Ultrasonics in orthograde endodontics

Dr. Sanjeev Bhanderi discusses the role ultrasonics can play in conventional (orthograde) treatment in the contemporary endodontic practice

Introduction

Endodontic disease is a result of bacterial breach of the hard tissues that protect and house the pulp. If left untreated, microbial advancement occurs into the pulp, and the ensuing inflammatory response ultimately leads to pulp necrosis and then an apical periodontitis. The key to restoring the health of periodontium around all the portals of exit from the pulp space is the judicious removal of infected pulp tissue and securing a seal from apex to crown.

The use of ultrasonics was first reported in the field of endodontics by Richman in 1957. In dentistry, ultrasonics can be generated via two methods. One method is magnetostriction, whereby a “sandwich” of magnetic strips is subjected to an oscillating magnetic field that produces elliptical vibrations at a frequency of around 20kHz. Another method, which is more effective in endodontic practice, is piezoelectric. Piezoelectric ultrasonic devices utilize a quartz crystal exposed to an electrical charge; this causes its deformation and produces mechanical vibration in a more linear back-and-forth fashion and at higher frequencies of 30-40kHz. Two popular piezoelectric devices are shown in Figures 1A and 1B.

Work carried out by Martin in the mid-1970s led to the development of the “endosonic” K-type file. These instruments were essentially driven by ultrasonic energy to cut and prepare root canal dentin. Unfortunately, endosonic files proved to be somewhat unpredictable in their performance, often leading to procedural errors particularly beyond curvatures (Dummer, et al., 1989; Stamos, 1985).

Ultrasonics has since seen a reemergence in contemporary endodontic practice, as it can be deployed at all stages of conventional (orthograde) treatment, including:

- Coronal access cavity refinement
- Canal exploration
- Removal of intracanal blockages
- "Activation" of irrigants
- Warm condensation of gutta percha

Educational aims and objectives

This clinical article aims to discuss the role that ultrasonics can play in conventional treatment in contemporary endodontic practice.

Expected outcomes

Correctly answering the questions on page xx, worth 2 hours of CE, will demonstrate you recognize that ultrasonics provides a very versatile adjunct at all stages of endodontic treatment and is proving to be a valuable tool in increasing the chemomechanical efficacy of irrigants, in particular NaOCl.

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Figure 1A: P5 Neutron ultrasonic device (Satelec, Acteon Group)

Figure 1B: Minipiezon ultrasonic device (EMS)

Figure 2: ET18D (Satelec, Acteon group)

Figure 3: Start-X tips (Dentsply Maillefer)
arrangement of the root(s). Knowledge of this information and experience will dictate the shape of the access cavity.

One of the dangers of access cavity preparation with a high-speed bur is the lack of tactile feedback for the clinician. In a tooth with a naturally open pulp chamber, the high-speed access bur will usually “drop” into the pulp chamber, providing that it is aimed reasonably centrally and perpendicular to the occlusal surface. Difficulty occurs when the pulp space is occluded, for example, by deep restorations, dystrophic calcifications as a result of age and response to insults, and naturally occurring pulp “stones.” Magnification is mandatory at this stage to discern subtle changes in texture and color of the coronal dentin that indicate the nature of the dentin, i.e., normal (physiological), reparative (“reactionary”/tertiary), or dystrophic calcifications.

At this depth, ultrasonics are very useful to break down these calcifications and clear the pulp floor. This will refine the “straightline” access, which is a prerequisite for good visualization and exploration of the canal orifices. There are numerous tips that have been designed specifically for refinement of the access cavity, e.g., ET18D (Satelec) [Figure 2], Start-X™ tips (Dentsply Maillefer) [Figure 3].

**Canal exploration**

Once the roof of the pulp chamber has been removed, exploration for the canal orifices can begin in earnest but can be a challenge with the presence of reactionary dentin formation. Careful examination under magnification and illumination, and use of ultrasonic tips such as the Start-X No. 3 (Figures 4A and 4B) or 10Z (Figures 5A-5D) can break down larger calcifications and are activated on a 80-100% power setting with water irrigation. An alternative is the narrower ET20 (Satelec) [Figure 6] on a 60-80% setting with water irrigation.

For deeper exploration and opening of canal orifices, finer diamond-coated tips such as the ETBD tip (Satelec) [Figures 7A-7E] can be employed to trough and grind away the whiter reactionary dentin that often occludes canal openings; this is used without intermittent irrigation and air on a 60-75% power setting.

