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Use of ultrasound in dentistry

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ABSTRACT

Ultrasound (US) is mechanical vibrations above the frequency range audible by the human ear in the frequency range of 20000–1010 Hz. The frequency boundary between sonic and ultrasonic waves is due to the properties of human hearing and corresponds to the upper limit of audible sound. Each ultrasonic frequency zone is characterized by its own application features. The use of ultrasound in dentistry significantly improves the quality of treatment of patients and facilitates the work of the doctor. The therapeutic effect of ultrasonication is a combination of thermal, mechanical and physico-chemical actions. During thermal action, tissues absorb energy, and consequently, deep heating occurs. Under mechanical action, microdisplacement of particles occurs, resulting in micromassage of cells and tissues. Under physical and chemical influences, the course of redox processes changes, enzymes are activated, and complex protein complexes are broken down into ordinary organic molecules. Ultrasound is a strong factor in stimulating blood flow, which makes its use possible in all cases of blood flow depletion and hypoxia. An increase in blood flow in the sounded tissue contributes to oxygen saturation and enrichment with nutrients, an increase in the rate of redox reactions and metabolic processes in general. This review discusses the modern principles of the use of ultrasound in dentistry.

Keywords: Ultrasound, mechanical vibration, ultrasonic echolocators, ultrasonic cleaning, tissue micromassage, dentistry.

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Introduction

At the end of the 19th century, Pierre Curie discovered the phenomenon of the piezoelectric effect, which made it possible to create mechanisms that register and create waves of unequal frequencies – from low to audible. For the first time, the use of ultrasonic devices on submarines began at the beginning of the 20th century, when ultrasonic echolocators were introduced to detect enemy ships. Furthermore, ultrasonication started to be used in industry to detect hidden defects in metal products, concrete blocks, etc., making it possible to create ultrasonic devices in the field of medicine [1-3]. Currently, ultrasonic research methods are used in various fields of clinical medicine and are significant techniques for diagnosis and treatment.

Ultrasonic waves can penetrate into the soft tissues of the body and be reflected by acoustic inhomogeneities, which makes it possible to use this property to study internal organs [4, 5].

Ultrasonic diagnostic methods subtly recognize the structure of tissues better than X-rays. Ultrasound is used in obstetrics for diagnostic examination of the foetus; in neurosurgery to study tumours in the brain; and in cardiology to study haemodynamics and to detect hypertrophy of the heart muscle. Tissue micromassage, activation of metabolic processes, and local heating of tissues under the action of ultrasound are used in medicine for therapeutic purposes [6-8]. Ultrasound is used in laboratories to disperse biological structures; in bacteriology to achieve a subtle effect on the structure of cells; and in immunology to obtain enzymes and antigens from bacteria and viruses and to study the morphological features and antigenic activity of bacterial cells. Ultrasonication activates metabolism in the body, enhances the activity of enzymes, and increases the permeability of membranes, releasing biologically active substances. Cavitation is able to remove biofilms from the surface of teeth and increase the permeability of tissues and the vascular wall. Therefore, by ultrasonication of tissues, it is possible to increase blood flow in hypoxic zones and promote oxygen saturation, as well as enrich tissues with nutrients. In this case, the rate of redox reactions and metabolic processes will increase [9, 10]. Additionally, due to the increased permeability of blood vessels and cell membranes and the restoration of tissue drainage systems, a decongestant effect can be manifested. The action of ultrasound on tissues is considered a kind of micromassage of cells.

Ultrasound (US) is mechanical vibrations above the frequency range audible by the human ear, ranging from 20000–1010 Hz. The frequency boundary between sonic and ultrasonic waves is determined by the properties of human hearing and corresponds to the upper limit of audible sound [11]. A person perceives sounds with a frequency of 2000 to 5000 kHz. The maximum hearing acuity is observed at the age of 15-20 years, and hearing decreases with age.

- It is customary to divide ultrasonic frequencies into three zones:
- low-frequency ultrasonic (ULF) – 1.5×104–105 Hz;
- medium-frequency ultrasonic (UHF) – 105–107 Hz;
- high-frequency ultrasonic (UHF) – 107–109 Hz.

Each ultrasonic frequency zone is characterized by its own application features. The upper limit of ultrasonic vibrations has boundaries close to hypersonic vibrations up to 1013 Hz. The peculiarity of low-frequency ultrasound is that it can propagate in air. Therefore, UZSCH and UZVCH are used in liquid and solid bodies, while UZNP is used in air and gases.

