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Properties, effects and clinical applications of ultrasound in periodontics: an overview

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Ultrasound is used in both the diagnosis and treatment of various diseases of the human body. Ultrasonography uses sound waves that reflect as echoes to produce images of structures within the body. It also has several applications in dentistry and in periodontics it is used to treat and maintain periodontal health. Through the cavitational effect and acoustic micro-streaming produced by oscillatory movements of ultrasonic inserts, mechanical debridement can be completed in a short time. The recent introduction of micro-ultrasonics and linear oscillating devices has improved mechanical debridement resulting in minimally invasive instrumentation. Ultrasonography plays a significant role in osteotomies and sinus lift procedures by its piezoelectric ultrasonic vibrations. Periodontal ultrasonography provides a non-invasive diagnostic method for measuring pocket depth and the assessment of periodontal health. In addition, low intensity pulsed ultrasound appears to be effective in periodontal healing and demonstrates the potential for periodontal regeneration.

■ Introduction

Sound frequencies above those of audible limits (30 Hz to 20 KHz) are known as ultrasound[1]. Since 1927, ultrasound has been used in the treatment of neuromuscular and musculoskeletal conditions[2]. However, the first industrial use of the magnetostrictive cutting device was to prepare cavities in synthetic sapphires to receive gold inserts[3]. Catuna[4] was among the first to use this cutting method in dentistry. However, such instruments use an abrasive slurry for cavity preparation[5], hence with the advent of high-speed drills, this technology was repositioned for power scaling, which revolutionised mechanical debridement[6]. Since its introduction in periodontics by Zinner[7] the single, bulky universal tip has now been replaced by a variety of site-specific, slimmer tips[8,9]. Oscillatory movements of inserts resulting in cavitation and acoustic microstreaming[10,11], as well as sonochemicals[12] are used for mechanical debridement. Johnson and Wilson[13] reported more rapid and adequate removal of calculus using ultrasonic tips while applying light pressure, resulting in little haemorrhage and a favourable patient reaction to the instrumentation, especially in acute necrotising ulcerative gingivitis (ANUG)[14]. Tunkel et al[15] found ultrasonic subgingival debridement requires less time, and Leon and Vogel[16] have shown that power-driven instrumentation is superior to hand instrumentation in the treatment of class II and class III furcations.

Ultrasound as a source of waves offers real-time imaging, and is a reliable diagnostic technique for differentiating periapical lesions based on echo-texture of their content and the presence of vascularity[17-19]. It has emerged as a non-invasive periodontal assessment tool that yields real-time information regarding clinical features such as pocket depth, attachment level, tissue thickness, histological change, calculus and bone morphology, as well as evaluation of tooth structure for fracture cracks[12]. Spranger[20] was first to use ultrasonography in periodontology. Later on, other researchers[21,22] attempted to image the crest of alveolar bone, whereas Eger et al[23] assessed the measurement of gingival thickness using an ultrasonic device with a 5 MHz transducer. Other investigators have shown that an ultrasonic device measures echoes from the hard tissue of the tooth surface, and periodontal attachment level can be inferred from these echoes[24,25].

■ Basic principles and properties

Ultrasonics is a branch of acoustics pertaining to sound vibrations in frequency ranges above an audible level[26-28]. Ultrasound imaging (or ultrasound scanning or sonography) is a method of obtaining images from inside the human body through the use of high frequency sound waves[26,28]. As an ultrasonic beam passes through or interacts with tissues of different acoustic impedance, it is attenuated by a combination of absorption, reflection, refraction, and diffusion[28]. The sound waves' echoes are recorded and displayed as a real-time, visual image[26,28]. Ultrasound uses the transmission and reflection of acoustic energy[26,27]. A pulse is propagated and its reflection is received by the transducer[26], a device that can convert sonic energy into electrical energy and vice versa[28].