**Removal of intracanal blockages**

One of the most challenging situations in endodontics is renegotiating a root canal with an obstruction such as a fractured instrument (Madarati, et al., 2010) or fractured post. The former requires high-power magnification and illumination so that the clinician can precisely apply ultrasonic energy to loosen and cut around the obstruction. This, therefore, requires long fine and non-abrasive tips, e.g., ET25 (Satelec) [Figure 8] and ProUltra™ 6-8 (Dentsply Maillefer) [Figure 9]. These tips are used on 60-75% power setting without water to minimize the buffering effect of moisture on transmission of ultrasonic energy and prevent formation of a dentin “mud” that will impair vision of the working field at these depths.
a number of clinical challenges that can prevent its penetration throughout the pulp space:

• Dystrophic calcifications
• Complex anatomy (Ricucci, Bergenholtz, 2003; Peters, 2004)
• Biofilm (Haapasalo, et al., 2005)
• Smear layer (Peters, 2000).

In vivo and in vitro studies, therefore, show a disparity in results with respect to the efficacy of NaOCl. Application of ultrasonics in irrigation was first suggested by Walmsley in 1987. Ultrasonics has been shown to exhibit two properties when applied to aqueous fluids such as NaOCl: cavitation and acoustic microstreaming. In the confines of the root canal, it is acoustic streaming that exerts most influence on an irrigant that immerses an activated instrument (Roy, et al., 1994; Lumley, et al., 1991).

Acoustic streaming is characterized by vortices of fluid movement (Figure 12), which have proportionately large hydrodynamic shearing forces. This turbulence is sufficiently powerful to disrupt bacteria on an intra- and extracellular level and radiates jets of irrigant from the instrument towards the root canal walls (Jiang, et al., 2011) that can extend up to 3 mm away from the energized tip (Malki, et al., 2012). There is the potential to improve the distribution of NaOCl, which is relatively poor when delivered by the traditional “positive pressure” syringe method (Boutsioukis, 2010; Gao, 2009).

Consequently, the turbulence of NaOCl created by ultrasonic activation has been shown to be effective in dealing with numerous clinical challenges faced by the endodontic clinician:

• Penetration into complex anatomy (Alves, xx Endodontic practice

The recommended technique (Ruddle, 1997) firstly requires preparation of a “staging platform” with a modified No. 3 Gates Glidden bur around the top of the fractured instrument. The ultrasonic tip is then activated with a combination of vibrational energy directly onto the fragment and cutting into the dentin platform, which should eventually loosen and unthread the fragment (Figures 10A-10C).

Removal of fractured posts beneath the orifice level utilizes a combination of more sturdy ultrasonic tips on a higher power to apply vibrational energy to loosen the fragment to vibrate the post and shatter the cement lute, e.g., ET40 (Satelec) or Start-X No. 4 (Dentsply Maillefer), and then finer ultrasonic tips similar to those used for instrument removal to carefully trough the canal dentin around the obstruction.

Post-core removal

Ultrasonics is an essential tool for loosening post-core units prior to retreatment, either as an adjunct but usually as the primary method. For cast metal post-cores, the key is to reduce the bulk of the metal core, leaving just 2 to 4 mm above the cervical level and a diameter continuous with the radicular part of the post. This will leave an optimum core of metal that will absorb high-power ultrasonic energy without disintegrating. A bulkier tip, e.g., Start-X No. 4 (Dentsply Maillefer) or ET40 (Satelec) [Figures 11A-E] can be used around the circumference of the core with water cooling to loosen and shatter the underlying cement lute.

For prefabricated threaded posts, it is important to preserve the original core as this can be loosened with a similar ultrasonic tip to shatter the cement lute and unthread the post. If available, an appropriate ratchet for the post system or lockable mosquito-type forceps can be used to complete unwinding and retrieval of the post.

Irrigation

Instrumentation and irrigation go hand-in-hand to remove the microorganisms and organic tissue to favor the host’s immune response. Sodium hypochlorite (NaOCl) in varying concentrations (1-8%) is very effective at killing planktonic microorganisms and is the gold standard for endodontic irrigation. However, it may not be as effective as we assume due to
et al., 2011; Siqueira, et al., 2008; van der Sluis, et al., 2005; Gutarts, et al., 2005; Lee, et al., 2004)
• Curvatures (Munoz, 2012; Amato, et al., 2011; Al-Jadaa, et al., 2009)
• Dissolution of pulp tissue and removal of smear layer (Al-Ali, et al., 2012; Stojicic, et al., 2010; Zehnder, 2006; Peters, 2000)
• Biofilm removal (Neilsen, 2007)
• Eradication of persistent bacterial species, e.g., E. faecalis (Harrison, et al., 2010).

One example of an ultrasonic irrigation tip is the IrriSafe™ 20/25 tip (Satelec) [Figure 13] that can be activated on a 35-45% power setting. This design has flute spaces that may provide a greater surface area for irrigant contact and generation of acoustic streaming.

Another design is the Endosoft instrument (EMS) [Figure 14], which has a smooth non-fluted tip that may have less potential to fracture with its constant diameter but with arguably less effective turbulence patterns at an equivalent power setting.

Both instruments are made from stainless steel but differ from traditional endosonic files in that they have no cutting edges, hence why the term passive ultrasonic irrigation (PUI) is often used to describe their use during irrigation. They can also be prebent to conform to canal curvatures.

