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Ultrasound in endodontics

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Key words *endodontics, root canal, ultrasound*

Ultrasound is sound energy with a frequency of more than 25 kHz; it can be useful during different stages of endodontic treatment. This article is an overview of the possible applications of ultrasound in endodontics.

Introduction

Ultrasound is sound energy with a frequency of more than 25 kHz. The application of ultrasound in dentistry had been limited mainly to periodontics, until Richman, in 1957, introduced this technique to endodontics. However, it took almost 20 years before a commercial system to instrument and clean root canals ultrasonically was developed in 1976 by Howard Martin, under the name 'endosonics'. The first devices were simply a modification of existing equipment: e.g. the Cavi-Endo was based on the Cavitron. The early instruments were sensitive to vibrations and during ultrasonic preparation of root canals the cutting motion of the file was completely uncontrolled, leading to possible damage in the apical part of the canal and an irregular canal wall[1]. In the last decade, there has been renewed interest in the application of ultrasound in endodontics. Further development of special equipment expanded the areas where it can be applied.

Ultrasound is now used in endodontics for:

- improving root canal access (e.g. removal of pulp stones)
- irrigating root canals
- removal of posts, broken instruments and other obstructions from the root canal
- distribution of sealer around the root canal walls
- condensing gutta-percha root fillings
- periapical surgery
- enhancing dentine permeability during bleaching.

Improving root canal access

With special tips, access to hidden and obliterated canal entrances can be improved (Fig 1). With these narrow tips, it is possible to obtain a good view of the base of the pulp chamber during canal location. These tips are generally used without water coolant. Specially designed tips for the preparation of the coronal third of the root canal are available, which can be used in combination with a surgical microscope for improved vision.

Fig 1 Ultrasonic tips for retreatment (Maillefer/Dentsply). Courtesy of Dr. F. van der Weijden.

Irrigation of root canals

Cleaning and shaping of the root canal system are important steps during root canal treatment. However, due to the complex anatomy, it is impossible to clean the root canal system completely with just files or reamers[2]. Even with newer, advanced instruments made of nickel-titanium (NiTi), it is still not possible to overcome this problem. Furthermore instrumentation produces a smear layer and dentine debris in the root canal, which has to be removed by irrigation[3]. Therefore irrigation remains an essential aspect of root canal treatment[4].

During passive ultrasonic irrigation (PUI), a small ultrasonically oscillating file or smooth wire (e.g. size 15, 20) is placed in the centre of the root canal, following canal shaping, to transmit the energy of the file as efficiently as possible to the irrigant. As a result, acoustic micro-streaming and/or cavitation can occur[5,6] (Fig 2). As the root canal has already been enlarged, the irrigant can flow through the canal and the file or wire can vibrate relatively freely. The file has a nodal and antinodal pattern, which also occurs on a pre-curved file, partly explaining the efficacy of PUI in curved canals[7] (Fig 3). PUI, with sodium hypochlorite (NaOCl) as irrigant, removes more dentine debris, planktonic bacteria and pulp tissue from the root canal than manual syringe irrigation[8].

NaOCl is very effective in combination with PUI, and more effective than water[9]. Ultrasonic activa-

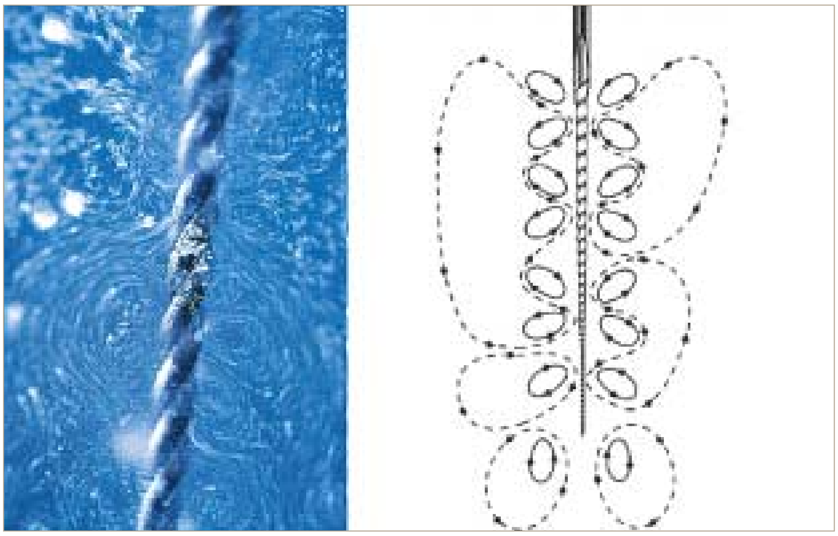

Fig 2 Acoustic streaming around a file in free water (left) and a schematic drawing (right), modified from Ahmad et al[5]. Courtesy of Dr. F. van der Weijden.

