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REVIEW

Ultrasound in periodontics

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ABSTRACT:

Ultrasonic instruments were introduced in periodontal therapy in 1955. Approximately 50 years later, their effects on the teeth and periodontium have become much clearer. Currently, ultrasonic instruments are frequently used in daily practice. Most of these instruments work according to the magnetostrictive or reciprocal piezo-electric principle. Though, they are mainly used for routine prophylaxis, there are various other functions of these in the field of Periodontics. This article explains the principle and mechanism of action of ultrasonic instruments with their various applications in Periodontics.

Key words: ***Acoustic micro-streaming; Cavitation; Ultrasound probe; Ultrasonic scalers; Ultrasound***

INTRODUCTION:

Ultrasound means sound that is not audible to the human ear with the frequencies above 20,000 vibrations per second. In daily life, an enormous number of sound frequencies are used, for example, for car alarms, burglar alarms, and remote controls. In medical profession they are used for scanning the human body, for instance during pregnancy, to detect any calculi etc. They are also used in the field of dentistry for various purposes for example, for professional debridement, root canal cleaning, during implant and osseous surgery etc. [1]

In 1880, Pierre and Jacques Curie discovered that crystals of many substances subjected to mechanical strains, develop electrical charges on their surface.[2] Soon as a natural corollary it was observed that when crystals of proper size or metals of proper configuration and content were subjected to an alternating electric field, they vibrated with an oscillation of specific frequency and amplitude. In 1927, Wood and Loomis published their work, "physical and biologic effects of high frequency sound waves of great intensity" .[3] Since that time; ultrasound has mostly been used for the treatment of neuromuscular and musculoskeletal ailments.

In dentistry, ultrasonic instruments have been in use since the 1950's. It was introduced by the industry as an alternative to the cord-driven, slow handpiece. In 1952, Balamuth acquired an important patent for the further development and possible uses of ultrasonics.[1] Matthew C. Catuna reported its first use in dentistry in 1953.[4] In 1955, Zinner introduced ultrasonic instruments as an aid in periodontal therapy.[5] In 1958, The manufacturer, Cavitron introduced the 'prophylaxis unit' and the brand name developed into a concept.

What is the principle behind the use of ultrasonics?

Ultrasonics is a branch of acoustics concerned with sound vibrations in frequency ranges above audible level.[6] Ultrasound imaging, or ultrasound scanning or sonography, is a method of obtaining images from inside the human body through the use

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of high frequency sound images. As the ultrasonic beam passes through or interacts with tissues of different acoustic impedence, it is attenuated by a combination of absorption, reflection, refraction and diffusion. The sound waves echoes are recorded and displayed as a real-time, visual image.[7]

Magnetostrictive devices undergo changes in their physical dimension when a magnetic field is applied to them achieved by placing a ferromagnetic stack within a solenoid through which a direct current is passed.[8] Magnetostrictive instruments operate between 18,000 and 25,000 cps/ Hertz. When an electric current is supplied to a wire coil in the handpiece, a magnetic field is created around the stack or rod transducer causing it to constrict. An alternating current then produces an alternating magnetic field that causes the tip to vibrate.[9, 10]

Piezoelectric systems are based on the fact that certain crystalline structures such as quartz are subjected to a shape change when placed within an electric field. [10] If an alternating voltage at an ultrasonic frequency is applied across a piezoelectric crystal, it will result in an oscillating shape change of the crystal at the frequency applied. This is then passed onto the working tip.[7] Piezoelectric unit operates in the 25,000-50,000 cps range and is activated by dimensional changes in crystals housed within the handpiece as electricity is passed over the surface of crystals. The resultant vibration produces tip movement that is primarily linear in direction, and generally allows only two sides of the time to be active at any time.[10]

Mechanism of actions:

Cavitation: A unique characteristic of the ultrasonic scalers is the cavitation effect and the micro-streaming that occurs in the cooling liquid. It encompasses a continuous spectrum of bubble activity in a liquid medium. It ranges from gentle linear pulsation of gas filled bodies in low amplitude sound fields to violent and destructive behavior of vapors filled cavities in high amplitude sound fields.[11, 12] The energy generated within these bubbles may result in shock waves or hydrodynamic shear fields which may disrupt biological tissues, and the production of these large disruptive forces causes removal of plaque and calculus during ultrasonic scaling.[13]

Acoustic microstreaming:

Acoustic microstreaming is a phenomenon that exists in a fluid environment such as water and is characterized by the production of large shear forces.[14] This depends on displacement amplitude, tip orientation and presence of water medium. In the liquid, a vortex-like situation is created which is generated by the powerful ultrasonic vibrations and the small space in which the tip can move. This has no bactericidal effect, but it helps to remove the plaque from the tooth's surface and to flush out the pocket. Both effects contribute to a better cleaning of a tooth surface covered with plaque.[1]

Chemical effects (sonochemicals):

The agitation of ultrasonic vibrations releases ions contained in the propagating medium at great speed and intensity.[2] When ultrasonic cavitation acts on aqueous solutions, free radicals are formed which are of particular biologic importance considering their chemical activities.[15]

Radiation forces:

Any medium or object in the path of an ultrasonic beam is subjected to a radiation force, which tends to push the material in the direction of the propagating wave.[8, 16] Though this force is small, it will be enhanced in a standing wave field and act over a short distance to drive the dense particles to regions of maximum acoustic pressure amplitude. Radiation forces may also enhance cavitational activity within a standing wave field.[8, 12]

Thermal effects:

As a wave of ultrasound passes through tissues its energy is reduced and is dissipated as heat, leading to an elevation of tissue temperature. The effects of this on the tissues will be an alteration in the blood flow in the region due to reflex relaxation of the arterioles. Though slight change in the temperature cause limited changes, excessive higher temperature inevitably leads to tissue damage.[2, 8]

Applications of ultrasound in Periodontics:

1. Diagnosis: Ultrasonography probe provides a mapping system for non-invasively making and recording differential measurements of depth of patient's periodontal ligaments relative to a fixed point such as cemento-enamel junction. This probe uses ultrasound to detect top of ligaments

as well as cement-enamel junction.[17] This probe captures a series of measurements painlessly across entire subgingival area.

