10.5005/jp-journals-10039-1044

REVIEW ARTICLE

Ultrasonics in Irrigation

[1]Anurag Singhal, [2]Mahak Jain, [3]Siddarth Gautam, [4]Anmol Mehrotra

ABSTRACT

Ultrasonic irrigation of the root canal can be performed with or without simultaneous ultrasonic instrumentation. When canal shaping is not undertaken the term passive ultrasonic irrigation (PUI) can be used to describe the technique. Passive ultrasonic irrigation can be performed with a small file or smooth wire oscillating freely in the root canal to induce powerful acoustic microstreaming. PUI is more efficient in cleaning canals than ultrasonic irrigation with simultaneous ultrasonic instrumentation. PUI can be effective in curved canals and a smooth wire can be as effective as a cutting K-file. The role of cavitation during PUI remains inconclusive. The influence of irrigation frequency and intensity on the streaming pattern as well as the complicated interaction of acoustic streaming with the adherent biofilm needs to be clarified to reveal the underlying physical mechanisms of PUI.

Keywords: Biofilm, Cleaning, Dentin debris, Irrigation, PUI, Root canal.

How to cite this article: Singhal A, Jain M, Gautam S, Mehrotra A. Ultrasonics in Irrigation. J Dent Sci Oral Rehab 2014;5(4):196-199.

Source of support: Nil

Conflict of interest: None

INTRODUCTION

There can be no doubt today that microorganisms, either remaining in the root canal space after treatment or re-colonizing the filled canal system, are the main cause of endodontic failure. The primary endodontic treatment goal must thus be to optimize root canal disinfection and to prevent re-infection. Infection of the root canal space occurs most frequently as a sequela to a profound carious lesion. But, in every endodontic problem, optimum debridement of the root canal is essential as it reduces root canal infection.[1]

Primary root canal infections are polymicrobial, typically dominated by obligatory anaerobic bacteria, Gram-negative anaerobic rods, Gram-positive anaerobic cocci, Gram-positive anaerobic and facultative rods, *Lactobacillus* species and Gram-positive facultative *Streptococcus* species.[2] The obligate anaerobes are rather easily eradicated during root canal treatment. On the contrary, facultative bacteria, such as nonmutans *Streptococci*, *Enterococci* and *Lactobacilli*, once established, are more likely to survive chemomechanical instrumentation and root canal medication.[3]

During the past few decades, endodontic treatment has benefited from the development of new techniques and equipment, which have improved outcome and predictability. Ultrasonics (US) have found indispensable applications in a number of dental procedures include Access refinement, finding calcified canals, and removal of attached pulp stones, ultraremoval of intracanal obstructions, condensation of gutta-percha, root-end cavity preparation and refinement and placement of root-end obturation material.[4] But, ultrasonic irrigation has gained special attention among all the applications.

The effectiveness of irrigation relies on both the mechanical flushing action and the chemical ability of irrigants to dissolve tissue. Furthermore, the flushing action of irrigants helps to remove organic and dentinal debris and microorganisms from the canal. The flushing action from syringe irrigation is relatively weak and dependent not only on the anatomy of the root canal but also on the depth of placement and the diameter of the needle. It has been demonstrated that an irrigant in conjunction with ultrasonic vibration, which generates a continuous movement of the irrigant, is directly associated with the effectiveness of the cleaning of the root canal space.[5] Acoustic streaming, as described by Ahmad et al has been shown to produce sufficient shear forces to dislodge debris in instrumented canals. When files were activated with ultrasonic energy in a passive manner, acoustic streaming was sufficient to produce significantly cleaner canals compared with hand filing alone. The tissue-dissolving capability of solutions with a good wetting ability may be enhanced by US if the pulp tissue remnants and/or smear layer are wetted completely by the solution and become subject to the ultrasonic agitation. US creates both cavitation and acoustic streaming. The cavitation is minimal and is restricted to the tip. The acoustic streaming effect, however, is significant.[6]

Two types of ultrasonic irrigation have been described in the literature. The first type is combination of simultaneous ultrasonic instrumentation and irrigation. The second type, often referred to as passive ultrasonic irrigation (PUI), operates without simultaneous instrumentation. Studies on endosonic systems have shown

