ORIGINAL RESEARCH PAPER

Dental Science

ACTIVATING TO SUCCESS: A COMPREHENSIVE REVIEW OF IRRIGANT AGITATION DEVICES IN ENDODONTICS

KEY WORDS: irrigation, activation, manual, machine-assisted

Snigdho Das* MDS, Conservative Dentistry & Endodontics. *Corresponding Author

ABSTRACT

Removal of vital and necrotic remnants of pulp tissues, microorganisms, and microbial toxins from the root canal system is warranted for ensuing successful treatment outcome. Irrigation plays a major role in achieving the same. The last few years have seen a spurt in technological advances in various irrigant activation devices. This article meticulously reviews the various irrigant agitation systems available, which assists in complete disinfection of the complex root canal system.

INTRODUCTION

An important goal for successful root canal treatment is the removal of organic and inorganic debris that, in an infected canal system, may contain bacteria and serve as a nidus for reinfection [1]This goal can be achieved by the combination of mechanical preparation with chemical irrigation to control and finally eliminate the causative agents of apical periodontitis .[2]However, large areas of untouched canal walls [3] and accumulation of hard tissue debris in fins, isthmuses, irregularities and ramifications have been reported by several authors as an undesirable effect of mechanical preparation.[4]In fact, within oval canals only 40% of the apical root canal wall area can be contacted by instruments when a rotating technique is used[5].Therefore, irrigation is an essential part of a root canal treatment as it allows for cleaning beyond the root canal instruments. No irrigating solution, individually or in combination till date has proved to be 100% efficacious in thoroughly debriding the root canal systems. Furthermore the deleterious products of the combination has challenged its efficacy. Thereby, to bring the various irrigants with direct contact of the walls of the root canals, various irrigant delivery systems and activation devices have been discovered as a solution to this longstanding challenge of complete root canal debridement. These systems can be mainly classified broadly into- i) manually operated devices and ii) machine-assisted systems.

MANUALLY OPERATED DEVICES

Syringe Irrigation

Perhaps the most traditional method of positive pressure irrigant delivery is by a syringe and a needle. Despite the development of various irrigation systems, conventional syringe irrigation remains widely accepted. The technique involves dispensing of an irrigating solution into a canal through needles of variable gauges, either passively or with agitation. The activation is achieved by moving the needle up and down the canal space. Some of these needles are designed to dispense an irrigant through their most distal ends, whereas others are designed to deliver an irrigant laterally through closed-ended, side-vented channels [6]. The side-vented needles has been proposed to improve the hydrodynamic activation of an irrigant, as it creates a laterally directed wall shear stress to remove the biofilms and also has a reduced chance of apical extrusion.[7] One of the advantages of syringe irrigation is that it allows comparatively easy control of the depth of needle penetration and the volume of irrigant within the canal. However, over the years it has been argued that the performance of root-canal irrigation is limited mostly because syringes and needles fail to deliver the irrigant to all the parts of the complex root-canal system, leading to the harboring of persistent microorganisms. Studies claim that the irrigant delivered through a syringe can only reach upto 1 mm from the tip[8], which is an alarming issue as most of the available syringes can penetrate only upto the middle third of a root canal.[9] The solution to address these issues encompasses closer proximity of the irrigation needle to the apex ,larger irrigation volume, and smaller-gauge irrigation needles. Also, irrigant flow rate and the exchange of irrigant should also be considered as factors directly influencing fluid flow beyond the needle/cannula which has inspired a lot of computational fluid dynamics-based studies.