The primary direction of application of low-frequency ultrasound is its effects on the main aspects of disease pathogenesis:

- release of tissues from infected masses;
- phonophoresis of medicinal substances;
- bactericidal effect on microflora;
- reduction of invasiveness during tissue dissection;
- haemostatic effects;
- polymerization of individual chemical composites;
- normalization of lymph and blood circulation in tissues;
- ablasticity;
- removal of foreign bodies, pins from root canals, etc.;
- acceleration of tissue regeneration and wound healing [12, 13].

Tissue repair involves three stages

The first stage is inflammation. An increase in the phagocytic activity of macrophages and polymorphonuclear leukocytes leads to the removal of cell fragments and pathogenic particles. Lysosomal enzymes of macrophages process this material; however, the application of ultrasound causes changes in lysosomal membranes, accelerating this step.

The second stage is the proliferation phase. After migrating to the affected area, the cells intensively divide and synthesize collagen. The intensity of healing increases, and the edges of the wound are pulled together with the help of myofibroblasts. The use of ultrasound accelerates the synthesis of collagen by fibroblasts.

The third stage is recovery. Normally, connective tissue determines its elasticity with the help of an ordered structure of the collagen network, which allows the tissue to tense and relax without deformation. Scar tissue lacks an ordered fibre structure, which prevents it from stretching without tearing. When exposed to ultrasound, scar tissue becomes stronger and more elastic [14-16].

The tool consists of a rod ultrasonic transducer and has a tip at the end. Longitudinal vibrations are excited in the tip, with a frequency in the range of 25–42 kHz and an amplitude ranging from 6–100 μm. The depth of penetration of liquid medicinal substances into tissue depends on the amplitude of the waveguide oscillations and the duration of sounding of the medium. In the Russian Federation, URSK-7N-18S ultrasonic units with needle waveguides are produced, and excavator waveguides, pluggers, and scalpels with smooth and rough working surfaces are also used. Tip waveguides perform reciprocating movements. Medicinal substances from a syringe or dropper can be transferred to the surface of the waveguide.

Abroad, Piezon Master 400 ultrasonic dental equipment (Supresson), which has a different design of acoustic unit instruments and medicinal solutions supplied from containers, has become widespread. When removing dental deposits and processing blind pits and fissures, cavitation of distilled water is an indispensable condition. However, antiseptics (furacilin, chlorhexidine) can be used instead of distilled water [17, 18].

The use of ultrasound in dentistry significantly improves the quality of treatment of patients and facilitates the work of the doctor.

The healing effect of ultrasonication is the combination of three types of action: thermal, mechanical and physico-chemical.

During thermal action, tissues absorb energy, and consequently, deep heating occurs. Under mechanical action, microdisplacement of particles occurs, resulting in micromassage of cells and tissues. Under physical and chemical influences, the course of redox processes changes, enzymes are activated, and complex protein complexes are broken down into ordinary organic molecules [19, 20].

Materials and Methods

Treatment of dental diseases with the help of ultrasound

Treatment of deep caries. The preparation of the carious cavity is carried out with a turbine tip using burs. The preparation of hard tissues using ultrasonication is also carried out with antiseptic solutions. If anaesthesia is necessary during dental procedures, a solution of 1% trimecaine with furacilin (1:5000) is used. In this case, the anaesthetic solution enters the carious cavity from a dropper or syringe and is sounded for 15-20 minutes, resulting in a decrease in pulp sensitivity to 40-50 mcd. Next, ultrasonic necrectomy of the carious cavity and drying are performed. A small amount of dentine sawdust is removed from the walls of the carious cavity with boron, a drop of medical glue MK-2 is added to them, and the prepared composition is sounded with a waveguide-pggopfer for 30–35 s, which leads to polymerization and the formation of a biological filling associated with the hard tissues of the tooth and does not extend beyond the enamel-dentine junction. Then, the carious cavity is sealed according to the generally accepted method [21, 22].

Biological method of pulpitis treatment. The method is used in cases of accidental exposure of the pulp. Under anaesthesia or phonophoresis, a 1% solution of trimecaine with furacilin is used for preparation and ultrasonic necrectomy of the carious cavity. Ultrasonic cleaning of the opened point of the arch is carefully carried out, and bleeding is stopped. Clean dentine filings are obtained from the walls of the carious cavity, impregnated with cyacrine, and sounded for 30–35 s, and a permanent filling is placed on the hardened biological filling [23, 24].

