The Use of Ultrasonic Instruments in the Dental Practice

Yuriy Andreevich Sergeev¹, Alexandr Anatolyevich Markov², Bayu Indra Sukmana³, Herlina Uinarni⁴, Elena Aleksandrovna Matveeva⁵ and Tuguz Salikhovich Nalbiy⁶

¹Stavropol State Medical University, Russia.
²Tyumen State Medical University, Tyumen, Russia.
³Department of Biology Oral, Faculty of Dentistry, Lambung Mangkurat University, Banjarmasin, South Kalimantan, Indonesia.
⁴Department of Anatomy, School of Medicine and Health Sciences, Atma Jaya Catholic University of Indonesia, Jakarta, Indonesia.
⁵Department of Prosthetic Dentistry, Sechenov First Moscow State Medical University, 119991, Trubetskaya st., 8-2, Moscow, Russia.
⁶Department of Higher Mathematics, Kuban State Agrarian University named after I.T. Trubilin, Krasnodar, Russia.

Authors’ contributions

This work was carried out in collaboration among all authors. Author YAS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AAM, BIS and HU managed the analyses of the study. Authors EAM and TSN managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JPRI/2020/v32i2330795
Editor(s): (1) Dr. Giuseppe Murdaca, University of Genoa, Italy.
     (2) Shohreh Ghasemi, Augusta University, Georgia.
     (3) Igna Cornel, Banat University of Agricultural Sciences and Veterinary Medicine, Romania.
     (3) S. Devakumari, Indira Gandhi Medical College and Research Institute, India.
Reviewers:
     (1) Shohreh Ghasemi, Augusta University, Georgia.
     (2) Igna Cornel, Banat University of Agricultural Sciences and Veterinary Medicine, Romania.
     (3) S. Devakumari, Indira Gandhi Medical College and Research Institute, India.
     Complete Peer review History: http://www.sdiarticle4.com/review-history/61509

Original Research Article

ABSTRACT

The ultrasonic instrumentation in dentistry has been used since the middle of the last century. Improved visualization, ease of operation and precise cutting ability have allowed ultrasonic instruments to be widely used in dentistry. The study considers the possibilities of using ultrasound instruments in various fields of dentistry.

*Corresponding author: E-mail: Serg_yuny@mail.ru;
Advantages of ultrasonic instruments include conservative preparation of the cavity, less painful caries removal procedure and minimal noise generation. All these improvements are presented in clinical cases. In addition, the gentle effect on soft tissues is a characteristic feature of ultrasonic devices when applied to operative or orthopedic dentistry during the preparation of the cavity. Although some issues, such as high-frequency noise, interference to cardiac pacemakers, and low cutting efficiency compared to conventional high-speed or low-speed air-turbine tools, still need to be considered, the results of previous research show that ultrasound tools have an extremely high potential to become a convenient and effective tool for various dental procedures deserve future development.

Keywords: Ultrasound; operative and orthopedic dentistry; periodontology; orthodontics.

1. INTRODUCTION

Ultrasonic instruments use ultrasound energy with a wave frequency that is usually 20 kHz higher than human hearing. Basically, ultrasonic vibration is created by two methods: magnetic and piezoelectric [1,2]. The magnetic method transfers the electrical magnetic energy of mechanical energy by changing the magnetic field. However, the piezoelectric method uses the transfer of electric charge to cause dimensional deformation of piezoceramic disks, thus creating vibration [3].

Compared to the magnetic method, the advantages of the piezoelectric method include higher energy transfer efficiency and greater vibration from linear motion. High-energy transfer efficiency reduces energy consumption and temperature rise during the transmission process [4,5,6]. In addition, linear forward-backward vibration can create a more precise vibration mode compared to the figure-eight movement mode created by the magnetic method.

Currently, the ultrasound frequency used in dentistry is approximately 25-40 kHz. The vibration mode and amplitude of ultrasonic instruments depend on the morphology, design, frequency, and power source of the devices. Due to physical properties such as node and anti-node vibration characteristics, ultrasound instruments require appropriate morphology and structure of construction with consistent frequencies to create the ideal vibration for clinical use [7].

