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 the 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-frequency devices were found to produce low 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 magnetostrictive, 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. Lee 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 desirable 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...
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by Richman (22) in 1957. However, it was not until Martin et al. (23,24,25) demonstrated the ability of ultrasonomically activated K-type files to cut dentin that this application found common use in the preparation of root canals before filling and 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).

The use of ultrasonics and sonic for root-end cavity preparations.

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 their utility 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 periapical 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 sonic for root-end cavity preparation.

One of the reasons 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 the 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). Amogst the possible iatrogenic errors, in a study by Walmley 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). Khazzaz 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-
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.

References

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