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Ultrasonics: An Indispensable Tool in Modern Endodontic Practice

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Introduction

Vibrations generate energy in the form of sound. Sound frequencies up to 20,000 Hz or 20 kHz are audible to humans. Originally, ultrasonic (US) units used frequencies in the 25–40 kHz range. Dental devices that use US technology transform electrical current into a very high frequency. Nowadays, low-frequency ultrasonic handpieces that operate between 1-8 kHz have also been developed. [1]

Evolution

Richman originally proposed the use of US in endodontics in 1957. Martin and Bertrand both published papers on US irrigation and retro-cavity preparation in 1976. However, this technique did not become widely used in the preparation of root canals prior to filling and obturation until 1980, when Martin et al. showed that ultrasonically activated K-type files could cut dentin. The synergistic approach of root canal instrumentation and disinfection along with US was coined as "Endosonics" by Martin and Cunningham in 1984. [2]

Methods of Ultrasound Production

1. Magnetostriction

According to Laird and Walmsley 1991, "Magnetostriction is defined as the changing of a material's physical dimensions in response to changing its magnetization". It produces mechanical energy from electromagnetic energy. In other words, when exposed to a magnetic field, a magnetostrictive material will undergo a dimensional change.

Mechanism of Action: A stack of nickel strips is subjected to an alternating electromagnetic field. The nickel stack elongates and then compresses along its length (i.e., changes dimensions) in reaction to the magnetization, causing longitudinal vibrations. These vibrations leave the stack and pass through a connecting body and cause the tip to oscillate at a high frequency (Figure 1 and 2). [3]

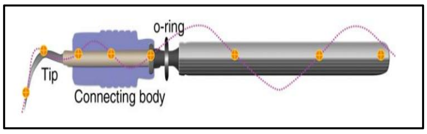


Figure 1: Diagram of a magnetostrictive insert. [3]

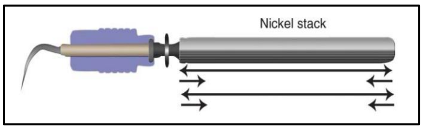


Figure 2: Diagram depicting longitudinal vibrations in a magnetostrictive device. Crosshairs denote points of no vibration or movement, referred to as nodal points or antinodes. [3]

2. Piezoelectricity

According to Laird and Walmsley 1991, "Crystalline structures, such as quartz and certain ceramics, undergo dimensional changes when subjected to an electrical field". This crystal's deformation is transformed into mechanical oscillations without generating heat.

Mechanism of Action: A ceramic or quartz disk is subjected to an alternating electrical current. The crystalline structure alternately expands and contracts in response. It produces longitudinal vibrations that cause the tip to oscillate at a high frequency (Figure 3). [3]

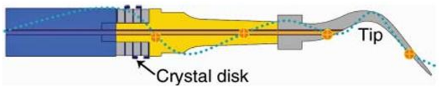


Figure 3: Diagram of a piezoelectric US handpiece. Crosshairs denote nodal points (antinodes), or points of no movement or vibration. [3]

A comparative evaluation between the magnetostrictive and piezoelectric devices has been illustrated in Table 1.

Biophysical Effects of Ultrasonics

	MAGNETOSTRICTIVE	**PIEZOELECTRIC**
Optimal frequency	Less cycles (24kHz)	More cycles (40kHz)
Stroke pattern	Elliptical or figure of 8 pattern	Linear or piston like motion
Tip movement	Longitudinal and transverse	Longitudinal
Heat generation	Present; requires adequate cooling	Absent
Power dispersion on tip	All surfaces are active (Face, back and 2 lateral surfaces)	Face and back surfaces are active
Transducer (converts energy to vibration)	Metal rod or stack of metal sheets	Ceramic or quartz
	Not ideal for surgical or non-surgical endodontic purposes	Can be used for troughing and surgical purposes

Table 1: Comparison between magnetostrictive and piezoelectric device.

