall contact.[49,64–67] Its effects may be due to acoustic streaming and cavitation and may result in more efficient cleaning in comparison with root canal irrigation without PUI.[49,62,65,66,68,69]

Van der Sluis*et al.*[70] reviewed the literature between 1965 and 2007 on the comparative efficiency of PUI and conventional syringe irrigation of root canals, and found that PUI was more effective than conventional syringe irrigation in removing organic tissue, planktonic bacteria, and dentine debris from the root canals.

An ultrasonically activated irrigating needle has been developed to work as an adjunctive device for root canal debridement.[8,16]This needle may be connected to a MiniEndo piezoelectric ultrasonic unit and can be set to the highest power setting without needle breakage, and with a constant stream of NaOCl. It has been suggested that a constant stream of ultrasonically activated NaOCl may allow shorter irrigation times in comparison with conventional syringe irrigation, making it attractive clinically.[15] It has been identified that combining this system with hand and rotary instruments removed vital pulp tissue from canals and isthmuses more effectively than hand and rotary instrumentation alone.[8,15,16]

7. *Pressure Alternation Devices*

The RinsEndo irrigation system and the EndoVac irrigation system
are examples of negative-pressure irrigation.

I. ***TheRinsEndo irrigation system*** *(RinsEndo, Co. Duerr-Dental, Bittigheim-Bissingen, Germany)* irrigates the canal by using pressure-suction technology. It is composed of ahandpiece, a cannula with a 7-mm-long exit aperture, and a syringe carrying irrigant.

II. ***TheEndoVac system*** *is regarded as an apical negative pressure irrigation system* composed of three basic components: a Master Delivery Tip (MDT), the Macrocannula, and the Microcannula. The MDT delivers irrigant to the pulp chamber and evacuates the irrigant concomitantly. Both the macrocannula and microcannulaare connected via tubing to a syringe of irrigant and the highspeed suction of a dental unit. The Macrocannula is made of plastic flexible polypropylene with an open end of 0.55 mm in diameter, an internal diameter of 0.35 mm, and a 0.02 taper, used to suction irrigants up to the middle segment of the canal. Lastly, the Microcannula is made of stainless steel and has 12 microscopic holes disposed in four rows of three holes, laterally positioned at the apical 1 mm of the cannula. Each hole is 0.1 mm in diameter, the first one in the row is located 0.37 mm from the tip of the microcannula, and the distance between holes is 0.2 mm. The microcannula has a closed end with external diameter of 0.32 mm can be used in canals that are enlarged to size 35 or larger, and should be taken to the working length (WL) to aspirate irrigants and debris. During irrigation, the MDT delivers irrigant to the pulp chamber and siphons off the excess irrigant to preventoverflow. The cannula in the canal simultaneously exerts negative pressure that pulls the irrigant from its fresh supply in the chamber by the MDT, down the canal to the tip of the cannula, into the cannula, and out through the suction hose. Thus, a constant flow of fresh irrigantis being delivered by negative pressure to working length.

Nielsen and Baumgartner[71] compared the efficacy of the EndoVac system and needle irrigation to debride the apical 3 mm of a root canal. No significant difference between the two irrigation techniques was noted at the apical 3 mm level. But at 1 mm apical level, the EndoVac system significantly resulted in less remaining debris. Another *in vitro* study indicated that EndoVac left significantly less debris behind than the conventional 30- gauge needle irrigation methods.[72] The Endovac irrigation system was also shown to achieve better microbial control than the traditional irrigation delivery system.[73,74] In contrast, two very recent studies showed the opposite results. The first by **Townsend and Maki**[75] who conducted a study on plastic simulated canals, found that the EndoVac irrigation system was significantly less effective in removing bacteria when compared with ultrasonic irrigation. Another study by **Brito*et al.*[76]** who found no significant difference in bacterial reduction efficiency between the Endovac system, the NaviTip needle and the EndoActivator sonic system.

8. *Laser activated irrigation*

The first functioning laser was developed in 1960.[77] A decade later it was used in endodontic research to attempt to seal the apical foramen.[78] Since that time lasers have been used for a variety of endodontic purposes such as dental pulp vitality testing, vital pulp therapy, pulpotomy procedures, dentinal hypersensitivity, shaping of the root canal, disinfection of the root canal system, obturation, peri-radicular surgery and tooth bleaching.[79] Disinfection of the root canal system using lasers has been attempted using either direct irradiation of the root canal wall, photo activated disinfection and laser activated irrigation.[80–82]

Laser activated irrigation definitions

Laser Activated Irrigation (LAI) is the general term used to describe the irradiation of an irrigant within a root canal.[82] The word "activation" is used to primarily describe the creation of physical turbulence as a result of laser energy. Although somewhat confusing, the word activation does not indicate that a previously inactive irrigant has been made chemically active by the laser. The laser does however increase the chemical efficiency and efficacy of certain endodontic solutions. For example, **Macedo*et al.*[83]** showed that laser activation of NaOCl in bovine teeth significantly increased the consumption of freely available chlorine in solution compared to a NaOCl that received no activation. The most likely reason for this is the rapid increased movement of the molecules (convection) in the root canal system caused by cavitation. The increased reaction rate of NaOCl was also found during rest intervals when the NaOCl was not being activated however the mechanisms of this phenomenon are not understood.

