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A New Diagnostic Tool for Detecting Dental Caries and Tooth Wear: Ultrasonic System

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ABSTRACT

Ultrasonic System depends on the principles that are; production of sound waves by a transducer, penetration of them into some media, reflection when they contact with another media or air, transformation of those echo waves into electrical waves and observation of the waves on a screen. That system has been used in industry, medicine and also in dentistry. In dentistry very few researchers studied this topic long time ago. This article gives some information about the parts and the mechanism of the ultrasonic system, how to use it and the effectiveness of the system on detecting dental caries and the erosions.

Ultrasound has been used in industrial business as one of the nondestructive measurement methods. It was hypothesized that nondestructiveness of the ultrasonics could be useful in determination of demineralization of non-cavitated carious lesions on human enamel. [1] Ultrasonic waves are elastic waves having 20-20000 frequencies that can be heard by human ear. The spread of sound waves can be described simply by dropping a rock into water. The formation of the waves created by direct pressure are similar and recurrence. No water mass is carried away, but sound waves pass through. These sonic waves also called as elastic waves or pressure waves. Ultrasonic waves are also elastic vibrations in frequencies beyond hearing limits. [2, 3] However they are mechanical pressure waves like hearable sound waves and they need a medium in order to be created. This medium can be solid or liquid and elastic characteristics of it create the waves as mechanical vibrations. The vibrations transmitted between the particules. The velocity of the wave (V) is described according to the elastic modulus (E) and density (ρ) of the medium. [2, 4, 5]
$V^2 = E / r$

The direction of movement of particles are paralell to the center of vibration for longitudinal waves which are mostly used in industry. The longitudinal waves can be called as real acoustic waves because we hear vibrations as sound by travelling of these waves in the air [2, 4] On the other hand transverse sound waves are the ones that the direction of movement of particules are perpendicular to the center of vibration. [3] Ultrasonic waves are reflected and absorbed while moving form one medium/tissue to another with different acoustic empedance. The absorbed waves are changed into heat energy and therefore attenuated. [2, 4, 5] Acoustic empedance is also called as acoustic electricity and related with density of medium/tissue and acoustic velocity (Figure 1).

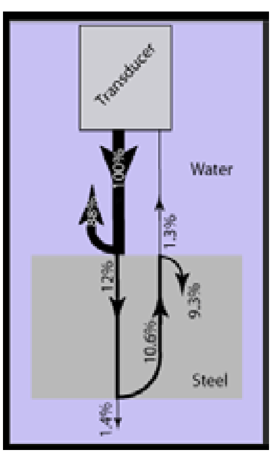

Figure 1: The direction of ultrasonic waves between medium/tissues

An ultrasonic system is composed of a transducer (ultrasonic probe), scanning generator, timer, display (A mode, B mode, M mode) and a grey-scale visualisation device used for creating images (Figure 2) [2, 6] The contact transducer is of the right angle type with a 1.5mm tip contact diameter, 11 MHz nominal center frequency with a removable plexiglass delay tip. [7] Generator supplies the electricity and pulser used for sonography reates the electrical impulses. These impulses are converted to high frequency ultrasonic waves by the transducer. Transducer is the device that cenverts one energy form to another and in this system it converts electrical energy to ultrasonic energy. This convertion starts a series of vibrations that creates ultrasound waves delivered to the medium/tissue. [8] The transducer contains thin cristals called piezoelectric which are mostly made of zirconium nitrate. These cristals, when stimulated with electricity, vibrates and creates electrical signals, therefore elastic waves in contacting medium/tissue are created. The frequency of the waves depend on the thickness of the cristals which is inversely proportional. [3, 4, 8] Coupling gel is used as conductor in ultrasonic medical devices therefore air space between transducer and medium/tissue is eliminated and ultrasonic waves with maximum power can travel continuously. [4] Visualization is achieved by detecting the reflecting waves, which are called as echos, by the transducer and formation of electrical signals. [4, 5] This detection system is also called as envelope-detection system and video signals are produced by this (Figure 2).