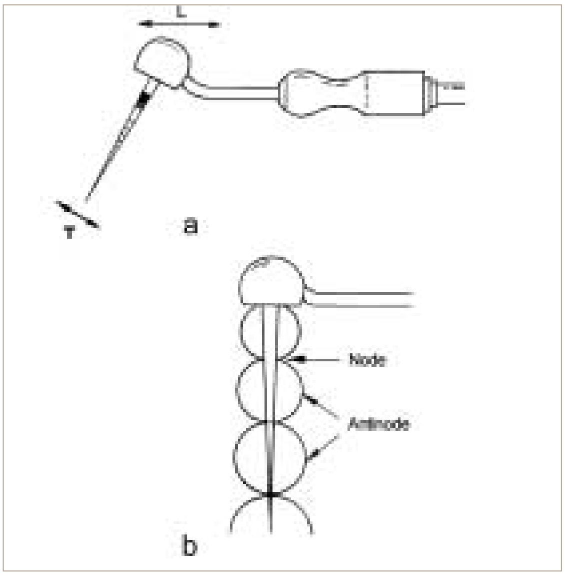

Fig 3 (a) Node- and anti-node pattern of a sonically activated file. The node is where the file is attached to the hand-piece, and the antinode is at the end of the file. The arrows show the direction of oscillation: L, longitudinally along the main axis; T, transversely along the file. (b) Node- and anti-node pattern of an ultrasonically activated file. Reproduced from Stock[1] with permission.

Fig 4 Smooth irrigation needle (Lime ESI from EMS). Courtesy of Dr. F. van der Weijden.

tion can also enhance the antibacterial-and organic-tissue-dissolving potential of NaOCl through temperature increment[10] and a more active streaming pattern[11]. Two flushing methods can be used during PUI, namely a continuous flush of irrigant from the ultrasonic hand-piece or an intermittent flush method using a syringe[10]. In the intermittent flush method, the irrigant is delivered into the root canal manually with a syringe, and refreshed after each ultrasonic activation. During ultrasonic activation, microorganisms, dentine debris or organic tissue can be detached from the root canal wall and will be absorbed or dissolved in the irrigant[12,13]. Hereafter, the root canal is flushed with 2 ml of fresh irrigant to remove remnants from the root canal. When the irrigation time was set at 1 minute, and the NaOCl refreshed after each ultrasonic activation of 20 seconds, the intermittent flush technique appeared to be better at removing dentine debris from the root canal than the continuous flush of irrigant (unpublished results). When the irrigation time was set at 3 minutes, the two methods were equally effective[9].

The diameter of the root canal has an influence on the effectiveness of dentine debris removal during PUI. For a root canal of size 20, taper 0.10, the dentine debris can be removed more easily than from a root canal size 20, taper 0.08 or 0.06[14]. A non-cutting or smooth wire is just as effective as a cutting file and has the advantage of not cutting the root canal wall and thus avoiding perforation of the apical part of the root canal[15] (Fig 4).

It is not clear what concentration of NaOCl is the most effective in combination with PUI. Some researchers show a higher efficacy when the concentration is higher[16], but more research is needed.

A much-repeated criticism against the use of a NaOCl solution is that the reservoir of an ultrasonic machine will accumulate corrosive products and sodium salts would clog-up and even corrode the tubings transporting the fluid through the machine. It is therefore important that after the use of NaOCl, the machine, the tubings and the hand-piece are flushed with demineralised water. With careful maintenance and by using NaOCl at concentrations no higher than 5%, most of the currently available equipment will function trouble free.