2. Periodontal assessment: An ultrasonic scanner that works at a frequency of 29 MHz has been used to assess the dimensional relationship between hard and soft structures.[18,19] This device was also used to evaluate gingival thickness before and after mucogingival therapy for root coverage and to measure masticatory mucosa.[19]
3. Calculus detection: There are varieties of subgingival calculus detection systems available. Meissner et al(2005) showed that dental surfaces may be discriminated by the analysis of tip oscillations of an ultrasonic instrument, which possesses computerized calculus detection features.[20]
4. Removal of plaque or the biofilm: The cavitation and acoustic micro-streaming effects of ultrasound helps in removing the bacterial plaque.[17] However, research has shown that there is no difference in the effectiveness of plaque removal using hand or mechanical instruments.[1] It is also used for scaling in cases of necrotizing ulcerative lesions as it has a lavage action.
5. Removal of calculus: Cavitation liberates energy that can remove the deposits. However, to be effective on the calculus, a direct contact between the vibrating tip and the calculus is necessary.[21]
6. Removal of endotoxin and root detoxification: The endotoxins are cell fragments and toxic products of bacteria and can be found in the radicular cementum or dentine, saliva and crevicular fluid. Endotoxins are cytotoxic and can affect the host immune system. It is suggested that, for treatment to be effective, the contaminated dentine and diseased cementum have to be removed.[1] Recent studies have shown that endotoxin is superficially associated with the cementum and calculus. They can be easily removed by rinsing, brushing, lightly scaling, or polishing the root surface.[22] Heat automatically generated from magnetostrictive units may assist in endotoxin removal or detoxification, as a result, areas of the tooth where the tip does not touch may inadvertently be detoxified as well.[17]
7. Curettage: Ultrasound is effective for debriding the epithelial lining of periodontal pockets. For this purpose, a Morse scaler shaped or rod shaped ultrasonic instruments are used. [23] Ultrasonic instruments are found to be as effective as manual curettage.[24]
8. Ultrasonic cleaner: The cavitation effect is effective in displacing the saturated layer of contaminant, allowing fresh cleaning solvent to come in contact with the unsaturated surface to attack and dissolve the remaining contaminant. It enhances the effect of chemical reactions mainly because of the high energy created by the high temperatures and pressure emitted by millions of individual cavitation bubble implosions.[25] So they are recommended as a part of procedures carried out to prevent cross-infections.
9. Osseous surgery: Ultrasonic bone cutting surgery has been recently introduced as an alternative to the conventional techniques. Piezosurgery® is a new and innovative method that uses piezoelectric ultrasonic vibrations to perform precise and safe osteotomies. Piezoelectric surgery uses a specifically engineered surgical instrument characterized by a surgical power that is 3-times higher than normal ultrasonic instruments. The unique feature of this technique is that the cutting action occurs when tool is employed on the mineralized tissue, but stops when soft tissue is encountered. This technique can be used for pre-prosthetic surgery, sinus elevation procedure, implant placement as well as alveolar crest expansion.[25]

Effects of ultrasonic scalers on the tooth and surrounding tissues: [1]

Effects on the enamel: On intact enamel, these cause a reduction in hardness though it has a little clinical consequence. Cemento-enamel junction is most sensitive to injury.

Effects on the root surface: Research has shown that curettes produce smoother root surfaces than ultrasonic instruments. However, ultrasonic instruments remove less cementum and expose the dentine only as isolated islands. Surface changes are also appears to be directly related to the amount of pressure used, duration of instrumentation, number of instrument strokes and the instrument tip angle.

Effects on the pulpal tissue: If ultrasonic instruments are used with the water coolant, the temperature of pulp chamber will not increase more than 8˚c. Otherwise, it can rise as much as 35˚c resulting in irreversible pulpitis. Research has shown that there was an increase in the number of blood vessels,, lymphatic vessels and vacuolation of the cells. Edema occurred in certain situations. There was formation of tertiary dentine in some cases. Therefore, sufficient cooling is essential to minimize the damage to the pulp tissue.

Effects on periodontal tissues: No negative effects have been reported as a result of ultrasonic instrumentation on the periodontal tissues. However, it has been shown that ultrasonic instrumentation leads to faster re-epithelialization and improved visibility because of the water spray. Thus, an ultrasonic scaler can also be used during flap surgery.

Conclusion:

Ultrasound is not new to the field of dentistry. Though they are used since many years for the routine prophylaxis and for irrigation during root canal therapy, their many possible applications are not yet been completely utilized. Their application in diagnosis and treatment of periodontal diseases show promising results. However, long term studies are required to put them into practical applications. It is clear that ultrasonic instruments are here to stay and deserve to play a significant role in periodontal therapy.

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