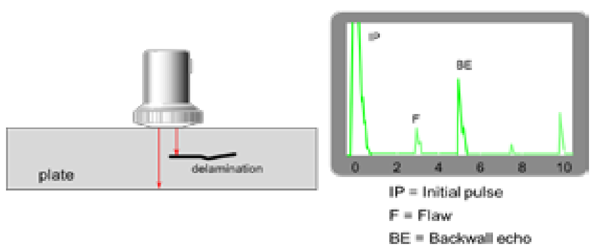

Figure 2: The principle of operation of ultrasonic system

The video signal can be gained in different visualization modes. Mode A is the graphical demonstration of the receiving echos. Horrizontal coordinate shows time and distance, perpendicular one shows the amplitude of the ultrasonic wave. This mode is generally used in industry and medicine and quantitative assessment without images can be done. Mode B shows sections of medium/tissue as images made of dots in various brightness. This mode is especially used in radiology for diagnostic purposes. Mode M shows the amplitudes of functional contents. Echos reflecting from dynamic tissues are saved as time/position graphics in this mode and especially used for examination of hearth as echocardiography. [4, 5, 9] Ultrasonic waves weaken while passing through tissues with different acoustic resistants due to absorbtion, reflection, refraction, diffusion and scattering. Ultrasonic waves reflect in the same reverse direction. Refraction happens if the acoustic resistant of two medium/tissue is different. Any irregularity on the surface of the medium/tissue causes diffusion and scattering. These readings are seen on the screen of the ultrasonic device as green lines. First echo can be seen on the very left of the screen. If there is an irregularity or discontinuity in the tissue, the echos received by the transducer and this defect is seen on the screen as low amplitude. Weakened continuing waves reflect back from the end of the medium/tissue and can be seen as reflecting echos with lower amplitudes on the screen. [5, 9]

Ultrasonic system has used in medicine and dentistry for diagnostic purposes as it is in industrial issues. Removal of calculus, removal of broken files, irrigation of root canals and mechanical disinfection of dental tools are one of the main usage areas of ultrasound in dentistry. [1, 10 – 16] Kossoff ve Sharpe used ultrasound in order to assess pulpitis. [8] Some researchers examined dentin and enamel tissues by using ultrasound. Barber et al. studied enamel-dentin junction and dentin-pulp junction [4], Katz et al. and Lees and Barber studied elastic properties of enamel and dentin tissues. [9, 10] Ultrosound was also used for detecting caries lesions. Ng et al. reported that ultrasonic waves could detect sound and demineralized enamel differences. [6] Bab et al. and Ziv et al. detected enamel and dentin caries by using ultrasound. [11, 12] Moreover Bab et al. also introduced "The Ultrasonic Caries Detector (UCD)." They used surface waves to detect proximal caries lesions. However they succeed only in deep dentin caries lesions. [11] Ziv et al. and Gazit et al., used the same device with 91,9 % spesificity and reported to be successful even in shallow dentin by using histology as gold standart. [12, 13] Yanikoglu et al. studied enamel caries lesions and remineralization potentials by using ultrasound. They prepared 8 slim enamel pieces buried in acrylic and kept them in a cycle of 4 days demineralization and 1 day remineralization for 25 days period. 300 – 3000 ppm fluoride applied once and three times a day and reported that ultrasound could detect the remineralizations on artificially created enamel lesions.[14] Fontana et al. created 20 micrometers deep caries lesions, applied demineralization/remineralization cycles and used QLF, ultrasound and confocal microscopy for detection. Only confocal microscopy could detect the demineralization but reported that remineralization detected by ultrasound. [15] Yanikoglu et al. detected natural white spot lesions on proximal surfaces by using ultrasound and compared with radiography and histology. They reported that ultrasonic system could detect the natural white spot lesions. [16] In one of the clinical studies performed, ultrasonic system used for detecting demineralizations and remineralizations of enamel tissue however it could not succeed in 50-86 micrometer deep enamel lesions. [17] Bozkurt et al, studied the capability of an ultrasonic system to detect early caries lesions on human enamel. [18] Tagtekin et al. detected proximal caries lesions by using ultrasound and DIAGNOdent devices and reported that both methods were valid and repeatable. [19] Matalon et al. introduced an ultrasonic caries detector device which could detect cavitated caries lesions with high sensitivity and low spesificity. [20] Wang et al. reported the successful detection of 14 days remineralization of human enamel and differences from demineralized enamel by using laser ultrasound technique. [21] Ultrasound was also used in dental wear studies. Huysmans and Thijssen measured enamel thickness and John et al. measured dentin thickness successfully. [22, 23] Tagtekin et al used ultrasound to measure enamel thickness on cusp tips of human molars and Bozkurt et al. reported the statistically harmony of different operators in measurement of premolar enamel thickness [24, 25] On the contrary Luowerse et al. reported that ultrasound could not detect thickness differences lower than 0,33 mm probably as a fact of inability to stabilize the ultrasonic prob for every measurement. [26]

According to all the studies ahead, the researchers approved ultrasound as a repeatable, reliable and sensitive method for detecting tooth wear however there is still need to study more about detecting caries lesions especially clinically. [17, 22, 25, 26] But ultrasonic system as a non-destructive, radiation-free and conservative diagnostic method, can still be called as a promising tool for the future of diagnostic dentistry.

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