Ultrasonography and Its Applications in Oral Medicine- An Overview

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ABSTRACT

Ultrasonography (USG) is a non-ionizing radiation technology that uses sound waves to capture images in real time. Ultrasound is the part of the acoustic spectrum characterized by sonic waves that emit at frequencies greater than the sound audible to humans, 20 kHz as human ear can hear only a limited range of sound frequencies that is between 20Hz - 20,000Hz. The piezoelectric effect and pulse-echo imaging are two basic principles that are used to generate ultrasound images. The ability of a tissue to reflect or transmit ultrasound waves in the context of surrounding tissues is referred to as echogenicity. Ultrasonography is an advanced imaging modality that scans the normal and diseased states of soft tissue and bone in the oral and maxillofacial region using sound waves. Its therapeutic benefits have made it a valuable tool in dentistry.

Keywords: Ultrasonography, Ultrasonography Applications, Oral Medicine

INTRODUCTION

Ultrasonography (USG) is a non-ionizing radiation technology that uses sound waves to capture images in real time.[1] The word "Ultra" denotes "beyond" or "excessive." The term "Sound" refers to audible sound energy. The term ultrasound means the form of sound energy beyond audible range. Ultrasound (US) is a component of the acoustic spectrum defined by sonic waves that radiate at frequencies higher than those audible to humans, such as 20 kHz, as the human ear can only hear between 20Hz and 20,000Hz.

The development of Ultrasound applications in medicine should probably start with the history of measuring distance under water using sound waves. Sound Navigation and Ranging is referred to as SONAR. Lorenzo Spallazani, an Italian scientist and physiologist, was the first to demonstrate the existence of inaudible sound in 1794. In 1880, Pierre Curie and his brother Jacques Curie discovered the piezoelectric phenomenon in some crystals, which marked a turning point in the growth of high frequency echo-sounding devices. Jean-Daniel Colladon, a Swiss physicist, used an underwater bell to calculate the speed of sound as early as 1826. Eminent French physicist Paul Langévin and Russian scientist Constantin Chilowsky created a powerful high frequency ultrasonic echo-sounding instrument. Christian Johann Doppler proposed in 1842 that the frequency of light received at a distance from a fixed source differs from the frequency emitted if the source is in the same location.[2]

In 1956, Ian Donald an Obstetrics and Gynecology introduced the Ultrasound in diagnostic medicine. Baum et al. introduced the first use of diagnostic Ultrasonography in dentistry in 1963, employing 15 MHz wave imaging to scan the internal architecture of teeth. Since then, the clinical uses of USG in dentistry have been extensively researched, with Palou et al. (1987) making the most notable contribution in the measurement of periodontal bone morphology.[3] USG is a noninvasive, nonionizing, safe, commonly available, and cost-effective advanced imaging technology used to diagnose soft tissue lesions and bone pathology in the oral and maxillofacial region.[4]

PRINCIPLE

Ultrasound is generated by two basic principles to from an image. They are as follows:

a. the piezo-electric effect
b. pulse-echo imaging

a. The piezo-electric effect

Some materials generates a pressure when distorted by an applied voltage and some generates a voltage when distorted by an applied pressure is the principle of piezo-electric effect. It expands or shrinks according to the polarity of the supplied voltage, when a voltage is employed to a crystal's faces. In turn, electricity is converted to ultrasound when the crystal echoes. The frequency of sound produced is determined by the crystal thickness. When the crystal collects an echo then the sound deforms it and a voltage is generated on its faces. The system then assesses this voltage.

Ultrasound is produced if expansion & contraction occurs more than 20000 times per second, which will last till the applied voltage is withdrawn.

b. Pulse-echo imaging

In US, images are formed by sending out a short pulse of sound in a narrow beam path and waiting for return echoes to be collected from structures that came across in the path. The transducer is a vital component of the system due to its noteworthy influence on image quality which generates and receives those sound pulses. The depth of the interface

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is determined by the delay between sending a pulse and receiving an echo.[5]

Color Doppler Ultrasound

Color Doppler Ultrasound is a tool which measures speed of blood and its flow. There are two ways for Color Ultrasound imaging that is Spectral Doppler and Color flow mode. The spectral mode examines the blood speeds of particular arteries. Color flow mode, on the other hand, evaluates vascularity by overlaying Color Doppler data on a B-mode scan image of the artery.[6]

TRANSDUCERS

The transducer is made up of a lead zirconate crystal with piezoelectric capabilities that can expand and contract in response to electrical pulses.[7] An electrical signal is converted into mechanical motion, and mechanical motion is converted into ultrasound using a transducer. This transducer emits ultrasonic waves into the body and receives sound waves that are reflected back. The ultrasound scanner receives the transducer data via a fibre optic cable, and the data is exported to a monitor to generate an image.[3] The shape, size, type, and frequency of the transducer which are necessary to obtain the field of vision appropriate for a certain application are determined by the position, size, and qualities of the objects being viewed.[7]

INTERACTION OF SOUND WITH TISSUE

Attenuation

As the sound beam traverses tissues within the body, various factors cause it to lose energy and therefore undergo a reduction in amplitude and intensity. This loss of energy is called attenuation. The four main processes, which contribute to the attenuation of the sound beam are Reflection, Refraction, Absorption and Scattering. All of the above factors affect the echoes returning to the transducer as well as the transmitted beam.[5]

INTERPRETATION OF USG IMAGE

Echogenicity

The ability of a tissue to reflect Ultrasound waves in the perspective of surrounding tissues is referred to as echogenicity. A visible difference in contrast will be displayed on the screen if structures with varying echogenicity comes together. A structure can be classified as hyperechoic (white on the screen), hypoechoic (grey on the screen), or anechoic (black on the screen) based on its echogenicity.

