Ultrasonics in endodontic surgery: a review of the literature

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Summary
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Currently, although ultrasonics (US) is used in dentistry for therapeutic and diagnostic applications as well as for cleaning of instruments before sterilization, its main use is for scaling and root planing of teeth and in root canal therapy, both for orthograde and retrograde therapy. Both in conventional and surgical treatments, US in endodontics has enhanced quality of clinical procedures and represents an important adjunct in the treatment of difficult cases. More precisely it has become increasingly more useful in applications such as gaining access to canal openings, cleaning and shaping, obturation of root canals, removal of intracanal materials and obstructions, and endodontic surgery. This review of the literature aims at presenting the numerous advantages of US in surgical endodontics and emphasizes its application in a modern-day endodontic practice.

Key words: endodontics, surgery, ultrasonics.

Introduction

In order to understand the basic concepts of the use of ultrasonics (US) in dentistry, it must be underlined that ultrasound is sound energy with a frequency above the range of human hearing, which is 20 kHz. In dentistry the range of frequencies employed in the first ultrasonic units was between 25 and 40 kHz (1). Later, low-frequency ultrasonic handpieces operating from 1 to 8 kHz were developed (2,3). This low-frequence devices were found to produce lower shear stresses (4), thus causing less alteration to the tooth surface (5). Currently, there are two basic methods of producing ultrasound (6,7,8). The first is magnetostriction, which converts electromagnetic energy into mechanical energy. A stack of magnetostrictive metal strips in a handpiece is subjected to a standing and alternating magnetic field, as a result of which vibrations are produced. The second method is based on the piezoelectric principle, in which a crystal is used that changes dimension when an electrical charge is applied. Deformation of this crystal is converted into mechanical oscillation without producing heat (1).

In the last decade piezoelectric units have become the most common ultrasonic devices in dentistry. They have some advantages compared with earlier magnetostrictive units because they offer more cycles per second, 40 versus 24 kHz. The tips of these units work in a linear, back-and-forth, "piston-like" motion, which is ideal for endodontics. Lea et al. (9) demonstrated that the position of nodes and antinodes of an unconstrained and unloaded endosonic file activated by a 30-kHz piezon generator was along the file length. As a result the file vibration displacement amplitude does not increase linearly with increasing generator power. This applies in particular when "troughing" for hidden canals or when removing posts and separated instruments. In addition, this motion is ideal in surgical endodontics when creating a preparation for a retrograde filling. A magnetostrictive unit, on the other hand, creates more of a figure eight (elliptical) motion, which is not ideal for either surgical or nonsurgical endodontic use. In endodontic surgery, for example, this characteristic does not allow a precise cut of a cavity. The magnetostrictive units also have the disadvantage that the stack generates heat, thus requiring adequate cooling (1). Once again, this overheating is not desiderable in surgical endodontics.

In dentistry ultrasonics (US) or ultrasonic instrumentation was first introduced to for cavity preparations (10,11), using an abrasive slurry. Although the technique received favorable comments (12,13), it never became popular, because it had to compete with the much more effective and convenient instruments, i.e. the burs mounted on high-speed handpieces (14). However, a different application was introduced in 1955, when Zinner (15) reported on the use of an ultrasonic instrument to remove deposits from the tooth surface. This was improved upon by Johnson and Wilson (16), and the ultrasonic scaler became an established tool in the removal of dental calculus and plaque. Currently, although US is used in dentistry for therapeutic and diagnostic applications as well as for cleaning of instruments before sterilization, its main use is for scaling and root planing of teeth and in root canal therapy, both for surgical and non-surgical approach. (1,17,18). More recently, the concept of minimally invasive dentistry (19,20) and the desire for preparations with small dimensions has stimulated new approaches in cavity design and tooth-cutting concepts, including ultrasound for cavity preparation (21).