[1]Professor and Head, [2]Endodontist, [3,4]Postgraduate Student

[1-4]Department of Conservative Dentistry and Endodontics Institute of Dental Sciences, Bareilly, Uttar Pradesh, India

Corresponding Author: Mahak Jain, Endodontist, Department of Conservative Dentistry and Endodontics, Institute of Dental Sciences Bareilly, Uttar Pradesh, India, e-mail: mahak2312@gmail.com

that teeth prepared ultrasonically with UI devices have significantly cleaner canals than teeth prepared by conventional root canal filing alone.[7]

The term PUI was first used by Weller et al to describe an irrigation scenario where there was no instrumentation, planing, or contact of the canal walls with an endodontic file or instrument. With this noncutting technology, the potential to create aberrant shapes within the root canal was reduced. During PUI, the energy is transmitted from an oscillating file or a smooth wire to the irrigant in the root canal by means of ultrasonic waves. The latter induces acoustic streaming and cavitation of the irrigant.

CONTINUOUS ULTRASONIC IRRIGATION

Chlorine, which is responsible for the dissolution of organic tissues and the antibacterial property of NaOCl, is unstable and is consumed rapidly during the first phase of tissue dissolution, probably within 2 minutes. Therefore, an improved delivery system that is capable of continuous replenishment of root canal irrigants is highly desirable. Recently, a needle-holding adapter to an ultrasonic handpiece has been developed by Nusstein. During ultrasonic activation, a 25-gauge irrigation needle is used instead of an endosonic file. This enables ultrasonic activation to be performed at the maximum power setting without causing needle breakage.[8]

MECHANISM OF PASSIVE ULTRASONIC IRRIGATION

Frequency and Intensity

An ultrasonic device converts electrical energy into ultrasonic waves of a certain frequency by magnetostriction or by piezoelectricity. On one hand, magnetostriction is generated by the deformation of a ferromagnetic material subjected to a magnetic field; on the other hand piezoelectricity is the generation of stress in dielectric crystals subjected to an applied voltage. The properties of the ultrasonic material determine the frequency of the oscillating instrument, which in dental practice, is fixed at 30 kHz. The intensity or energy flux, expressed in units of Watt cm^2, of the oscillating instrument can be adjusted by the power setting. Frequency and intensity do play a role in the transmission of energy from the ultrasonically oscillating file to the irrigant but a full understanding of the mechanism is still lacking. A higher frequency should in principle result in a higher streaming velocity of the irrigant. This in turn, results in a more powerful acoustic streaming. Increasing the intensity does not result in a linear increase of the displacement amplitude of the oscillating.[9]

ACOUSTIC STREAMING

Acoustic streaming is the rapid movement of fluid in a circular or vortex-like motion around a vibrating file. The acoustic streaming that occurs in the root canal during ultrasonic irrigation has been described as acoustic microstreaming. This is defined as the streaming which occurs near small obstacles placed within a sound field, near small sound sources, vibrating membranes or wires, which arise from the frictional forces between a boundary and medium carrying vibrations of circular frequency. Several papers have confirmed that acoustic microstreaming occurs during PUI (Fig. 1). The streaming pattern corresponds to the characteristic pattern of nodes and antinodes along the length of the oscillating file. The displacement amplitude is at its maximum at the tip of the file, probably causing a directional flow to the coronal part of the root canal . When the file touches the root canal wall at an antinode a greater reduction in displacement amplitude will occur compared with when it touches at a node. When the file is unable to vibrate freely in the