Brushes

Endodontic brushes have been used as an adjunct in proper debridement of the root canals. NaviTip FX (Ultradent Products Inc, South Jordan) , UT is a commercially available 30-gauge irrigation needle covered with a brush. Improved cleanliness was reported by a study which compared this with its brushless variant.[10] However, the limitations were that any friction created between the bristles and the canal could lead to the dislodgement of the former, leading to a challenging retrieval of the same as the bristles were radiolucent and cannot be identified in routine radiographs.[11]

Manual Dynamic Irrigation

One of the challenges posed by a syringe needle irrigant delivery is that it can create an apical vapor lock due to formation of air bubbles caused by an interaction of irrigants with the necrotic debris, all of which prevents the further penetration of any irrigant or instrument in the apical third. Research has shown that gently moving a well-fitting gutta-percha master cone up and down in short 2-3 mm strokes within an instrumented canal can produce an effective hydrodynamic effect, also allowing proper mixing of the fresh irrigant with that of the depleted one.). Although studies have claimed that the frequency of push-pull motion of the gutta-percha point (3.3 Hz, 100 strokes per 30 seconds) is higher than the frequency (1.6 Hz) of positive-negative hydrodynamic pressure generated by RinsEndo, a negative pressure irrigating system.[12]; the laborious nature of this system has questioned its usage in routine clinical practice.

MACHINE ASSISTED DEVICES

Rotary Brushes

The Endobrush (C&S Microinstruments Ltd, Ontario, Canada) is a spiral brush designed for endodontic use that consists of nylon bristles set in twisted wires with an attached handle and has a relatively constant diameter along the entire length. The bristles of the brush were claimed to extend to the non-instrumented canal walls and into the fins, cul-de-sacs, and isthmuses of the canal system to remove trapped tissue and debris. However, the Endobrush, due to its size has prevented its usage to full working length because of its size, which might lead to debris accumulation into the apical section of the canal after brushing.[13]

Sonic Irrigation Systems

Sonics operate at a frequency of 1-6 kHz, producing smaller shear stresses than ultrasonics, but a relatively larger amplitude in back and forth motion. Also, it has 1 node and 1 antinode compared to multiple nodes and antinodes in the ultrasonics.

a) The Vibringe System is an irrigation device that combines manual delivery and sonic activation of the solution, has been introduced by a Dutch company Vibringe B.V. The Vibringe is a cordless handpiece that fits in a special disposable 10-mL Luer-Lock syringe that is compatible with every irrigation needle.[14]

b) The more recently introduced Endoactivator system (Dentsply Tulsa Dental Specialties, Tulsa, OK) consists of a portable handpiece and 3 types of disposable polymer tips of different sizes (15/0.02, 25/0.04, 35/0.04). The tips are flexible and so don't cut dentin easily. The battery driven handpiece operates at 10,000 cycles per minute(cpm) and has been reported to be able to effectively clean debris from lateral canals, remove the smear layer, and dislodge clumps of simulated biofilm within the curved canals of molar teeth.[15]

Ultrasonic Irrigation Systems

The use of ultrasonic devices in Endodontics traces its origin back to 1980 when Martin *et al.* made it available for commercial use. Ultrasonic files are designed to oscillate at high frequency (25-30 kHz) but with low amplitudes, hence producing multiple node and antinode patterns.

Two types of ultrasonic systems are primarily available. One being ultrasonic irrigation with simultaneous instrumentation (UI) and the other being ultrasonic irrigation without instrumentation. The usage of UI has been proved controversial as the waves get dampened within the constraints of unflared canals, besides carrying the risk of overcutting the dentin.[16]

The term PUI or Passive Ultrasonic Irrigation was first used by Weller *et al.* This technique involves the pre-flaring of the root canals before introducing the ultrasonic file for activating the irrigant. The energy is transmitted from the file to the irrigation form of ultrasonic waves by the mechanism of acoustic streaming and cavitation. Acoustic streaming encompasses the rapid movement of the irrigant in form of circles or vortices, while cavitation is the rapid creation of small vapor-filled cavities and subsequent collapsing of the same, leading to a shock wave which has been proved to disengage the biofilm from the canal walls and eliminating the bacteria.[17]Ultrasonic irrigation has shown to be more efficacious than sonic irrigation in literature.