The ultrasonic instrument was first introduced to the dental field as a method of preparing the cavity with an abrasive suspension [8,9,10]. Although ultrasonic instruments have lower cutting efficiency compared to conventional high-speed or low-speed air-turbine devices, they have many advantages in dentistry, including improved visualization, a conservative approach, selective and accurate cutting performance, and acoustic streaming response.

Depending on the clinical requirements, there are various ultrasound instruments available on the market with different devices [11,12]. In addition, they are widely used in dentistry, including operative and orthopedic dentistry, periodontics, endodontics, orthodontics, oral and maxillofacial surgery and oral diagnostics.

2. MATERIALS AND METHODS

Special literature in the field of ultrasonic application in dentistry is studied. The main methods were comparative and analytical.

3. RESULTS AND DISCUSSION

Ultrasonic instruments in operative and orthopedic stomatology are under the question. The first use of ultrasonic instruments in dentistry was made for preparing teeth in the 1950s. Ultrasonic instruments were combined with an abrasive suspension to facilitate the preparation of the tooth structure.

The development of ultrasonic dental preparation has been stopped due to lower efficiency compared to high-speed or low-speed instruments with air turbines. However, improving the production process with diamond coating, chemical vapor deposition methods, and new tip designs effectively increases the efficiency of cutting by ultrasonic tools on the tooth structure. Although the cutting efficiency of ultrasonic tools is still not comparable to high-speed or low-speed tools with air turbines, even after corresponding improvements [13].

Advantages of ultrasonic instruments include conservative preparation of the cavity, less painful caries removal procedure and minimal
noise generation. All these improvements are presented in clinical cases. In addition, the gentle effect on soft tissues is a characteristic feature of ultrasonic devices when applied to operative or orthopedic dentistry during the preparation of the cavity. Previous studies have shown that the increase in intrapulpal temperature after ultrasonic preparation is similar or higher than that of high-speed air turbine preparation, but the increase remains below the critical value of 5.5°C.

The authors determined that the temperature change during ultrasonic preparation was also below the critical value with sufficient irrigation. This indicated that in this state, an ultrasonic preparation with sufficient irrigation can ensure the safety of the surrounding tissue during the procedure. Although the scanning electron microscopy (SEM) study showed that the surfaces of the teeth after ultrasound equipment are rougher than the surfaces after high-speed equipment with an air turbine, there is no significant difference in the edge compaction of the resin recovery between two medicines.

Conversely, ultrasound instruments can also be an auxiliary tool to improve the quality of treatment and facilitate the procedure process. In a previous study, ultrasonic instruments were used to install composite tabs and then compared to planting composite tabs when pressed with a finger. Results showed that the ultrasonic method is better than the finger pressure method for high-viscosity cement [14].

Walmsley and Lumley also demonstrated that using the ultrasonic loading method of a composite luting agent results in significantly shorter loading times and lower loads. When comparing the tensile strength of polymer composite laminates with conventional or ultrasound cementation, technique is that even if the fracture strength of composite laminates is not affected by both methods, the ultrasonic technique group has more suitable types of failures.

Other conclusions on the use of ultrasound instruments in surgical and orthopedic stomatological procedures, such as edge insertion of ceramics, insertion of composite inserts and packed composites used as axis, have also shown that the ultrasound method is a benefit to the procedure process and has favorable results compared to conventional techniques. As invasive treatment in the application of ultrasound is minimal, ultrasound training can be alternative approach to the preparation procedures of the teeth. Based on clinical experience, ultrasonic instruments are useful for removing caries near the pulp or proximal caries, which is difficult to approach with traditional high-speed dental instruments.

Ultrasound diagnostics is also used in periodontology. Ultrasonic instruments have been used in periodontal treatment since the 1960s, and many aspects of ultrasonic instruments compared to hand dental instruments used in periodontal treatment have been widely discussed. There is no significant difference in the effectiveness of manual or ultrasonic instruments when removing subgingival plaque [15].