Clinically, PUI is employed after canal preparation to the desired taper and apical dimension at full working length has been completed. The PUI tip is activated in the canal with the access cavity filled with NaOCl. Frequent replenishment of NaOCl provides a continuous release of nascent Cl that is released by ultrasonic energy, and works on the organic dissolution of pulp tissue (Zehnder, 2006).

The author’s recommended protocol for the IrriSafe 25 (Satelec) tip is as follows:
• Three 20-second ultrasonic bursts on a 35-45% power setting, replenishing the NaOCl in between each activation
• The IrriSafe tip should be kept mobile with slight vertical movements up to 2 mm short of WL and gentle prebending of the ultrasonic tip in curvatures to limit contact and dampening against canal walls
• Blot dry each canal with paper points to remove NaOCl
• Irrigate canal(s) with 15-18% EDTA solution, and activate with the IrriSafe tip
• for 10 seconds up to 2 mm from WL. Replenish the EDTA and leave for 2 minutes
• Final washout with NaOCl solution, and activate with IrriSafe tip for 10 seconds
• Blot dry canal(s) with paper points ready

One could speculate that using ultrasonic energy to debride or cut dentin over or around an exposed vital pulp (e.g., traumatic exposure in immature teeth) may be more effective than newer “negative pressure” irrigation systems (Jiang, et al., 2012). Another finding is that ultrasonic energy at low intensity and low frequency has a positive effect on the differentiation and proliferation of odontoblasts-like cells.
might be conducive to reparative dentin formation. Or, PUI may influence the healing response of the apical tissues just beyond the root canal terminus after canal preparation. This may be an interesting area for future research.

**Sonic vs PUI?**

Sonic endodontic instrumentation has been described in the late 1980s (Walmsley, et al., 1989) but fell out of favor as its performance was unpredictable and risked procedural errors in the more complex canal anatomy. However, in the light of a resurgence of PUI to “energize” irrigation, sonic devices have also seen a reemergence in the shape of the EndoActivator® (Dentsply Maillefer) developed by Dr. Clifford Ruddle.

Unlike an ultrasonic instrument that is characterized by a multiple oscillations along its length (a sinusoidal wave pattern of nodes and antinodes), a sonic instrument produces just a single waveform with one node and antinode along its entire length. It is therefore suggested that there is less dampening effect upon contact with the canal wall with a sonic (Walmsley, Williams, 1989) rather than an ultrasonic device. In addition, EndoActivator utilizes a polymeric tip rather than metallic without the risk of fracture or cutting canal walls. With a lower frequency (up to 10kHz) but high amplitude, the novel sonic device maximizes hydrodynamic agitation of an irrigant when immersed.

However, evidence for its performance over PUI remains questionable (Sabins, 2003; Stamos et al., 1987). It has already been mentioned that PUI is effective in curved canals and, contrary to what has been claimed, may in fact outperform sonic irrigation (Paragiola, et al., 2010). Another study showed superior performance by this sonic device (Rodig, et al., 2010; Jensen, 1999); however, both studies used a size No. 15 endosonic file and the former on a low power setting of 25%, which is not comparable to the recommended protocol for using the IrriSafe tip, for example.

It has also been shown that the taper of an energized instrument can affect performance. PUI seems to perform better in conservative 04 tapered canals than a wide-tapered sonic device (Merino, et al., 2012; Munoz, 2005), probably due to the fact that the narrower .02 taper of PUI instruments can produce a greater volume of activated irrigant by acoustic streaming. Future research will no doubt determine the most effective and predictable protocol for irrigant activation but certainly the choice of either sonic or PUI is a step forward in our ability to achieve the common goal of canal disinfection.

**Obturation with gutta percha (GP)**

One of the features of ultrasonic instruments is the transfer of this energy form into heat when an activated instrument contacts and “dampens” against another material surface. In fluids such as irrigants, this serves to increase its temperature, and the same effect can apply to gutta percha (Bailey, et al., 2004).

One suggested technique utilizes a No. 15 endosonic file activated on high power and is driven into the mass of master/accessory gutta-percha cones or a matched greater tapered gutta-percha cone fitted to working length. The
endosonic file is immediately dampened by the gutta percha, and the local heat generated “thermoplastizes” the material to flow (Figure 16). The warm gutta-percha void that is created is then widened with a finger spreader, a matching accessory gutta-percha cone is fitted, and the process repeated until the canal is completely obturated. As the ultrasonic condensing instrument can be inserted to within 2 mm of working length for the first couple of activations, this may provide a predictable and economical alternative to currently available warm vertical condensation obturation devices.

Conclusion
It is the clinician’s prerogative to rise to the challenge of achieving optimal disinfection in the myriad of root canals that can present. Ultrasonics provides a very versatile adjunct at all stages of endodontic treatment and is clearly proving to be a valuable tool in increasing the chemomechanical efficacy of irrigants, in particular NaOCl.

REFERENCES