Pressure Alternation Devices

For the complete disinfection of the root canal system, it is necessary for the irrigating solutions to reach upto the apex. But in actual clinical scenario, it is not always possible, either due to risk of extrusion beyond the apical foramina leading to accidents or air entrapment and producing the so called "Vapor-Lock effect". Vapor Lock effect is a phenomenon seen in closed ended channels just like the root canal, where an air entrapment is caused due to liberation of ammonia and carbon dioxide gas, often a byproduct of reaction between the irrigant and the bacterial products. This entrapped air at the apex prevents any further entry of irrigant, thus compromising disinfection in this region. A probable solution to these problems is the use of devices which are based on irrigant delivery and simultaneous evacuation by negative pressure.

a) Endo Vac System-A prototype of pressure alternation device is the Endo Vac system (Discus Dental, Culver City, CA), which comprises 3 basic parts. i) a plastic microcannula with open end of size 55 with a 0.02 taper used for initial flushing of the coronal part of the root canal ii) a size 32 microcannula made of titanium with 12 laser cut holes resembling a closed -ended multi-vented needle used mainly in the apical part of the canal iii) a master delivery/evacuation tip attached to a high volume suction unit. During irrigation, the delivery/evacuation tip delivers irrigant to the pulp chamber and siphons off the excess irrigant to prevent overflow. The cannula in the canal simultaneously exerts negative pressure that aspirates the irrigant from its fresh supply in the chamber, down the canal to the tip of the cannula, into the cannula, and out through the suction hose. Thus, a constant flow of fresh irrigant is ensured by negative pressure to working length.[11] The Endo Vac system shows better microbial control and significantly better removal of debris at 1 mm apical level than needle and other traditional irrigation.[14]

b)The RinsEndo system (Durr Dental Co) is based on the same technology. The system involves the usage of 65 μL of a rinsing solution oscillating at a frequency of 1.6 Hz is drawn from an attached syringe and transported to the root canal via a cannula. During the suction phase, the used solution and air are extracted from the root canal and automatically replenished. The pressure-suction cycles change approximately 100 times per minute. An in vitro study claimed its effectiveness than the conventional systems but also stated that it carried the risk of apical extrusion.[7]

c)Endo Irrigator Plus-It is a recently introduced device invented by Dr.Mandar Pimprikar, marketed by K Dent Dental Systems, which is based on the ACWIS concept, i.e. activated continuous warm irrigation and evacuation system. The unit first warms Sodium Hypochlorite to 45°C and then delivers it upto the apex, concomitantly aspirating the irrigant with negative pressure. In a recent study it has proved to be effective in preventing periapical debris extrusion.[18]

The State Of The Art Technologies

a) Gentle-Wave System by Sonendo is an evolved technology which multi-sonic waves compounded with negative pressure is aimed at effective tissue dissolution and disinfecting even the complex areas such as apical-thirds, isthmuses, lateral fins, dentinal tubules, and other anastomoses. Sodium Hypochlorite and EDTA solutions are incorporated into the system which has a machine-assisted delivery.[19] A recent clinical study shows that only 3% of the patients experience moderate post-treatment pain, and 97% of successful healing in the teeth treated with the GentleWave System at 12 months.[20]

b)Electrochemically Activated (ECA) Solutions involves the electrolysis of water with low concentrated salt solutions, separated by a special semi-permeable membrane (diaphragm) which separates water to alkaline fraction – the catholyte and acidic fraction – the anolyte. The ECA water exposes the microorganisms to powerful oxidizing solutions leading to the rupture of their cell membranes. A comparative study by Gulabivala *et al*., in 2004, found that bacterial culture study for CFU showed the hydroxyl ions in ECA water reduce the biofilm formed by E. faecalis in infected tooth models.[21] More recently its antimicrobial efficacy was found comparable to Sodium Hypochlorite.[22]

c)Ozonated Solutions- Ozone, an allotrope of Oxygen is a powerful bactericidal agent due to its high oxidation property and, also doesn't carry the risk of developing of bacterial resistance. Various delivery systems available for endodontic irrigation like HealOzone (Kavo) unit, the OzoTop unit and Neo Ozone Water-S unit. Though effective against Candida albicans and Enterococcus faecalis, it fails to neutralize E. coli and other lipopolysaccharides inside the root canal, thus preventing its usage in daily practice.[23]