Thus, the researchers note that subgingival treatment of a wound either by the hand or by an ultrasonic instrument was equally effective in reducing the probing depth of the pockets, bleeding estimates, and microscopic amounts of bacteria.

In other studies, ultrasound devices have also shown comparable results in clinical and microbiological aspects compared to other treatment methods, although ultrasound instruments produce a rougher root surface and remove less dental matter compared to hand dental instruments. On the contrary, after the introduction of improved tip design and coating methods, the effectiveness of ultrasonic instruments were increased for specific treatments

Experts demonstrate that the ultrasonic furcation head, a head specifically designed to remove mucous membranes, can significantly improve the treatment of grade II furcation involvement in the lower jaw molars.

Also in the literature, there is a study with a newly developed mucosal removal tip that can create a smoother root surface compared to a conventional ultrasonic head or a Gracie curette. Diamond coating technology can also improve the ability to remove the root surface with an ultrasonic instrument, although the residual roughness of the root surface is still increasing. This minor side effect should be taken into account when using an ultrasonic instrument during periodontal planning procedures.

Head shape design and surface treatment are two important issues for ultrasound instruments
in periodontal therapy. Based on our recent research, the finite element analysis (FEA) performed before the head is manufactured can simulate the vibration mode to increase the head's efficiency and flexibility to create a better vision to facilitate clinical operations. In addition, the newly developed coating technology, chemical vapor deposition, is another achievement in improving cutting efficiency.

In 1999, a system of ultrasonic instruments called "Vector" was introduced. The "Vector" system has the principle of linear vibrations, which provides a vibration parallel to the surface of the root, and differs from the usual ultrasonic system. Previous studies have shown that "Vector" system can reduce pain and discomfort during treatment and improve patient compliance with the treatment regimen, but it may not be suitable for removing large masses of supragingival stone [3].

The "Vector" system also provides comparable results in the treatment of moderate to severe chronic periodontitis compared to manual or conventional ultrasound instruments. The "Vector" system reports advantages such as less cement removal and a smoother root surface after instruments compared to conventional ultrasonic tools. These characteristics make the "Vector" system suitable for supportive periodontal therapy.

Since the 1980s, after Martin and Cunningham introduced an ultrasound and synergetic system for root canal instruments and disinfection, the use of ultrasonic instruments for endodontic procedures has expanded in three areas: dentin preparation, chemical irrigation, and procedure improvement. Due to the physical properties and rigidity of stainless steel files, ultrasonic testing instruments caused undesirable results, such as deflection or knee formation when preparing root canals [3].

Compared to hand tools, ultrasound tools are less effective for increasing channel space, removing debris, and planning channel walls for histological evaluation. In addition, the formation of the root canal shows a continuous narrowing after obturation.

Although some reports still indicate a lower frequency of lightning or knee formation and a similar quality of formation compared to hand dental instruments, ultrasonic root canal formation technology is not recommended in modern endodontics, especially after the development of rotating instruments.

However, ultrasonic instruments can provide better results for root canal irrigation, such as chemical disinfection, debris removal, and smear layer removal. The vibration of an ultrasonic instrument can stimulate two mechanisms in the root canal filled with irrigation solution. These are the cavitation effect and the acoustic flow reaction, which in turn have a cleaning and disinfecting effect. Although the effect of cavitation may be limited in a narrow space, such as a root canal system, the acoustic flow response from a passive ultrasonic irrigation technique can still provide better efficiency in cleaning and disinfecting the canal compared to conventional irrigation techniques using a syringe.

Moreover, these results show that during endodontic treatment, passive ultrasonic irrigation is a reliable method. With a suitable tool design, improved visualization, precise preparation properties, and high-frequency vibration, ultrasonic tools can facilitate endodontic re-treatment, including removing gutta-percha, silver point, and support, separating a separate instrument, and searching for the missing channel [3].

Compared to methods using a traditional hand instrument and solvent, the ultrasonic gutta-percha removal method produces heat from high-frequency vibration, which in turn softens the gutta-percha and makes it easier to remove it. Previous studies have shown that the ultrasonic gutta-percha removal method is faster and has similar removal effects compared to traditional hand instruments and the solvent method.