1. **Acoustic Streaming:** According to Laird and Walmsley 1991, it is defined as the "Generation of time independent, vigorous circulation of fluid in the vicinity of a small vibrating object." It causes the removal/disruption of biofilm by turbulent currents of water surrounding the tip (Figure 4). [4]

Figure 4: Depiction of the waves generated around a vibrating US file. [4]

2. **Cavitation:** According to Laird and Walmsley, 1991, it is defined as the "Formation and subsequent implosion of pulsating cavities or 'bubbles' in a flowing liquid that is the consequence of forces acting on the liquid". It causes the removal/disruption of biofilm by shock waves resulting from the implosion of bubbles (Figure 5). [5]

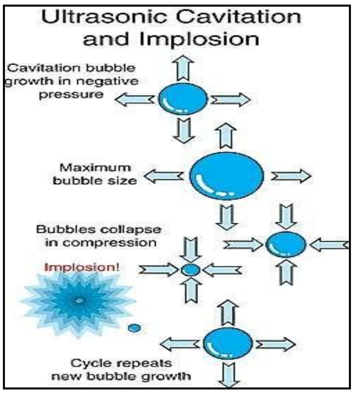


Figure 5: US cavitation and implosion cycle. [5]

3. **Miscellaneous:** US activation is also able to increase the temperature of the surrounding irrigant in a root canal up to 10 degrees Celsius. US vibration of a metallic post under dry conditions can produce significant heat transfer to surrounding tooth structures in as less as 20 seconds. Intermittent cooling with air or water is recommended.

When an US device is used with a water coolant, aerosols are generated that may contain microorganisms or even contaminated blood. Extraoral high-volume evacuation is able to significantly reduce the aerosols produced. Pre- procedural mouthrinse of 0.12% chlorhexidine is recommended.

Magneto-strictive US devices could also potentially interfere with pacemakers. However, piezoelectric US units used in patients with pacemakers have found no interference till date and are therefore considered safe. [3]

Clinical Applications

1. Refinement of access opening, locating calcified canals and removal of pulp stones

In the initial phase, larger tips with a limited diamond coated extension should be used. They offer maximum cutting efficiency and enhance control while working in the pulp chamber. In the subsequent phase, thinner, longer and finer tips that facilitate working in deeper areas while maintaining clear vision are preferred. Microscopic visualization combined with US (Non-Surgical Proultra tips) provide a safe and effective combination to achieve optimal results (Figure 6). [2][6]

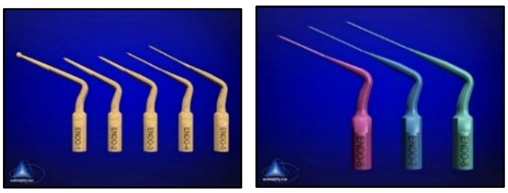


Figure 6: Non-Surgical Proultra Tips

2. Retrieval of intracanal obstructions

It includes retrieval of the separated instruments**,** silver points, fractured metallic posts and cemented posts**.** Before the application of US energy, the canal is vigorously flushed and thoroughly dried. Cotton pellets are placed over other exposed orifices. A gates-glidden drill (GG drill) is modified such that it is cut perpendicular to its long axis at its maximum diameter and a staging platform is prepared (Figure 7). [7]

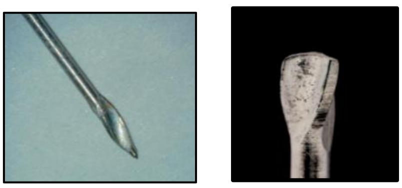
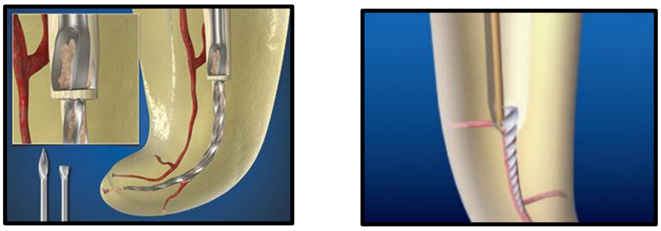


Figure 7: Unmodified GG drill and a modified GG drill.