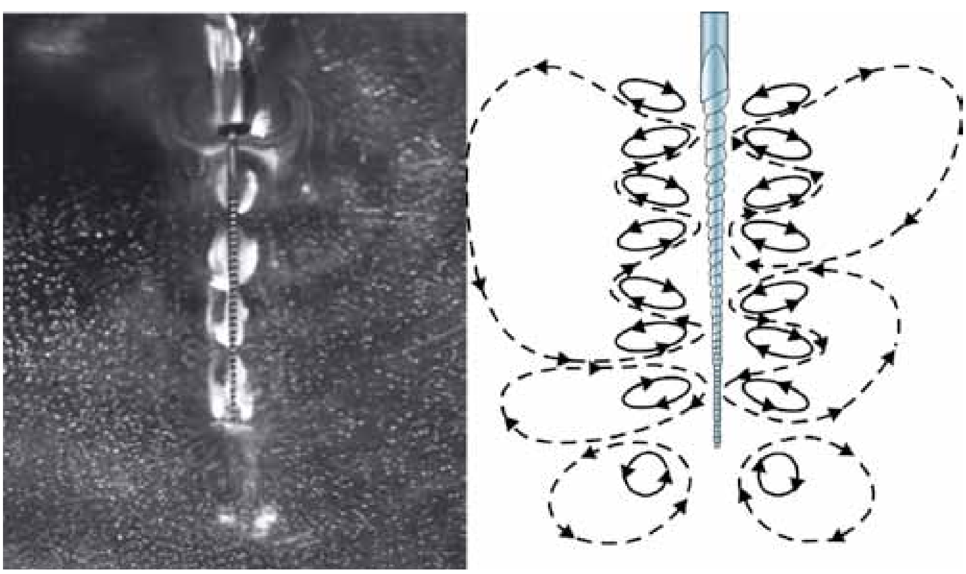

Fig. 1: Acoustic streaming around a file in free water (left) and a schematic drawing (right)

root canal, acoustic microstreaming will become less intense, however, it will not stop completely. The intensity of the acoustic microstreaming is directly related to the streaming velocity.[9]

CAVITATION AND CAVITATIONAL MICROSTREAMING

Cavitation in the fluid mechanical context can be described as the impulsive formation of cavities in a liquid through tensile forces induced by high-speed flows or flow gradients. These bubbles expand and then rapidly collapse producing a focus of energy leading to intense sound and damage, e.g. pitting of ship propellers and pumps. Acoustic cavitation can be defined as the creation of new bubbles or the expansion, contraction and/or distortion of preexisting bubbles (so-called nuclei) in a liquid, the process being coupled to acoustic energy. According to Roy et al (1994), two types of cavitation could occur during PUI of root canals: stable cavitation and transient cavitation. Stable cavitation could be defined as linear pulsation of gas-filled bodies in a low amplitude ultrasound field. Transient cavitation occurs when vapor bubbles undergo highly energetic pulsations (Fig. 2). When the acoustic pressures are high enough, the bubbles can be inertially driven to a violent collapse, radiating shock waves and generating high internal gas pressures and temperatures. The energy at the collapse point is in some cases sufficient to dissociate the gas molecules in the bubble, which recombine radiatively to produce light, a process known as sonoluminescence. In the studies of Ahmad et al (1988), Lumley et al (1993) and Roy et al (1994), sonoluminescence was used to detect transient cavitation.[10]

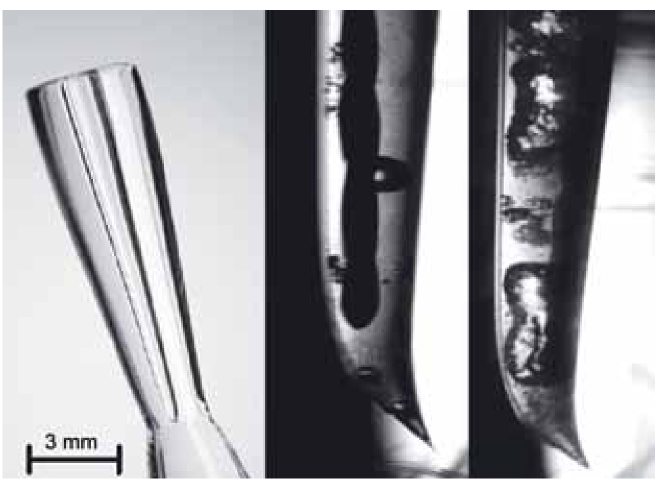

Fig. 2: Left: Glass root canal model allowing optical access to the vibrating file for high-speed visualization of ultrasonic irrigation. Middle: File in operation captured at microseconds time scale displaying both transient and inertial cavitation phenomena and, in addition, local streaming patterns (only visible in video mode), right: a high-speed recording of a noncutting K-file is shown, displaying vigorous microstreaming and collapsing cavitation bubbles