In addition, the design of ultrasonic instruments provides better visualization compared to high-speed or low-speed instruments with air turbines, and this advantage can increase the probability of success and safety when removing individual instruments or when searching for missed channels, especially when combined with use of the microscope. Ultrasonic vibration of the generated heat can diffuse through the dentin and cause necrosis from the periodontal ligament or bone tissue. Ultrasonic instruments require proper watering for cooling during the entire procedure.

Ultrasound instruments are also used in other procedures during endodontic treatment. For
example, Baumgardner and Krell demonstrated ultrasonic condensation of the gutta-percha mass is more solid and shows fewer voids compared to condensation without ultrasonic activation.

A number of authors have investigated manual condensation with indirect ultrasonic activation for the condensation of mineral trioxide aggregates (MTA), which resulted in significantly heavier and denser MTA filling in curved and straight channels than manual-only MTA condensation.

Some authors have used ultrasonic instruments to lay pastes, such as calcium hydroxide, in the root canal, which have shown better results in groups activated by an ultrasonic instrument [16].

Orthodontic treatment, ultrasonic instruments were used in 1990, when Bishara and Trulov used ultrasound techniques to detach orthodontic braces. They found that the failure rate of the bracket during ultrasonic loosening was significantly reduced to 0% compared to the failure rate of 10-35% for conventional loosening methods. In addition, in the group of ultrasonic technology, the number of failures of combination connections is significantly reduced. Although the loosening time is much longer, the ultrasonic group has a lower surface roughness.

After completion of orthodontic treatment, a smoother enamel surface can facilitate finishing preparation. In contrast, in 1995, Boyer developed an ultrasonic chisel for peeling off a ceramic bracket. This ultrasonic chisel noticeably reduces the pull-off force required to remove the brackets. However, due to the duration of treatment and patient complaints of discomfort, this experimental device is not recommended for orthodontic use.

Ultrasound instruments are also used to facilitate the setting of glass-ionomer cement during bracket bonding procedures.

In the study of the setting reaction *In vitro*, glass-ionomer cement showed a significantly shorter setting time and higher adhesion strength to the enamel surface after 60 seconds of using ultrasonic instruments during the setting procedure. There is an example in the literature demonstrating that ultrasonic excitation leads to a significant decrease in the internal porosity of glass-ionomer cement during setting.

Ultrasound instruments have many advantages in surgical applications, such as a micrometer incision that can produce an accurate and safe action that limits tissue damage, selective incision between soft and hard tissues using frequency control, and better visualization of the surgical site through instrument design. With the use of ultrasonic instruments, dental surgery improves in many aspects, such as the success rate and reduction of surgical risks. Thus, there is evidence in the literature that ultrasonic instruments used to remove the lower third molar contributed to wound healing and the formation of new bone [17].

It is shown that retrograde preparation with ultrasound instruments after surgical apicectomy has a more controlled apical preparation and a more successful result. Application with ultrasonic root resection lasts longer and results in coarser cutting surfaces compared to high- and low-speed air turbine carbide. However, research shows that preparing the root cavity with ultrasonic instruments results in cleaner and deeper root cavities, which can help retain root filling materials and effectively remove infected dentin, compared to the results of conventional high-speed processing.

In addition, ultrasound instruments accurately and safely perform an osteotomy to increase the crest of the alveolar bone, elevation of the maxillary sinus and removal of dental implants. The authors point out that implantological surgical procedures, such as bone extraction, cleavage of the crest bone, and sinus lift can be performed with greater ease and safety due to the use of ultrasonic instruments.

The use of ultrasound instruments is relatively important for dental surgery. With precise and easy-to-handle characteristics, ultrasound instruments provide a minimally invasive surgery technique that can not only minimize accidental damage to neighboring soft tissue structures, but also speed up bone ablation.

The role of ultrasound diagnostics in dentistry should not be underestimated.

The reflection of high-frequency ultrasound at the tissue interface can detect abnormal masses or damage in the human body and provide operators with real-time information. This data cannot be obtained using other radiological
diagnostic methods, such as computed tomography (CT).