Ultrasound waves do not pass through air[29], they have difficulty penetrating in bone and therefore can only be used to see the outer surface of bony structures and not what lies within[26]. Unlike x-rays, where the image is produced by transmitted radiation, the reflected portion of the beam produces the image in ultrasonography[28]. Ultrasound imaging is based on the same principles as those involved in the sonar used by bats, ships at sea and anglers with fish detectors. As the sound passes through the body, echoes are produced that can be used to identify how far away an object is, how large it is, its shape and its consistency (fluid, solid or mixed)[26]. Ultrasonography with no ionising radiation[26,29] is a non-invasive and a relatively inexpensive technique for imaging superficial tissues in real time[26,27,29]. Ultrasound waves have a nearly constant velocity of ~1500 m/s in water and this is similar to the velocity in soft tissue[26]. As a wave of ultrasound passes through tissues its energy is reduced and is dissipated as heat, leading to an elevation in the tissue temperature. The effects of this on the tissues are dependent upon the amount of temperature rise, the time over which it is maintained and the thermal sensitivity of the tissue. In most tissues the normal physiological response will be an alteration in the blood flow in the region due to reflex relaxation of the arterioles. The resultant increase in blood flow through the area brings about a limited increase in temperature, of less than 1°C, resulting only in a minor overall increase in local metabolic rate. However, an excessive high temperature inevitably leads to tissue damage[1,30].

■ Ultrasound as an effector for oscillatory movements of an insert

For clinical purposes ultrasound is generated by transducers, which convert electrical energy into ultrasonic waves. This is usually achieved by magnetostriction or piezoelectricity. Magnetostrictive devices undergo changes in their physical dimension when a magnetic field is applied to them. This is usually achieved by placing a ferromagnetic stack within a solenoid through which a direct current is passed. This produces stresses leading to a change in shape of the material. When an alternating current is passed through the solenoid, the stack will then change its shape at twice the frequency of the applied magnetic field. Magnetostriction with a laminated ferromagnetic stack is commonly used in the design of ultrasonic scaling instruments, as it is a robust and easily manufactured system[31]. Magnetostrictive instruments operate between 18,000 and 45,000 cycles per second (also known as Hertz), using flat metal strips in a stack or a metal rod attached to a scaling tip[32]. When an electrical 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. The tip movement of magnetostrictive units is either elliptical or circular, depending on the type of unit, shape and length of the tip. Magnetostrictive tip movement allows for activation of all surfaces of the tip simultaneously, providing the option to use the side, back or front of the tip for adaptation to the tooth surface[31,32].

The piezoelectric system is based on the fact that certain crystalline structures such as quartz will be subject to a change in shape when placed within an electrical field[31]. 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. Currently, the most widely used piezoelectric material is lead zirconate titanate (PZT)[28]. Piezoelectric generators are more efficient at frequencies in the MHz rather than the kHz range, although some have been developed for use in dentistry. However, the crystalline structure has poor shock resistance and such instruments are more fragile than their magnetostrictive counterparts. The piezoelectric unit operates in the 25 kHz to 50 kHz range and is activated by dimensional changes in crystals housed within the hand piece, as electricity is passed over the surface of the crystals[31]. The resultant vibration produces tip movement that is primarily linear in direction, and generally allows only 2 sides of the tip to be active at any time[31,32]. Most current ultrasonic technology has advanced to include computer chips for regulating sustained power to the tip[33].

■ Cavitation

Cavitational activity in relation to ultrasound 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 (stable cavitation) to violent and destructive behaviour of vapour-filled cavities (transient cavitation) in high amplitude sound fields[1,34-36]. The energy generated within these bubbles may result in shock waves or hydrodynamic shear fields, which may disrupt biological tissues, and it is the production of these large disruptive forces that are of use in the removal of plaque and calculus during ultrasonic scaling[1,37-39]. The occurrence of cavitation requires the presence of gaseous bodies or bubbles in the medium, which have been termed cavitation nuclei[1,36]. In the presence of an ultrasound field, a bubble will grow and will undergo breathing pulsation in response to the applied pressure oscillations set up by the field[1,34]. As the bubble pulsates, transverse waves are set up on its surface, which become distorted and unstable as the ultrasonic amplitude increases. Micro-bubbles occur around the original bubble and act as new sites for cavitational activity. Formation of micro-bubbles is associated with the onset of transient cavitation, where the bubbles show a 'collapse' phenomenon with the temperature of the gas in the bubble reaching thousands of degrees Celsius and several thousand atmospheres of pressure[1,30,40]. The demanding effects of transient cavitation are due to the shock waves radiated during the final stages of bubble collapse or high velocity liquid jets from non-linear motions of the bubble's face. At low ultrasound frequencies of the order of 20 to 40 kHz, growths of micronuclei and subsequent transient cavitation readily occur[1]. Cavitation occurring in human blood can result in a thrombogenic effect and can cause lysis of erythrocytes and platelets[38]. This may explain the reduction in haemorrhage when using ultrasonic surgical instruments and dental scalers[1,10].