The US tip is placed in intimate contact against the obstruction. Then the selected US instrument is moved lightly, in a counter clockwise (CCW) direction around the obstruction. US action trephines and precisely sands away dentin and exposes the coronal few millimeters of the obstruction. The obstruction begins to loosen, unwind and then spin (Figure 8). [8]



(a) (b)

Figure 8: a) A modified GG drill is rotated counter-clockwise (CCW) to create a staging platform at the most coronal aspect of the obstruction, b) Trephining action using an US instrument. [8]

3.Increased action of irrigating solutions

A syringe needle delivers the irrigant to the root canal in an US irrigation system. The energy for tip oscillation is provided by a piezoelectric US energy generating device in combination with the piezoflow irrigation needles. The US needle's luer-lock connector is connected to a syringe or other irrigation source. The traditional suction method is used to remove the irrigant. A 25-gauge irrigation needle is used for US activation. [9] A luer-lock irrigation delivery syringe delivers an irrigant while the Sonic (Endoactivator by Dentsply Sirona) or US handpiece (Endoultra cordless ultrasonic activator by Vista Apex) simultaneously activates the needle (Figure 11 and 12). The apical region receives an efficient delivery of the irrigant. US irrigation has been shown in numerous studies to be very effective for both vital and nonvital teeth. [4][10]

4. Ultrasonic condensation of gutta-percha

US can be used for the warm lateral condensation of gutta percha. For this procedure, the gutta percha cone is initially placed till the working length followed by cold lateral condensation of two or three accessory cones using a finger spreader. US spreader is then placed into the center of the gutta-percha mass, 1 mm short of the working length and activated. US spreader vibrates linearly and produces heat, thus thermoplasticizing the gutta-percha. The US spreader is then removed and an additional accessory cone is placed. A homogenous mass is achieved. This process is repeated until the canal is filled. During each subsequent step, the US spreader should be placed slightly more coronally. [11]

Various protocols for US condensation of gutta percha have been recommended such as:

- US softening of the master cone followed by cold lateral condensation
- One or two times of US activation after completion of cold lateral condensation
- US activation after placement of each second accessory cone
- US activation after placement of each accessory cone

5. Placement of mineral trioxide aggregate (MTA)

Direct US energy can be used in the placement of MTA. The activated tip generates vibrations and moves in a vertical packing motion. This causes better adaptation of 1-2mm increments of the cement to the canal walls.

Indirect US energy can also be used for placement of MTA. MTA is first incrementally placed into the canal. A pre-curved 15 or 20 stainless steel file is then inserted into the material and placed to within 1 or 2 mm of the working length. This is followed by indirect ultrasound, which involves placing the working end of an US instrument on the shaft of the file. This vibratory energy encourages MTA to move and conform to the configurations of the canal laterally as well as controlling its movement. [5][12]

6. Surgical endodontics: Root-end cavity preparation and refinement and placement of root-end obturation material

Root end cavity preparation with a bur poses a high risk of lingual perforation (Figure 9). Also, there is limited access to the root end, insufficient depth of cavity preparation which compromises retention. Necrotic isthmus tissue also cannot be adequately removed. [13]

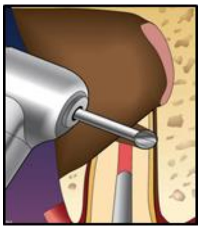


Figure 9: Preparation with a bur ends up in a dome-shaped preparation. [14]

US tips (Kim Surgical US tips by Obtura Spartan) (Figure 10) can also be used for retro-end cavity preparation. Correct alignment of the US tip parallel to the long axis of the root is crucial so as to prepare a Class I root end cavity (Figure 11). US tips are considered safer as compared to burs since they preserve the integrity of the root end. [14]

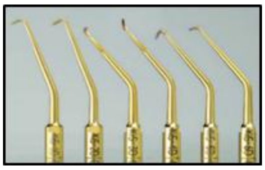


Figure 10: Kim Surgical tips (Image courtesy: Obtura Spartan).

Rarely, if the tip is incorrectly aligned, then it may cause an off-angled preparation.

7. Root canal preparation

US devices were introduced for use in root canal preparation in 1957 by Richman. In 1980, Martin et al. demonstrated the ability of ultrasonically activated K-type files. However, he failed to demonstrate the superiority of US or sonics as a primary instrumentation technique. The relative inefficiency of US debridement has been attributed to file constraint within the unflared root canal space. However, ultrasound activated for a few minutes after hand preparation showed better results. [15]

Figure 11: Off-angled preparation resulting from the wrong angulation of the US tip. [14]

Conclusion

Ultrasonic technique has become a needful aid in everyday endodontic practice and its use in combination with magnification and a coaxial light source make complex clinical situations simpler and much more predictable.

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