Ultrasonic versus sonic irrigation

Sonic instruments use a lower frequency (1,000–6,000 Hz) than ultrasonic instruments (25,000 Hz). Both types of instruments have a similar construction: the file is connected at an angle of 60–90 degrees to the long axis of the (ultra)sonic hand-piece. The vibration pattern of the ultrasonic files, however, is different from that of sonic instruments. Ultrasonic files have numerous nodes and antinodes across the length of the instrument, whereas the sonically operated ones have a single node near the attachment of the file and one antinode at the tip of the file (Fig 3). Sonic instruments produce an elliptic, lateral movement, similar to that of the ultrasonic files. When the movement of the sonic file is hampered in such a way that the lateral movement disappears, the remaining vibration will be in a longitudinal direction. The longitudinal movement could theoretically have a favourable effect on irrigation; however, this has not been confirmed by research. Ultrasonic irrigation is more efficient than sonic irrigation, probably because of the higher frequency, resulting in more effective acoustic streaming[8].

Clinical advice on ultrasonic irrigation:

- use NaOCl as the irrigant
- continuous flush method: 3 minutes of irrigation per canal, the canal flushing can be reduced to 15 ml/min
- intermittent flush method: 1 minute of irrigation per canal with three ultrasonic activation sequences of 20 seconds each and refreshed with 2 ml of NaOCl three times
- use, if possible, a thin (size 15 or 20) non-cutting file or wire
- when a non-cutting file or wire is used, the instrument can be inserted 1 mm short of working length, if a non-cutting file or wire is not available, it is advised to insert the file 3 mm short of working length (not further than the curve in the root canal) to prevent apical perforation
- in a curved canal, pre-bending of the instrument is advised.

Removal of posts, broken files and other obstructions

Ultrasound can prove useful for the removal of all kinds of instruments from root canals. When removing a post (Figs 5 to 8), a thicker tip (Fig 9, second from right) is used to break the cement lute between the post and root canal, to facilitate removal. The application of ultrasonic vibration for 10 minutes can reduce the retention provided by zinc phosphate and glass ionomer cements by 39% and 33% respectively[17]. To facilitate manipulation of the post, initial removal of cement from the coronal part of the root canal can be performed with long and thin preparation tips (Fig 9). The post can then be extracted or, in the case of a screw post, unscrewed from the root canal. The threads visible on the radiograph may indicate in which direction the post can be unscrewed. In the case of a metal post and core, the coronal part is reduced to the same size as the post, to facilitate removal. Unfortunately, ultrasound is ineffective if the post is inserted with resin-based cement[17].

Depending on the need for direct vision, water-coolant can be used. Dominici et al[18] found that the application of ultrasound to the post for longer than 15 seconds without water-coolant generates a high temperature on the root surface. Budd et al[19] concluded that without water-coolant the temperature rise can exceed the accepted limit of 10°C, which may injure the periodontal ligament. A minimal flow of water-coolant of 30 ml/min is advised[18,19]. Other researchers have reported a more limited temperature rise[20]. Much depends on the condition of the tooth structure, the power setting of the ultrasonic device and the efficacy of the water-coolant. Therefore it is difficult to give clear-cut advice. It is safest to use water-coolant abundantly; if not, regular periods of cooling should be allowed during the treatment. Keep in mind that heat damage of the periodontal ligament can occur with the use of ultrasound without water-coolant. Garrido et al[21] have a different opinion on using water-coolant. In their study they commented that posts cemented with zinc phosphate cement are loosened more easily when water-coolant is used, whereas posts cemented with resin are loosened more easily without the use of water-coolant. Their explanation is that water helps to dissolve the zinc phosphate cement and that heat along the post, generated during ultrasonic stimulation without water-coolant, deteriorates the resin because of its high thermal expansion value.

There are many ultrasonic tips available that are designed specifically for the removal of obstacles such as hardened cement, broken files and silver points from the root canal (Fig 10). A surgical microscope is required, since direct vision of the root

Fig 5 Post in the root canal. Courtesy of Dr. M. Elst.

Fig 6 Placement of the tip against the post. Courtesy of Dr. M. Elst.

Fig 7 Post loose after ultrasonic stimulation. Courtesy of Dr. M. Elst.

Fig 8 Post removed from the root canal. Courtesy of Dr. M. Elst.

Fig 9 Ultrasonic tips for retreatment (Satelec). Courtesy of Dr. F. van der Weijden.