■ Acoustic microstreaming

The rapid cyclical volume pulsation of a gas bubble results in the formation of a complex steady state streaming pattern within the liquid close to the bubble surface[1]. Acoustic microstreaming is a phenomenon that exists in a fluid environment such as water and is characterized by the production of large shear forces[41]. It can be demonstrated around an oscillating solid cylinder within a fluid or a stationary cylinder within an oscillating fluid[1]. Acoustic microstreaming occurs around ultrasonic scalers and depends on displacement amplitude, tip orientation and presence of water medium. It increases with increasing displacement amplitude, although it depends upon tip geometry, tip orientation and distance from the oscillating tip[41].The dimensions of the patterns demonstrate a rapid rate of change of streaming velocity with distance[34]. Therefore, although the velocities themselves are only of the order of a few centimetres per second[36], the gradients due to the rate of change of velocity will produce large hydrodynamic shear stresses close to the oscillating object (i.e. probe or gas bubble), which may disrupt or damage biological cells or tissues[1]. Acoustic microstreaming may play a role in the disruption of sub-gingival biofilms associated with periodontal diseases[41]. Acoustic microstreaming may also result in the disruption of blood flow and cells such as human platelets exposed to probes operating at 20 kHz (the level used in dentistry). At higher amplitudes gelatinous aggregates of platelets can form an embolism, resulting in possible blood vessel occlusion[1,42].

■ Sonochemicals

In addition to mechanical cavitational effects, ultrasonic treatment for tooth descaling also results in the formation of sonochemical products[12]. The agitation of ultrasonic vibrations releases ions contained in the propagating medium at great speed and intensity[30]. When ultrasonic cavitation (similar to ionising radiation) acts on aqueous solutions of certain compounds, including dissolved air oxygen and nitrogen, free radicals produced due to water molecule decomposition react with these compounds or gases. Both free radicals and other compounds formed inside the solution (hydrogen peroxide or nitrous and nitric acids) are of particular biological importance considering their chemical activity[12]. The free radicals produced are related to both displacement amplitude and the geometry of the scaling tip[43].

■ Clinical applications

■ Scaling and root planing

Energy liberated during cavitation alone is not sufficient to remove the calculus, so direct contact with the vibrating tip is necessary[44] and the mechanical energy produced by the vibrating tip (chipping action) along with cavitation (flushing action) is responsible for the removal of deposits[13,32,45,46]. In addition, microstreaming or acoustic mainstreaming generated by ultrasound in the presence of a fluid environment[8,31] and caviational activity[47,48] has an adverse effect on bacteria within dental plaque[49], which disrupts bacterial cell walls and the subgingival microbial environment[48], and thus is effective in removing bacterial plaque[8,31]. Ultreo® (Ultreo Inc, Redmond, WA, USA) is a revolutionary power toothbrush that combines ultrasound waveguide technology with precisely tuned sonic bristle action. Clinical studies have shown that Ultreo can remove up to 95 percent of plaque from hard-to-reach areas in the first minute of brushing[49]. Currently, it is understood that endotoxin (or lipopolysaccharide, LPS) is a surface substance that is superficially associated with the cementum and calculus and is easily removed by washing, brushing, lightly scaling or polishing the contaminated root surface[31,50-55]. 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, also be detoxified[8].