The concept of using US in endodontics was first introduced by Richman (22) in 1957. However, it was not until Martin et al. (23,24,25) demonstrated the ability of ultrasonically activated K-type files to cut dentin that this application found common use in the preparation of root canals before filling andalso obturation. The term *endosonics* was coined by Martin and Cunningham (26,27) and was defined as the ultrasonic and synergistic system of root canal instrumentation and disinfection. The most frequent applications of US in endodontics are the following. (i) Access refinement, finding orifices and calcified canals, and removal of attached pulp stones. (ii) Removal of intracanal obstructions (separated instruments, root canal posts, silver points, and fractured metallic posts). (iii) Root canal preparation using ultrasonically activated k-files. (iv) Root canal irrigation with an increased action of irrigating solutions, due to cavitation and microstreaming action. (v) Ultrasonic condensation of gutta-percha. (vi) Placement of calcium hydroxide and mineral trioxide aggregate (MTA). (vii) Surgical endodontics: root-end cavity preparation and refinement and placement of root-end obturation material

The aim of the present literature review is to analyze and discuss the use of US in surgical endodontics, focusing attention mainly of the advantages of US-activated instruments for cavity preparation and refinement. Moreover the use of US for the placement of root-end filling materialswill also be addressed.

The use of ultrasonics in Surgical Endodontics

In the past decades root-end cavities have traditionally been prepared by means of small round or inverted cone burs in a micro-handpiece. In the mid-1980s, standardized instruments and aluminum oxide ceramic pins were introduced for retrograde filling (28), but that system could not be used in cases with limited working space or in teeth with large oval canals. Soon after sonically or ultrasonically driven microsurgical retrotips became commercially available in the early 1990s (29,30,31,32), this new technique of retrograde root canal instrumentation has become rapidly popular and been established as an essential adjunct in periradicular surgery (33,34). However, the cutting properties of the retrotips at that time were limited and seemed to be dependent on loading, power setting, and orientation of the tip to the long axis of the handpiece (35,36). Moreover in some retrotips, cooling of the working tip was insufficient, and dentin and bone were at risk of being overheated.

However, the technique was promising and led to significant improvement in the instruments, which have significantly enhanced the treatment outcome in apicoectomy with retrofilling (37). As the prognosis of endodontic surgery is highly dependent on good obturation and sealing of the root canal, an optimal cavity preparation is an essential prerequisite for an adequate root-end filling after apicoectomy (38,39). The first root-end preparation using modified ultrasonic inserts following an apicoectomy is attributed to Bertrand et al. (40). Others followed, but it was not until 1987 that Flath and Hicks (41) further reported on the use of ultrasonics and sonics for root-end cavity preparation.

One of the reason for the success of US retrotips is due to the fact that conventional root-end cavity preparation using rotary burs in a micro-handpiece is faced with several problems (42,43), such as a cavity preparation not being parallel to the canal, difficult access to the root end, and risk of lingual perforation of the root. Furthermore, the inability to prepare to a sufficient depth, thus compromising retention of the root-end filling material, means that the root-end resection procedure requires a longer cutting bevel, thus exposing more dentinal tubules and isthmus tissue, of which the latter is difficult to remove. The development of ultrasonic and sonic retrotips has revolutionized root-end therapy, improving the surgical procedure with better access to the root end, resulting in better canal preparation (44,45). Ultrasonic retrotips come in a variety of shapes and angles, thus improving some steps during the surgical procedures (46,47).

Probably, the most relevant clinical advantages are the enhanced access to root-ends in a limited working space. This leads to a smaller osteotomy for surgical access because of the advantage of using various angulations and the small size of the retrotips (48). However, a number of studies compared root-end preparations made with microsurgical tips to those made with burs. They demonstrated additional advantages of this technique, such as deeper and more conservative cavities that follow the original path of the root canal more closely (49,50,51,52,53,54). A better-centered root-end preparation also lessens the risk of lateral perforation. Furthermore, the geometry of the retrotip design does not require a beveled root-end resection for surgical access, thus decreasing the number of exposed dentinal tubules (55,56,57) and minimizing apical leakage (58,59,60,61). They also enable the removal of isthmus tissue present between two canals within the same root (62,63,64). It is considered a time-saving technique that seems to have a lower failure rate.

More recently, the cleaning effect and the cutting ability of ultrasonic retrotips have been described as satisfactory by many authors (65,66). Furthermore, US produced less smear layer in a retro-end cavity compared to a slow-speed handpiece (67). Moreover, the refinement of cavity margins that were obtained with the ultrasonic tips may positively affect the delivery of materials into the cavities and enhance their seal (68,69,70), even if cavities prepared with erbium:YAG lasers have been shown to produce significantly lower microleakage than ultrasonic preparations (71).