Since ultrasound still has two complex aspects, namely insufficient accuracy and sensitivity to dental diagnosis, it is usually not recommended to diagnose any oral and maxillofacial pathology. The diagnostic situation can be improved by developing technologies, including a suitable detection sensor design and improved analysis software.

In 2000, Cotti et al. described echography in real time, and ultrasound imaging for the detection of periapical lesions, and in all cases of their study received an echographic image. This study proves that real-time ultrasound is a promising diagnostic method.

To compare the effectiveness of differential diagnosis of periapical lesions among ultrasound, digital, and conventional images based on simple films, Gundappa et al. studied 15 patients with periapical lesions associated with the front teeth of the upper jaw or lower jaw that required endodontic surgery. They showed that ultrasound images can be used to assess the size, content and vascular supply, as well as for pre-diagnosis, which can distinguish between cysts and granulomas.

Radiation imaging can diagnose the presence of a lesion more accurately than ultrasound. However, radiation imaging cannot determine the pathological nature of the lesion, such as whether it was a cyst or granuloma tissue, whereas ultrasound imaging can provide accurate information about the pathological nature of the lesion.

Periapical lesion is a common pathological problem. The combination of ultrasound with a powerful doppler and CT allows overcoming difficulties in histological diagnosis and differentiation between periapical cysts and granuloma tissue, which is one of the factors for evaluating the need for treatment [18].

Aggarwal et al. demonstrated that diagnoses obtained using computed tomography and ultrasound energy doppler flowmetry are consistent with histopathological data from a surgical biopsy sample.

Ultrasound can also be used to determine the location of the lesion in other anatomical structures. Some authors have used ultrasound methods to compare the proximity of a periapical lesion to the maxillary sinus before surgery.

Other authors have applied an ultrasound method to assess the proximity of the apical focus to the mandibular canal. Visualization of the tongue nerve using an ultrasound device was also demonstrated in the study [19].

Ultrasound devices can provide information about the area around the lesion before surgery, in addition to determining the distance to anatomical landmarks during surgery, by combining an ultrasound probe and a surgical osteotome.

The ultrasound method can be used to evaluate the rate of ultrasound transmission, to assess the quality of bone, and to differentiate bone types, for example, between cortical, spongy, and mixed bones. Compared to histomorphometry, cone-beam CT computer microtomography, ultrasound measurement is similar to other methods of distinguishing bone types. Tsiolis et al. It has been demonstrated that ultrasound imaging provides a better and more reproducible result when measuring the level of periodontal disease in the pig’s jaw than traditional transgingival diagnostics.

When an injury occurs, diagnosing whether a fracture has occurred is crucial, and ultrasound can be used to investigate potential fracture lines of the damaged bone through a real-time examination. Compared with CT scans and submento-vertex films, ultrasound can assess zygomatic fractures with a sensitivity of 88.2% and specificity of 100% [19].

In cases of orbital trauma, ultrasound can have a sensitivity of 77%, specificity of 89%, and accuracy of 97% for subglacial rim fractures, and specificity of 57% and accuracy of 96% for orbital fundus fractures. These results show that ultrasound diagnostics accurately visualize bone fractures and provide real-time information without irradiation [20].

Ultrasound is a non-invasive, cost-effective and painless diagnostic tool for tissue imaging, and it can be used to examine many oral lesions or structures for reasons including surgical assessment and differential diagnosis, examining the possibility of mobility by measuring bone level and thickness, and even detecting a fracture line.
4. CONCLUSIONS

Thanks to better visualization, ease of operation and precise cutting ability, the use of ultrasonic tools has increased significantly. After improvements and design improvements, ultrasonic instruments can be widely and effectively used in dental fields.

Although some issues, such as high-frequency noise, interference to cardiac pacemakers, and low cutting efficiency compared to conventional high-speed or low-speed air-turbine tools, still need to be considered. The results of previous research show that ultrasonic instruments have an extremely high potential to become a convenient and effective tool for various dental procedures and deserve future development.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES


© 2020 Sergeev et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/61509