■ Precautions during scaling and root planing

As with any dental procedures, universal precautions during ultrasonic instrumentation consisting of eyewear and/or face shield, mask and gloves must be worn. At the beginning of the day the handpiece should be held over a sink or drain, the power set to low, the foot control activated and the water line of unit flushed at maximum water-flow for at least 2 minutes to clear stagnant water and reduce water films in the tubing[8]. All the inserts are autoclavable and should be sterilised before every use. The patient should also rinse with an approved antimicrobial. High vacuum suction should also be used to help minimise aerosols. An aerosol reduction device (ARD) that is attached to the ultrasonic handpiece has been shown to reduce the contamination cloud by placing suction in close proximity to the ultrasonic tip[56]. Harrel et al[57] showed that a high volume evacuator attachment to an ultrasonic handpiece significantly reduced the detectable aerosols splatter produced during ultrasonic scaling by 93%. Veksler et al[58] reported that a 30 second rinse with an essential oil mouth rinse before instrumentation reduces bacterial count in the aerosol by 92.1%, salivary bacterial level by about 50% for up to 40 minutes and 97% reduction for up to 60 minutes following two 30 second rinses with 0.12% chlorhexidine. Aerosols can be suspended in air for up to 30 minutes after using power driven scalers[59], so infection control is to be maintained even after the procedure is finished. A light pen grasp, and fulcrum (intra- or extra-oral) should be used. The lightest amount of lateral pressure possible while still maintaining control of the instrument and proper adaptation of tip is necessary for calculus removal[8]. Increasing the pressure decreases the mechanical vibrations, the chipping action and ultimately the effectiveness. To prevent root damage in scaling and root planing (SRP) the magnetostrictive ultrasonic scaler should be used with a lateral force of 0.5 N, at a low or medium power setting and tip angulation close to zero degrees with the tooth[60] . Increasing the power also increases aerosol formation, which results in reduced water cooling and cavitational effect and can increase patient sensitivity. Chapple et al[61] showed that using the half power setting was as effective as using the ultrasonic scaler at full power. Ultrasonic tips are now shaped more like probes. The tip should be inserted vertically, parallel to the long axis of tooth, sliding it into proximal surfaces by keeping the tip adapted to the tooth like a probe. To ensure patient comfort, the tip should be kept moving at all times when in contact with the tooth[8]. Direct vision is preferred when using ultrasonics, as indirect vision is compromised by irrigant mist. Ultrasonic tips cannot be used for prolonged periods, and as tips wear, the scaling efficiency decreases. One millimetre of tip wear results in approximately 25% loss of efficiency, and 2 mm of wear results in approximately a 50% loss of efficiency, and at this point the tip should be replaced[8,62] . Clinicians who retain their inserts for years may find their instrument tips become reduced in length through wear, potentially leading to a change in the performance of the scaling system[63]. The instrument should be kept away from bone to avoid the possibility of necrosis and sequestration[64].

Calculus detection

There are a variety of subgingival calculus detection systems in the market including DetecTar® (Ultradent Products, South Jordan, Utah, USA), Keylaser II® (KaVo Dental, Biberach, Germany) and Dental Endoscope[65] (Dental View, Irvine, CA, USA) as well as systems for *in vitro* studies[66,67]. Meissner et al[68] developed an ultrasound-based device for in-office use, which is automatically able to detect subgingival calculus. It was shown that dental surfaces may be discriminated by the analysis of tip oscillations of an ultrasonic instrument, which possesses computerised calculus detection (CCD) features, and thus may help to judge other systems *in vivo*.