Amongst the possibile iatrogenic errors, in a study by Walmsley et al. (72) the breakage of ultrasonic root-end preparation tips was investigated and attributed to the design of the tip. Increased angulation of retrotips increases the transverse oscillation and decreases the longitudinal oscillation, putting the greatest strain at the bend of the instrument. The authors suggested reducing the angulation and increasing the dimensions of the tip to resist breakage. This may be true, but a straighter design will restrict access and a thicker instrument prevents instrumentation of isthmuses. A controversial issue with sonic or ultrasonic root-end preparation is the formation of cracks or microfractures and its implications for healing success (73,74). Some studies indicated that this was a possible drawback (75,76,77,78,79). Other studies, however, disputed these findings and did not report a higher prevalence of microfractures (80,81,82,83,84,85,86,87,88,). Khabbaz et al. (53) found that cracks did not correlate directly with the surface area of the root-end surfaces but rather with the type of retrotip used. Preparation with smooth stainless steel ultrasonic tips produced fewer intradentin cracks than diamond-coated stainless steel ultrasonic tips and sonic diamond-coated tips. It is recommended that the ultrason-

ic unit be set at medium power and the cavities be prepared to a depth of 2.5-3 mm (89). This depth allows for a minimum thickness of material that can still provide an effective apical seal (90). The cavity walls should be parallel and follow the anatomic outline of the pulpal space (91). It has also been suggested that root-end cavities should be initiated with a diamond-coated retrotip, using its better cutting ability to provide the main cavity. This aids in the removal of root canal obturation materials and should be followed by a smooth retrotip to smooth and clean cavity walls. It must be underlined the fact that the influence of root-end microfractures on the periradicular healing process and apical leakage should be clarified. Apical resorption after healing (92) may eliminate the surface defects and contribute to the overall success of treatment. Also, such defects can be removed by finishing resected and retrofilled root-end surfaces (93). Several in vivo studies reported excellent success rates when the root-end preparation was performed using ultrasonic retrotips (94,95), thus demonstrating that modern surgical endodontic treatment using an operating microscope and ultrasonic tips significantly improves the outcome compared to the traditional techniques (96).
In order to improve retrograde filling techniques, it has been suggested the use of condenser tip ultrasonically activated for placement of retrograde filling materials, as the ultrasonic vibration is meant to improve the flow, settling and compaction of these materials to root-end dentinal walls. This should improve the delivery of materials into the cavity thus enhancing their seal. Ultrasonic tips can also be used to polish root end material and apical surfaces. Utilizing specific ultrasonic tips for refinement of the external radicular surface may be beneficial in the elimination of extraradicular bacteria, which may be responsible for infection (97).
More recently, Witherspoon and Ham (98) described the use of US to aid in the placement of MTA. The inherent irregularities and divergent nature of some open apices may predispose the material to marginal gaps at the dentin interface. It was demonstrated that, with the adjunct of US, a significantly better seal with MTA was achieved. Placement of MTA with ultrasonic vibration and an endodontic condenser improved the flow, settling, and compaction of MTA. Furthermore, the ultrasonically condensed MTA appeared denser radiographically, with fewer voids. These results contradicted those of Aminoshariae et al. (99), who concluded from an in vitro study that hand condensation was superior. The recommended placement method consists of selecting a condenser tip, then picking up and placing the MTA with the ultrasonic tip, followed by activating the tip and slowly moving the MTA material down using a 1- to 2-mm vertical packing motion. Direct ultrasonic energy will vibrate and generate a wavelike motion, which facilitates moving and adapting the cement to the canal walls. In a case of repairing a defect apical to the canal curvature, Ruddle (100) recommends incrementally placing MTA deep into a canal, then shepherding it around the curvature with a flexible trimmed gutta-percha cone utilized as a plugger. A precurved 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 ultrasonic 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. This technique was recommended initially for placing MTA in open and diverging apices, but it can also be used to put the material in root-end cavities, in perforations, and especially in perforations of the floor of the pulp chamber.

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