Vital pulp amputation. In vital amputation, the coronal pulp is amputated using a waveguide excavator with an exposure of 2–3 s at each root canal orifice. Ultrasonic treatment of the mouths with a solution of chlorhexidine accelerates the reparative processes of the pulp amputation wound. In parallel, haemostasis of the root pulp stump, protected by biologically active material, occurs. After the action of ultrasound, the pulp stump should not bleed. If necessary, the step is repeated until the bleeding stops completely. Dentine sawdust is obtained from the walls of the carious cavity, impregnated with cyacrine, sounded for 30–35 s, and sealed.

Vital pulp extirpation. This is indicated for acute diffuse pulpitis and for all forms of exacerbation of chronic pulpitis. The mouths of the root canals are treated with a needle waveguide, the bend of which is up to 15 degrees. For difficult, curved root canals, waveguides bent at an angle of 90–120 degrees are used with solutions of EDTA, sodium hypochlorite 0.5–2.5%, and citric acid 30–40%. Innovative endodontic tips enhance root canal treatment to a new level, such that ultrasonic energy is applied at all stages of root canal treatment, which makes the root canal walls smooth and clean and prepared for filling [25, 26]. Root canals are filled with pastes based on calcium hydroxide or zinc oxide and eugenol. It is also possible to condense the material with an ultrasonic file when filling with gutta-percha pins.

Results and Discussion

Periodontitis. Treatment of all forms of periodontitis is carried out with ultrasound in combination with laser therapy. When retreating canals, ultrasonication is used to remove root filling material, such as gutta-percha and paste based on resorcin formalin. Ultrasound is used both for direct contact with the obturation material and for the activation of various solvents. Retreatment of root canals with fixed intracanal pins, as a rule, presents certain difficulties for dentists due to the increased risk of perforation, fractures and weakening of existing tooth tissues. When using ultrasonic instruments, this risk is reduced. If zinc phosphate cement or GIC is used for fixation, then the use of ultrasound is justified [27, 28].

Periodontal diseases. The use of ultrasonic devices helps to reduce inflammation in periodontal tissues. Ultrasonic tooth cleaning is one method in the complex of professional dental hygiene. In the case of periodontal diseases, soft and hard dental deposits are removed with ultrasound, and the gingival pocket is treated with a needle waveguide by means of a continuously supplied antiseptic solution. After ultrasonic cleaning, the tooth surface becomes smoother than that after manual processing. Ultrasonic calculus removal includes mechanical treatment, irrigation, cavitation and acoustic turbulence. This action makes it possible to remove deposits both directly in contact with the scaler and near it at a distance. The principle of these oscillations is based on the piezoelectric effect [29]. Then, the movement of the working part of the tip is linear or reciprocating, which leads to the work of only two sides of the nozzle.

When treating periodontal pathological bone pockets with ultrasound in periodontitis, an excavator waveguide and a needle waveguide are used. Of the solutions, furacilin, chlorhexidine, saline solutions, and antibiotics are used. In complicated forms of periodontitis, ultrasound is used in combination with curettage and laser therapy.

The use of ultrasonic instruments without solutions has an effect in removing fragments of instruments and intrapulpal pins from root canals. To remove residual phosphate cement, an EDTA solution or 30% citric acid solution is used [30].

With the help of ultrasound, it is possible to carry out the extraction of teeth due to the generation of ultrasonic vibrations, affecting only the bone tissue without injuring the soft tissues. The root of the tooth is detached using ultrasound and removed without damaging the gums or bone tissue. A sterile solution is constantly supplied to the area of intervention, which has a therapeutic effect and promotes rapid healing of tissues.

Ultrasonic waves have a detrimental effect on all types of microorganisms. This property of ultrasound is used to sterilize dental instruments.

Ultrasonic physiotherapy. This approach has analgesic, anti-inflammatory and tonic effects. Ultrasonic micromassage relieves pain, stimulates the activity of the nervous and endocrine systems, improves the functional state of connective tissues, enhances the protective reactions of the body, and improves the functions of joints and muscles; in some cases, there is a decrease in pressure. The simultaneous effect of ultrasound and drugs on the body, called ultraphonophoresis, has become widespread. A medicinal substance is applied to the skin and ultrasonicated, which increases the permeability of particles of the medicinal substance, forming a depot from which they diffuse into the blood and lymph. With the solutions introduced in this way, they remain in the body longer, exerting their therapeutic and micromassage effect, thereby increasing the activity of enzymes, activating the processes of intracellular metabolism, and improving lymph and blood circulation [33].

Conclusion

Thus, ultrasonication as a method of diagnosis and treatment has found its application in medicine and, in particular, in dentistry. It is important to understand in which cases it is possible to use ultrasonic methods and where the use of ultrasound will be more effective

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