Micro-ultrasonics

Kwan[69] and Hawkins[9] coined the term 'micro-ultrasonics' in the early 90s as a generic term that identifies the refined use of powered instrumentation for high-powered, supragingival, gross debridement. Micro-ultrasonics are innovative, power-driven (magnetostrictive or piezoelectric) scaler products featuring thinner tips and varied shapes. These are small, approximately the size of a periodontal probe, and can used for supra- and subgingival treatment at low to high power, with little to no water spray and little or no adjunctive use of hand instrumentation[8,9,69]. Tips of micro-ultransonic instruments measure about 0.2 to 0.6 mm in diameter, and are powered to move up to ultrasonic speeds (25 kHz to more than 40 kHz); with active working sides on all surfaces of the vibrating instrument, they provide ultrasonically activated lavage in working field[69]. Ultrasonic motors need no deceleration mechanism because they have high torque output in low rotation speed[70]. Micro-ultrasonic instruments are less likely to over-instrument roots and endoscopic debridement can be accompanied in a non-surgical, minimally invasive way by combining a simple array of micro-ultrasonic instruments with a periodontal endoscope[69].

Vector™ ultrasonic system

The linear oscillating device, namely the Vector™-system (Duerr Dental, Bietigheim-Bissingen, Germany), is a new generation non-aggressive ultrasonic system[71], which is comparable to the manual probe or curette in dimensions, comprises a ring-shaped resonant body vibrated by an ultrasonic device (at 25 kHz)[72-76] attached to the working end at an angle of 90 degrees[75] and uses non-ellipsoid vibrations of the instrument tip that moves in a plane parallel to the tooth surface[73-76] with a small amplitude of about 30 to 35 µm[73,75] resulting in minimally invasive instrumentation[75]. The efficiency of calculus removal depends on the selection of inserts and irrigation fluids[76]. The addition of hydroxylapatite particles to the irrigation suspension (Vector fluid polish) removes subgingival deposits and polishes the root surface by hydrodynamic forces[71]. Guentsch and Presshaw[75] in their review concluded that Vector can be recommended for periodontal maintenance, the treatment of moderate to severe chronic periodontitis and can be used with a carbon fibre insert to remove plaque and calculus effectively with smooth abutment surface for implant maintenance (but not if large masses of supragingival calculus, deep pockets of >7 mm are present). Karring et al[77] found no added advantage with this system in peri-implantitis treatment. Studies with the Vector-system reported effective removal of subgingival calculus and predictable root surface preservation[78], which make the tooth surface more conducive to fibroblast attachment[79] and reduced pain sensations compared with conventional methods. Thus, this system may be useful in improving patient's compliance with periodontal maintenance programmes[80,81]. However, Kocher et al[82] found little pain and exclusive biofilm removal with the Vector device and conventional ultrasonics at low power.

Application in bone surgery

Ultrasonic bone-cutting surgery has been recently introduced as a feasible alternative to conventional tools of craniomaxillofacial surgery, due to its technical characteristics of precision and safety[83,84]. Piezosurgery® (Mectron Medical Technology, Carasco, Italy) is a new and innovative method that uses piezoelectric ultrasonic vibrations to perform precise and safe osteotomies[85]. It was first invented by Tomaso Vercelotti to overcome the limitations of traditional instruments in oral bone surgery[86], and first reported for preprosthetic surgery, alveolar crest expansion and sinus grafting[86,87]. The equipment consists of a piezoelectric handpiece and a foot switch connected to a main unit that supplies power, and has holders for the handpiece and irrigation fluids. It contains a peristaltic pump for cooling with a jet of solution that is discharged from the inserts with an adequate flow of 0 to 60 ml/min and removes detritus from the cutting area[85]. Piezoelectric surgery uses a specifically engineered surgical instrument characterised by a surgical power that is three times higher than normal ultrasonic instruments[88]. The device used is unique in that the cutting action occurs when the tool is used on mineralised tissues, but stops on soft tissues[83]. Nerves, vessels and soft tissue are not injured by the microvibrations (60 to 200 mm/sec), which are adjusted to target only mineralised tissue[89]. It has variable modulations of frequency (25.25 to 30 kHz) that give inserts a specific vibration that allows the cut to keep clean of bone splinters. The elevation of membrane from the sinus floor is performed using both piezoelectric elevators and due to the force of a physiological solution subjected to piezoelectric cavitation[88]. Piezosurgery resulted in more favourable osseous repair and remodelling in comparison with carbide and diamond burs. In addition, the force necessary to obtain a cut by the operator is much less compared with a rotational bur. Patients perceived greater comfort with this instrument in osseous surgery as it eliminates the noise of the high-speed handpiece[90].