d)Self- adjusting file System (SAF)- It utilizes a file with a hollow tube consisting of rough nickel titanium lattices. It is available with the VATEA system (ReDent) which is an irrigant reservoir, allowing the flow of the irrigant through the hollow tube while the file is "scrubbing" the canals. The flow rate of the irrigant delivery ranges from 1-10 ml per minute. The vibrations (frequency of 5000 Hz) of the file along with the trans-axial motion results in the continuous mixing of the irrigant present in the root canal with fresh, fully active irrigant. The effectiveness of cleaning the root canal has been studied using scanning electron microscopy (SEM). It was found to be effective in thorough cleaning of C-shaped, curved, and oval shaped canals.[24]

e) Photo activated disinfection (PAD)- It is a novel disinfection strategy that involves a laser irradiation (red light with wavelength of 665 nm) of an appropriate wavelength to a photosensitizer (often methylene blue) to promote its transition from low-energy level "ground state" to a higher-energy "triplet state". This triplet-state sensitizer can react with biomolecules to produce free radicals and radical ions or with molecular oxygen to produce singlet oxygen. These cytotoxic species can cause oxidation of cellular constituents such as plasma membranes and DNA, resulting in cell death.[25] Studies by Bago I *et al.* [26] and Balakrishna N *et al.*[27]demonstrated greater reduction in number of CFUs of E. faecalis in PAD group with Diode Laser than conventional 2.5% NaOCl syringe irrigation.

CONCLUSION

Effective irrigant delivery and activation is essential for thorough cleaning of the root canal systems. This article gives an overview of the various irrigation devices available. Recent technological advancements have introduced a plethora of irrigation devices based on different mechanisms in past few decades. However, despite the innumerable studies available in literature, no evidence-based study has been able to establish the most efficacious irrigation system in correlation with desired treatment outcome. Thus, it has become the need of the hour to further investigate the existing systems for their clinical efficacy and, also explore and invent more user-friendly devices with improved treatment outcomes.