A recent protocol for LAI has been developed and marketed as Photon-Initiated Photoacoustic Streaming (PIPS).[84] This system proposes the use of an Er:YAG laser with a specifically designed radial and stripped tip and recommends that the tip be positioned in the pulp chamber and that the laser is activated at subablative parameters (average power 0.3 W, 20 mJ at 15 Hz).[85]

The efficacy of laser activated irrigation:

1. Smear layer removal:

Laser activated irrigation may assist in the removal of the smear layer. **George *et al.*[82]** showed that laser activated irrigation significantly improved the action of EDTAC on removing the smear layer from the apical third of root canals compared to traditional syringe irrigation using a combination of NaOCl and EDTAC. They also found no significant difference in smear layer removal between two commonly used erbium (Er,Cr:YSSG and Er: YAG) lasers. Laser activation of 3% hydrogen peroxide did not improve smear layer removal compared to syringe irrigation with EDTAC.

Peeters&Suardita[86] confirmed that laser activated EDTA improves smear layer removal compared to 60 seconds of ultrasonic activated irrigation. Like **George *et al.*[82]** they activated the Er,Cr:YSSG laser at a high power setting of 1 W using an end firing fibre (600 μm diameter) however they positioned the tip in the pulp chamber and did not enter the canal. This showed that LAI effectively disperses EDTA to the working length however it is not known whether apical extrusion will occur using high power settings. **DiVito*et al.*[29]** used an Er:YAG laser with a low power setting (20mJ 15 Hz) in comparison to **George *et al.*[31]** and **Peeters&Suardita**[33]. They showed that smear layer removal was improved by laser activation of EDTA compared to syringe irrigation. They also showed that smear layer removal was improved when activation time was increased from 20 to 40 seconds.

Recently **Lagemann*et al.*[88]** showed that smear layer removal was significantly enhanced when a near infrared diode laser was used to activate EDTA compared to syringe irrigation methods. Although not tested in their study, the risk of extrusion is far less likely to occur with near infrared diode lasers compared to erbium lasers. This is because near infrared diode lasers move fluid at about 4-5 mm/s compared to ~30 m/s for erbium lasers.[89,90]

Sodium hypochlorite is effective at removing pulpal debris and pre-dentine from root canal walls however it is relatively ineffective at removing inorganic components of the smear layer in comparison to EDTA.[91] It has been proposed that laser activation of NaOCl may improve its smear removing capabilities, thereby negating the need to use a chelating agent. **Moon *et al.*[92]**obturated root canals with different irrigating protocols and assessed sealer penetration depth using confocal laser scanning microscopy. They found that laser energised 5.25% NaOCl was more effective than syringe irrigation using 5.25% NaOCl or 17% EDTA at improving sealer penetration into the dentine tubules. Although this is an indirect method of assessing smear layer removal and relies on the assumption that sealer will penetrate dentine tubules, it does indicate that laser activation of NaOCl does improve smear layer removal which may decrease the need for using a chelating solution before obturation.

Zhu *et al.*[93] confirmed that laser activation (using the PIPS protocol) of 3% NaOCl was as effective as conventional syringe irrigation using alternating rinses of 3% NaOCl and 17% EDTA. Although both groups successfully removed the smear layer in the coronal and middle third, neither groups effectively eliminated the smear layer in the apical third. Unfortunately they did not assess whether smear layer removal could be improved in the apical third by laser activating both NaOCl and EDTA.

All studies in this area have used teeth with relatively straight single canals. Further research is needed to see if laser energy can be utilised to improve smear layer removal in teeth that have curved narrow canals with complex anatomical features. New technology and treatment protocols will most likely be incorporated into clinical practice if they are not prohibitively expensive, safe to use and can provide substantial improvements in teeth with complicated root canals systems that are not cleanable using current treatment modalities.

2. Debris removal:

Removal of infected debris from the root canal system is important because improved clinical outcomes are expected when there is less bioburden remaining within the root canal system.[94] **De Moor *et al.***[95] used a pre-established debris model to compare debris removal from the apical third. They activated 2.5% NaOCl for 20 seconds by either a laser or ultrasonic device. Laser irradiation was performed using an Er,Cr:YSSG laser (power setting of 1.5 W) with the tip of the end firing fibre being positioned 5 mm away from the apex. Laser activated irrigation was shown to be far more effective at removing the artificially packed debris compared to ultrasonic activation. These findings were confirmed by **de Groot *et al.***[96] using both an Er,Cr:YSSG and Er:YAG lasers. Interestingly, in a later study, **De Moor *et al.***[97] showed that UAI was just as effective as LAI when the number of UAI cycles (20 seconds of activation followed by 2 mL irrigation with 2.5% NaOCl) was tripled. This indicates that both treatment modalities may improve debris removal from areas located outside the main lumen of the canal. To achieve comparable results, ultrasonic activation requires both an increase in irrigant volume and activation time.

Deleu*et al.*[226] in a similar study to **De Moor *et al.***[228], investigated debris removal from the apical third using 2.5% NaOCl and a variety of different irrigating methods. They found that all irrigating activation methods removed more debris than syringe irrigation. The Er:YAG laser (power setting of 1.2 W), fitted with an end firing fibre, positioned 5 mm away from the apex, was more effective than activation with a Er:YAG laser and PIPS tip (positioned in the pulp chamber). No significant difference was found between the Er:YAG laser and the UAI treatment groups.

Debris removal from lower molar mesial roots was assessed recently by **Lloyd *et al.***[99] using x-ray microfocus computed tomographic imaging. After chemomechanically preparing the roots to a size 30/0.06 they performed laser activated irrigation using the PIPS protocol. The PIPS protocol removed 2.6 times more debris than syringe irrigation using a combination of EDTA and NaOCl. This study by **Lloyd *et al.*** [99]is the only study that has assessed the efficacy of removing debris from canals using LAI with known complex anatomical features. More studies are needed that compare this new technology with other adjunctive irrigating methods in teeth with complex anatomical features.

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