Application as an ultrasonic cleaner

The dye/paper method of mapping ultrasound fields demonstrated cavitational activity in an ultrasonic cleaning bath[91]. The ultrasonic cavitation implosion effect is incredibly effective in displacing the saturated layer of contaminant, as it allows fresh cleaning solvent to come in contact with the unsaturated surface and attack and dissolve the remaining contaminant. It is especially effective on unsmooth and out-of-reach surfaces that are normally inaccessible through conventional means such as brushing. It has been shown to speed up and enhance the effect of numerous chemical reactions. The most probable reason for this enhancement is due to the high energy created by the high temperatures and pressure emitted by millions of individual cavitation bubble implosions[92]. Along with the use of such baths as a part of the process of controlling cross-infection in dentistry, it is suggested that manual cleaning of reusable instruments may also be necessary[91].

Ultrasound as a source for waves and its application

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 propagation wave[1,93]. This force is small, but in a standing wave field it may be enhanced and act over a short distance, so that dense particles in the medium are driven to regions of maximum acoustic pressure amplitude. In blood vessels this may cause local aggregation of blood cells leading to stasis[1,94]. Radiation may also enhance cavitational activity within a standing wave field[1,34].

Secondary effects

Responses that may be elicited from or produced in a tissue during or following ultrasonic irradiation are secondary effects. Vibrations of 25 kHz by frictional movement can be pressed directly against the tissue to produce coagulation. Gentle massage may produce a hyperaemia with no tissue destruction, provided that the propagating medium is flowing continuously between the tool and the tissue. Ultrasound applied to tissues of high fluid content will evoke bubble formation or degassing within tissue (cavitation)[30]. Tissue turgid with fluid or frozen solid may be cut with ultrasonic instruments of proper design and frequency (tissue surgery)[30,95].

Research workers have demonstrated that the application of high frequency vibrations has helped improve myalgia and tendon extensibility. In medicine it has been shown that scar tissue, particularly resulting from burns, may be softened following the use of ultrasound. The fibrotic gingiva of chronic gingivitis, being a type of scar tissue, was subjected to ultrasound and showed similar results to those described. Rubbing or pressing a vibrating tool tip against soft tissue coagulates the surface and produces a form of soft tissue curettage. Such curettage may be performed within the crevice or on the buccal or labial aspects of the gingiva[30]. When applied to gingiva in experimental animals, ultrasonic vibrations disrupt tissue continuity, lift off epithelium, dismember collagen bundles, and alter the morphology of the fibroblast nuclei[96]. Ultrasonic vibrations directed at tissue interfaces, that is, the epithelium-connective tissue junction, spread laterally lifting off the epithelium. The connective tissue below is dehydrated and the collagen bundles are mechanically pushed apart and the defect thus created in the tissues is a form of coagulated wound[30]. In the past, ultrasound has been used for debriding the epithelial lining of periodontal pockets resulting in microcauterisation using Morse scaler-shaped and rod-shaped ultrasonic instruments[97] and found it to be as effective as manual curettage[98-100] with less inflammation and less removal of connective tissue[97]. However, these procedures are now outdated. In addition to soft-tissue curettage, ultrasound may be used for gingival surgery. Periodontal curettes sharpened to a razor edge and activated with ultrasonic vibrations are able to excise gingival tissue[30].

Clinical applications

Periodontal ultrasonography

Ultrasound technology used in periodontal ultrasonography was initially used as an ultrasound-based time-of-flight technique used routinely in NASA Langley Research Centre's Non-Destructive Evaluation Sciences Laboratory to measure material thickness and, in some cases, length. The primary applications of that technology have been in aircraft skin thickness for corrosion detection and bolt length for bolt tension measurements[101]. The ultrasound probe works somewhat like a sonogram. With a sonogram, the probe is pressed against the body and the beam penetrates the womb. The echoes are recorded and displayed as an image of the foetal face. The same technology is adapted to image the periodontal structures (mainly by making the probe that sends the ultrasound signals and receives the echoes very small). Computer software interprets the echoes and makes an image of attachment level, pocket depth, etc[102].