Fig 10 Ultrasonic tips for retrieval of broken instruments (Maillefer/Dentsply). Courtesy of Dr. F. van der Weijden.

canal is important when using these instruments. Ultrasonic vibrations can easily loosen hard steel instruments due to the stiffness of the metal. NiTi instruments are more flexible, making them more difficult to remove by ultrasound. Furthermore, NiTi instruments can easily disintegrate when they come into contact with an ultrasonic tip. Ultrasonic tips are easily damaged and should not be used with higher power settings; therefore, it is important to use the power settings advised by the manufacturer. For the novice, it is advisable to practise initially on extracted teeth.

Depending on where they are lodged, the removal of broken instruments is time-consuming, especially when the instrument is located in the apical third of a curved root canal. It is important to realise that although broken instruments can be removed, unfortunately it is usually at the expense of having to remove much dentine. The weakened tooth may be more prone to fracture[22]. Therefore removal of the broken instruments from the apical third of a root canal should be considered carefully[23]. In addition, depending on circumstances, the presence of a retained instrument has a relatively minor impact on the outcome of endodontic treatment. When teeth with and without fractured instruments were compared, the survival rate of teeth with pre-treatment periapical radiolucency was 87% versus 93%, whereas with vital teeth the results were 92% versus 94.5%[24].

Distribution of sealer in the root canal

A complete and uniform coating of the root canal wall with cement/sealer is important, as it is the luting agent between the gutta-percha root filling and the root canal wall. However, a complete and uniform coating is often difficult to accomplish. An ultrasonic oscillating file may be one solution. Compared with the placement of the sealer with a master gutta-percha cone, an ultrasonically activated file resulted in more effective and thorough sealer placement[25].

Condensing of gutta-percha

Ultrasonically activated spreaders are a useful aid for warming gutta-percha during lateral and warm vertical condensation techniques. When used, the ultrasonic vibrations and the heat generated led to a similar or higher density of condensed gutta-percha compared with using a warm spreader[26]. The ultrasonically activated spreader is used the same way as the warm spreader. One advantage of an ultrasonic-assisted obturation is that gutta-percha does not stick to the spreader during the condensation procedure.

Periapical surgery

The field of vision is limited during periapical surgery and this makes instrumentation difficult. Conventional hand-pieces and drills are relatively large compared with ultrasonic tips so they often hamper visual access to the work area. When the surgical microscope is used, vision is improved but specially designed instruments are required. Ultrasonic tips are smaller, which enables them to be used with precision when combined with the surgical microscope. The ultrasonic tips may have different coatings (e.g. zirconium, diamond), making them either more or less aggressive. Furthermore, tips at different angles facilitate manipulation and allow the operator to work within the periapex (Fig 11). Therefore, small apical preparations can be made parallel to the longitudinal axis of the root. With these tips, accurate preparation of the isthmus running between canals can also be achieved.

Fig 11 Ultrasonic tips for retrograde preparation (Maillefer/Dentsply). Courtesy of Dr. F. van der Weijden.

Enhancement of dentine permeability during non-vital bleaching

Internal bleaching to lighten teeth is a conservative option that provides good results at relatively low cost. The action of an internal bleaching agent is dependent on its ability to penetrate into dentinal tubules and modifying, by means of an oxidation-reduction reaction, the pigments that caused the chromatic alteration of the dentine substrate. Ultrasonic activation of an irrigant, 1% NaOCl or 17% EDTA, in the pulp chamber can significantly increase dentine permeability[27]. In a previous study[27], the irrigant was placed in the pulp chamber and then ultrasonically activated for 15 seconds; this procedure was repeated three times. An ultrasonic tip (e.g. one to remove calculus) was used without touching the cavity walls. After this procedure the bleaching agent can then be applied.

Micro-cracks after ultrasound

There are contradictory reports regarding the occurrence of micro-cracks in the dentine after the use of ultrasonic tips during periapical surgery or for the removal of posts and/or instruments. The power setting and tip design seems to have an influence on the occurrence of micro-cracks[28,29]. Therefore it is recommended to use the power setting advised by the manufacturer and to choose the type of tip carefully.

Closing remarks

It is now accepted that an ultrasonic device is indispensable in everyday endodontic practice. It is a valuable tool not only for cleaning the root canal, but also for non-surgical re-treatment and in periapical surgery.

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