PUI *vs* SYRINGE IRRIGATION

After shaping the root canal, cleaning can be completed with PUI or a final flush of syringe irrigation. From the studies where PUI and syringe irrigation were compared, it can be concluded that PUI is more effective in removing remnants of pulp tissue and dentin debris and planktonic bacteria. In all these studies, NaOCl was used as the irrigant except the study of Spoleti et al (2003) and Weber et al (2003), where sterile saline and chlorhexidine and NaOCl was used respectively. In the study of Mayer et al (2002), no significant difference was found between PUI and syringe irrigation in dentin debris removal from the root canal. Before activating ultrasonically, the NaOCl, EDTA was left in the root canal. Removal of EDTA before the injection of 2 ml NaOCl in the root canal was not mentioned. EDTA inactivates the NaOCl and it is possible that this had an influence on the outcome.[11]

PUI WITH NaOCl AS IRRIGANT

During PUI, NaOCl removes significantly more smear layer or bacteria from artificial smear layer, pulp tissue or dentin debris from the root canal than water. The significant increase in dissolving capacity of organic material by NaOCl, when NaOCl is agitated by ultrasound or when the temperature rises because of ultrasound can be an explanation for the enhanced performance of NaOCl. When a greater concentration of NaOCl is used the efficacy appears to increase.[12]

PUI IN CURVED CANALS

The PUI can also be effective in curved canals and the best result is obtained when the file is prebent.[13]

PUI AND THE CLEANING OF THE ISTHMUS

Some studies specifically evaluated the cleaning efficacy of PUI in the isthmus which runs between two canals. Their results confirm a significantly cleaner isthmus when PUI is used compared with syringe irrigation.[14]

PUI WITH A SMOOTH WIRE

A smooth wire is as effective as a normal cutting file in dentin debris removal during PUI. It seems preferable to use a smooth wire during PUI because it does not intentionally cut into the root canal wall and it may, therefore, prevent aberrant root canal shapes or perforation of the (apical) root.[6]

PUI PARAMETERS

Taper of the File and Diameter of the Root Canal

The taper and diameter of the root canal have an influence on the efficacy of PUI in dentin debris removal from the root canal. In the studies by Lea et al and van der Sluis et al,[18] 3 minutes of PUI with 2% NaOCl was performed in each canal. From their results, it can be concluded that within certain limits (size 20, taper 0.04 to size 20, taper 0.10) the greater the taper the more dentin debris can be removed.[14]

Application of Irrigant during PUI

Two flushing methods can be used during PUI, namelya continuous flush of irrigant from the ultrasonic handpiece or an intermittent flush method using syringe delivery. In the intermittent flush method, the irrigant is injected into the root canal by a syringe, and replenished several times after each ultrasonic activation.[15] During ultrasonic activation, an ultrasonically oscillating instrument (file or smoothwire) will activate the irrigant in the root canal such that microorganisms, dentine debris and organic tissue will be detached from the root canal wall and be absorbed or dissolved in the irrigant. Hereafter, the root canal is flushed with 2 ml of fresh irrigant to remove the remnants from the root canal. Both flushing methods were equally effective in removing dentin debris from the root canal in an *ex vivo* model when the irrigation time was set at 3 minutes.[16]

Irrigation Time

The influence of irrigation time on the efficacy of PUI is not clear. One study claimed an increased removal of the smear layer after 5 minutes of PUI as opposed to 3 minutes. In the study of Sabins et al,[17] no significant difference was found between 30 and 60 s of PUI in dentine debris removal from the root canal. In their study, instead of a continuous flow of NaOCl during PUI, the NaOCl was injected in the root canal by a syringe and not refreshed during the ultrasonic activation of NaOCl.[6]

Ultrasonic *vs* Sonic Irrigation

Sonic irrigation is different from ultrasonic irrigation because it operates at a lower frequency. For sonic application, the frequencies ranges from 1000 to 6000 Hz. Consequently, following equation 1, the streaming velocity of the irrigant will be lower. Moreover, the oscillating patterns of the sonic instruments are different. They have one node near the attachment of the file and one antinode at the tip of the file. When the movement of the sonic file is constrained, the sideway movement will disappear, but will result in a longitudinal vibration.[16]

CONCLUSION

Based on this literature review, it is concluded that PUI appears to be an effective adjunctive treatment for cleaning the root canal system and that PUI is more effective than syringe irrigation.