The current method of diagnosing periodontal disease (walking probe) is invasive, uncomfortable and inexact. The ultrasonography probe (US probe) provides a mapping system for non-invasively making and recording differential measurements of depth of any patient's periodontal ligaments relative to a fixed point (the cementoenamel junction [CEJ]). The mapping system uses ultrasound to detect the top of ligaments at various points around each tooth and uses either ultrasound or an optical method to find the CEJ at the same points, thus depth of sulcus is calculated as the difference between these two points[101].

The periodontal ultrasonic probe consists of a transducer, which is housed within a contra-angled handpiece at the base of the hollow conical tip. This is responsible for emitting and receiving sound waves. The hollow tip focuses the acoustic beam into periodontal tissue. The transducer is mounted at the base of a dual taper, convergent-divergent coupler to provide an acoustically tapered interface with a throat area of the order of 0.5 mm. A throat area of 1.5 mm represents an active area reduction from transducer element to aperture. Such a reduction is mandated by geometry and a very small window is offered by the gingival margin. The ultrasonic probe is also able to be used with a small tip size and this adds to the ability of the ultrasonic probe to examine the interdental area[24,102-104].

The equipment required to run the probe includes a computer, monitor, keyboard, separate electron box for water pressure control and a foot pedal all mounted on a large cart so as to transport conveniently. The probe tip incorporates a slight flow of water to ensure good coupling of ultrasonic energy to tissues. Couplant water can come either from a suspended IV type sterile bag or be plumbed via the dental chair[103]. The ultrasonic probe tip is held in a vertical position, parallel to the long axis of the tooth. The tip is gently placed on the gingival margin until a slight blanching of the gingiva is seen; ensuring the complete coupling of water into the gingival sulcus, the probe is then activated with a foot pedal. When the foot pedal is engaged, a small stream of water will flow into the sulcus along with a thin beam of ultrasonic waves. The ultrasonic probe projects a narrow frequency (1 to 20 MHz) ultrasonic pulse into the gingival sulcus or periodontal pocket and then detects echoes of returning waves. An ultrasonic beam entering the tissues is absorbed, reflected or scattered. The reflected portion is received by the machine and used for reconstruction of the ultrasonic image. As these sound waves bounce off the periodontal tissues, echoes are recorded by a tiny transducer in the handpiece and analysed simultaneously by a computer attached to an ultrasonic unit. As the examiner passes the probe tip across the gingival margin, the computer records the incoming data and uses artificial intelligence algorithms to translate data into estimates of probing depths in millimetres[102,103]. Unlike manual probing where measurements are obtained at six sites per tooth, the ultrasound probe tip is gently placed on the gingival margin then swept along the entire gingival area. Thus, the ultrasonic probe is able to painlessly capture a series of observations (depth measurements and contour) across the entire subgingival area as the probe tip passes the gingival margin, therefore, yielding more information[103]. This non-invasive method for measuring pocket depth seems to be accurate, but long-term studies still need to be carried out.

Ultrasound imaging for periodontal assessment

A recent study using the ULTRADERM® (Longport International Ltd, Silchester, UK) ultrasonic scanner that works at the frequency of 20 MHz in an animal (pig jaw) model has shown that periodontal ultrasonography can produce images suitable for the assessment of the periodontium as well as accurate measurement of the dimensional relationship between hard and soft structures[105,106]. The technique of ultrasonography has also been applied in human subjects. In different studies, the device has been used to evaluate gingival thickness before and after mucogingival therapy for root coverage[106,107]. It was also used to assess the dynamics of mucosal dimensions after root coverage with connective tissue grafts[106,108], bioresorbable barrier membranes[106,109] and for the measurement of masticatory mucosa[106,110]. The ultrasonic scanner provides satisfactory results both in terms of accuracy and ease of reproducing the technique.