REFERENCES

1. Versiani, M. A., Alves, F. R. F., Andrade-Junior, C. V., Marceliano-Alves, M. F., Provenzano, J. C., Rôças, I. N. & Siqueira Jr, J. F. (2016). Micro-CT evaluation of the efficacy of hard-tissue removal from the root canal and isthmus area by positive and negative pressure irrigation systems. International endodontic journal, 49(11), 1079-1087.
2. Lee, S. J., Wu, M. K., & Wesselink, P. R. (2004). The effectiveness of syringe irrigation and ultrasonics to remove debris from simulated irregularities within prepared root canal walls. International Endodontic Journal, 37(10), 672-678.
3. Peters, O. A., Schönenberger, K., & Laib, A. (2001). Effects of four Ni–Ti preparation techniques on root canal geometry assessed by micro computed tomography. International endodontic journal, 34(3), 221-230.
4. De-Deus, G., Marins, J., Silva, E. J. N. L., Souza, E., Belladonna, F. G., Reis, C., ... & Neves, A. A. (2015). Accumulated hard tissue debris produced during reciprocating and rotary nickel-titanium canal preparation. Journal of Endodontics, 41(5), 676-681.
5. Wu, M. K., Sluis, L. W. M., & Wesselink, P. R. (2003). The capability of two hand instrumentation techniques to remove the inner layer of dentine in oval canals. International endodontic journal, 36(3), 218-224.
6. Kahn, F. H., Rosenberg, P. A., & Gliksberg, J. (1995). An in vitro evaluation of the irrigating characteristics of ultrasonic and subsonic handpieces and irrigating needles and probes. Journal of Endodontics, 21(5), 277-280.
7. Hauser, V., Braun, A., & Frentzen, M. (2007). Penetration depth of a dye marker into dentine using a novel hydrodynamic system (RinsEndo®). International Endodontic Journal, 40(8), 644-652.
8. Ram Z. (1977) Effectiveness of root canal irrigation. Oral Surg Oral Med Oral Pathol; 44:306–12.
9. Chow TW. (1983) Mechanical effectiveness of root canal irrigation. J Endod;9:475–9.
10. Al-Hadlaq, S. M., Al-Turaiki, S. A., Al-Sulami, U., & Saad, A. Y. (2006). Efficacy of a new brush-covered irrigation needle in removing root canal debris: a scanning electron microscopic study. Journal of endodontics, 32(12), 1181-1184.
11. Gu, L. S., Kim, J. R., Ling, J., Choi, K. K., Pashley, D. H., & Tay, F. R. (2009). Review of contemporary irrigant agitation techniques and devices. Journal of endodontics, 35(6), 791-804.
12. McGill, S., Gulabivala, K., Mordan, N., & Ng, Y. L. (2008). The efficacy of dynamic irrigation using a commercially available system (RinsEndo®) determined by removal of a collagen 'bio molecular film' from an ex vivo model. International endodontic journal, 41(7), 602-608.
13. Keir, D. M., Senia, E. S., & Montgomery, S. (1990). Effectiveness of a brush in removing post instrumentation canal debris. Journal of Endodontics, 16(7), 323-327.
14. Elumalai, D., Kumar, A., Tewari, R. K., Mishra, S. K., Iftekhar, H., Alam, S., & Andrabi, M. (2014). Newer Endodontic irrigation devices: An update. IOSR J Dent Med Sci, 13(6), 4-8.
15. Caron, G. (2007). Cleaning efficiency of the apical millimeters of curved canals using three different modalities of irrigant activation: an SEM study. Paris: Paris VII University.
16. Ahmad, M., Ford, T. R. P., & Crum, L. A. (1987). Ultrasonic debridement of root canals: an insight into the mechanisms involved. Journal of Endodontics, 13(3), 93-101.
17. Cameron, J. A. (1995). Factors affecting the clinical efficiency of ultrasonic endodontics: a scanning electron microscopy study. International Endodontic Journal, 28(1), 47-53.
18. Gadaalay, S., Hariramani, S. I., Dhore, P., Kale, A., Agrawal, M., & Doshi, S. (2017). Comparative evaluation of efficacy of three different irrigation activation systems in debridement of root canal isthmus: An in vitro study. Endodontology, 29(1), 39.
19. Vandrangi, P. (2016). Evaluating penetration depth of treatment fluids into dentinal tubules using the GentleWave system. Dentistry, 6(366), 2161-1122.
20. Sigurdsson, A., Garland, R. W., Le, K. T., & Woo, S. M. (2016). 12-month healing rates after endodontic therapy using the novel GentleWave system: a prospective multicenter clinical study. Journal of endodontics, 42(7), 1040-1048.
21. Gulabivala, K., Stock, C. J. R., Lewsey, J. D., Ghori, S., Ng, Y. L., & Spratt, D. A. (2004). Effectiveness of electrochemically activated water as an irrigant in an infected tooth model. International Endodontic Journal, 37(9), 624-631.
22. Lata, S., Mohanty, S. K., Pradhan, P. K., Patri, G., Sinha, S. P., & Agrawal, P. (2016). Anti bacterial effectiveness of electro-chemically activated (ECA) water as a root canal irrigant-An in-vitro comparative study. Journal of Clinical and Diagnostic Research: JCDR, 10(10), ZC138.
23. Ng, R. P. Y. (2004). Sterilization in root canal treatment: current advances. Hong kong dental journal, 1, 52-57.
24. Metzger, Z. (2014). The self-adjusting file (SAF) system: An evidence-based update. Journal of conservative dentistry: JCD, 17(5), 401.
25. Maisch T, Szeimies RM, Jori G, Abels C. (2004). Antibacterial photodynamic therapy in dermatology. Photochem Photobiol Sci;3:907-17.
26. Bago, I., Plecko, V., Gabric Panduric, D., Schauperl, Z., Baraba, A., & Anic, I. (2013). Antimicrobial efficacy of a high-power diode laser, photo-activated disinfection, conventional and sonic activated irrigation during root canal treatment. International endodontic journal, 46(4), 339-347.
27. Balakrishna N, Moogi P, Kumar G V, Prashanth B R, Shetty NK, Rao KR. (2017).Effect of conventional irrigation and photoactivated disinfection on Enterococcus faecalis in root canals: An in vitro study. J Conserv Dent, 20, 125-128