REFERENCES

1. Cameron JA. The use of ultrasonics in the removal of the smear layer: a scanning electron microscope study. J Endodont 1983 July;9(7):289-292.
2. Lea SC, Walmsley AD, Lumley PJ, Landini G. A new insight into the oscillation characteristics of endosonic files used in dentistry. Phy Med Biol 2004 May;49(10):2095-2102.
3. Gutarts R, Nusstein J, Reader A, Beck M. In vivo debridement efficacy of ultrasonic irrigation following handrotary instrumentation in human mandibular molars. J Endod 2005 Apr;31(3):166-170.
4. Huque J, Kota K, Yamaga M, Iwaku M, Hoshino E. Bacterial eradication from root dentine by ultrasonic irrigation with sodium hypochlorite. Int Endodont J 1998 July;31(4):242-250.
5. Abbott PV, Heijkoop PS, Cardaci SC, Hume WR, Heithersay GS. An SEM study of the effects of different irrigation sequences and ultrasonics. Int Endod J 1991 Nov;24(6):308-316.
6. Cameron JA. Factors affecting the clinical efficiency of ultrasonic endodontics: a scanning electron microscopy study. Int Endod J 1995;28(1):47-53.
7. Jensen SA, Walker ThL, Hutter JW, Nicoli BK. Comparison of the cleaning efficacy of passive sonic activation and passive ultrasonic activation after hand instrumentation in molar root canals. J Endod 1999 Nov;25(11):735-738.
8. Van der Sluis LWM, Wu MK, Wesselink PR. The efficacy of ultrasonic irrigation to remove artificially placed dentine debris from human root canals prepared using instruments of varying taper. Int Endod J 2005 Oct;38(10):764-768.
9. Spoleti P, Siragusa M, Spoleti MJ. Bacteriological evaluation of passive ultrasonic activation. J Endod 2003 Jan;29(1):12-14.
10. Walker ThL, del Rio CE. Histological evaluation of ultrasonic and sonic instrumentation of curved root canals. J Endod 1989 Feb;15(2):49-59.
11. Weber CD, McClanahan SB, Miller GA, Diener-West M, Johnson J. The effect of passive ultrasonic activation of 2% chlorhexidine or 5.25% sodium hypochlorite irrigant on residual antimicrobial activity in root canals. J Endod 2003 Sep; 29(9):562-564.
12. Cheung GSP, Stock CJR. In vitro cleaning ability of root canal irrigant with and without endosonics. Int Endod J 1993 Nov;26(6):334-343.
13. Druttman AC, Stock CJ. An in vitro comparison of ultrasonic and conventional methods of irrigant replacement. Int Endod J 1989 July;22(4):174-178.
14. Krell KV, Johnson RJ, Madison S. Irrigation patterns during ultrasonic canal instrumentation. Part I: K-type files. J Endod 1988 Feb;14(2):65-68.
15. Langeland K, Liao K, Pascon EA. Work saving devices in endodontics: efficacy of sonic and ultrasonic techniques. J Endod 1985 Nov;11(11):499-510.
16. Cunningham WT, Martin H, Pelleu GB, Stoops DE. Evaluation of root canal debridement by the endosonic ultrasonic synergistic system. Oral Surg Oral Med Oral Pathol 1982 Apr;53(4):401-404.
17. Sabins RA, Johnson JD, Hellstein JW. A comparison of the cleaning efficacy of short-term sonic and ultrasonic passive irrigation after hand instrumentation in molar root canals. J Endod 2003 Oct;29(10):674-678.
18. Van der Sluis LWM. Passive ultrasonic irrigation of the root canal: a review of the literature. Int Endod J 2007 Jun;40(6): 415-426.