■ Application in osteoconduction

Since the first therapeutic ultrasound application in 1932, ultrasound therapy has evolved within the practice of physiotherapy mainly to treat soft tissue disorders. The first prospective randomised double blind clinical trials were published in the nineties and indicated that the healing time of fresh tibial and radial fractures could be reduced by 38% when low intensity pulsed ultrasound with an intensity of 30 milliwatts per square centimetre was used. This was carried out for 20 minutes a day by placing a transducer onto the skin across the fracture[111]. It also became clear that slow or non-uniting fractures could be healed by the application of ultrasound, and furthermore, it seemed that the effect of ultrasound is not limited to fracture healing, but that bone healing after osteotomy or osteodistraction could be stimulated as well. It was, therefore, concluded that there may be a potential for ultrasound to stimulate maxillofacial bone healing[111]. Based on the literature, it seems to be reasonable to assume that ultrasound has an effect on bone cells during bone healing, but that a possible observed effect may be related to the mechanical and circulatory conditions at the site. However, Schortinghuis et al[112] showed that low intensity pulsed ultrasound (LIPUS) is not effective in stimulating bone growth in a rat mandibular defect, either with or without the use of osteoconductive membranes. Also, no evidence suggests that low-intensity pulsed ultrasound stimulates osteoconduction in a bone defect in the rat mandible that is covered by a collagen membrane[112,113].

Application to regrow teeth

High intensity focused ultrasound has been shown to stop bleeding in blood vessels non-invasively[58], whereas low intensity pulsed ultrasound (LIPUS) has been reported to be effective in liberating preformed fibroblast growth factors from a macrophage-like cell line, in stimulating angiogenesis during wound healing[114], enhancing mandibular growth in growing baboons[115], enhancing bone growth into titanium porous implants[116], accelerating healing of resorption by reparative cementum[117], enhancing bone healing after fractures[118] and in mandibular osteodistraction[119]. Routine use of low intensity ultrasound appears to have a modest beneficial effect on recurrent aphthous stomatitis[120]. Reports also suggest that LIPUS can enhance the growth of mandibular incisor apices and, in rabbits, can accelerate the rate of eruption of teeth that received ultrasound[121]. Using LIPUS, Dr Tarak El-Bialy from the faculty of medicine and dentistry and Dr Jie Chen and Ying Tsui from the faculty of engineering have created a miniature system-on-a-chip that offers a non-invasive and novel way to stimulate growth of the jaw and dental tissue healing[122-125]. The prototype ultrasound device can be mounted on braces or a plastic removable crown[125]. The wireless device, which is roughly half the size of a nail on the baby finger, will be able to gently massage the gums to stimulate growth of the tooth root[126]. LIPUS seems to play an effective role in repair and healing, the role of LIPUS in periodontal regeneration was given by Ikai et al[127] and they evaluated the effect of LIPUS on wound healing in periodontal tissues after mucoperiosteal flap surgery. Heat shock protein 70-positive cells were found around the basal and spinous layer of LIPUS-exposed gingival epithelium at 4 weeks suggesting certain anabolic mechanical induction mechanisms.

Conclusions

Ultrasonics have now been adopted and acknowledged as a wonderful tool for non-surgical periodontal therapy. Recently ultrasound has been used both for diagnosis and periodontal therapy. The diagnostic use of ultrasound waves offers non-invasive, non-ionising radiation for dimensional assessment of periodontal structures. This could eventually lead to its application in the evaluation of soft and hard tissue healing after various periodontal surgeries as well as for clinical assessment and treatment planning prior to implant placement. In therapeutics, both conventional and new generation ultrasonics provide superior results to manual instrumentation. This results in better patient compliance for long-term periodontal maintenance.

Immunohistochemical analysis has shown that mechanical stress loaded by low intensity pulsed ultrasound (LIPUS) can accelerate periodontal wound healing and osteoconduction. Thus the potential use of ultrasound in periodontal regeneration has tremendous scope in the future although more studies need to be carried out.

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