On the USG, bone appears black or anechoic, with a brilliant hyperechoic rim. The US beam produces an auditory shadow beyond bone since it can't penetrate it. Cartilage has a hypoechoic appearance and is more permeable to ultrasound than bone. Blood vessels can also be dark or anechoic in appearance. Muscles have a striate structure that makes them hypoechoic; fat is anechoic, while fascia and fascicles appear as hyperechoic lines. Anechoic or hypoechoic lymph nodes are visible. The honeycomb pattern is hyperechoic in the distal nerves. Without the honeycomb pattern, ligaments and tendons are hyperechoic. Tendons are more anisotropic than nerves and feature distinctive striation in the long axis view.[8]

Advantages of USG[9]

1. The USG employs non-ionizing radiation.
2. Inflammatory soft tissue is well recognized.
3. Muscle structures are more visible than they are on computed tomography.
4. The recent usage of energy and dosages in diagnostic ultrasonography has no ill effect on any physiological tissues.
5. Images can be quite sensitive and can explain high-quality discrimination between normal and diseased soft tissues.
6. It is a non-invasive procedure that causes no pain to the patient.
7. It is widely available and reasonably priced.
8. Affordability
9. Easily transportable
10. Convenient and fast

Disadvantages of USG[10]

1. At high exposure levels, USG waves can cause tissue damage.
2. Heat and sonic cavitation have teratogenic effect.
3. Due to artefacts caused by the metal, metallic implants, dental fillings, and restorations may cause visual blurring of image.
4. Poor hard tissue details.
5. Technique sensitive.
6. The images must be interpreted by an expert radiologist.

Applications of ultrasonography in oral medicine

Ultrasonography is a type of advanced imaging that scans the normal and diseased states of soft tissue and bone in the mouth and maxillofacial region using sound waves. Its diagnostic and therapeutic benefits have made it a valuable tool in Oral Medicine.[4]

1. Salivary gland tumors

Salivary gland tumors account for 1 to 3% of all head and neck cancers. Around 80% of salivary gland tumors arise from parotid gland. Ultrasound is used to establish the presence of a mass and distinguish between intra- and extra-glandular lesions. [11] Ultrasound has been proven to be able to diagnose all tumors of the salivary glands. It was also shown that Ultrasonography could detect numerous and bilateral cancers and reveal the nature of the tumor to a much larger extent than clinical examination.[12]

2. Sjögren syndrome

Normal salivary gland displays hyperechoic and homogenous tissue on USG. They may be distinguished from the surrounding muscles and soft tissue with ease. The salivary glands are essentially hypoechoic and homogeneous in Sjögren's syndrome because of the increase in size of parotid glands (i. e. sagittal diameter >20 mm). The diagnosis has a sensitivity of 60 - 90% and a specificity of 90%. Thus, Ultrasonography has become a crucial technique in the detection of Sjögren syndrome.[13]

3. Sialolithiasis

The presence of calculi within the salivary gland or duct characterizes sialolithiasis.[14] USG has a sensitivity of 80–96% for detecting calculi. An echogenic, round or oval structure of a salivary stone appears in a US image. Salivary gland stones in salivary ducts can cause the duct to distend as seen in US. Stones smaller than 2 mm, on the other hand, may not cast an acoustic shadow.[15] As a result, Ultrasonography has been shown to be a reliable method in the diagnosis of salivary gland stones.[14]

4. Oral Submucous Fibrosis(OSMF)

The number, length, and thickness of the fibrotic band in OSMF patients can be determined using USG. The fibrous bands or diffuse fibrosis are represented by enlarged hyperechoic regions in OSMF. According to a study, that examined the Ultrasonographic characteristics of the buccal mucosa in patients with OSMF, the submucosa appeared hypoechoic in the control group and had considerably enhanced echogenicity in the case group. As a result, in OSMF cases, there was increased submucosal echogenicity and diminished echo differentiation in the submucosa and muscle layer.[3] The therapeutic use of Ultrasound as an adjuvant indicates a considerable improvement in mouth opening in OSMF patients, thus it should be included in the treatment of OSMF patients.[16] The use of ultrasonography in patients with OSMF was investigated, and vascularity was measured in terms of peak systolic velocity (PSV). It was discovered that as the severity of the disease progressed, there was a direct relationship between submucosal thickness and PSV. [17]

5. Lymph nodes

Ultrasonography is a valuable diagnostic tool for evaluating lymph nodes in the neck. The size, distribution, and internal architecture of lymph nodes are measured using greyscale Ultrasonography. Doppler ultrasonography assesses the lymph node's intranodal vascular pattern and resistance.[10] The lymph nodes in lymphadenitis are swollen (axial diameter greater than 10 mm) and ovoid to spherical in form. In metastatic lymph nodes, there is increase in size, shape is round, keratinization, or cystic degeneration and heterogeneity caused by tumor necrosis inside the tumor which can all be seen on Ultrasonography. A round shape is generally regarded as more suspicious than an oval or flat shape. The presence of lymph nodes is the most significant markers in head and neck cancers and it is crucial for the treatment plan.[18]

6. *Muscle disorders*

On USG, the temporalis muscle appears as a narrow hypoechogenic band close to the medial part of temporalis fossa. The masseter muscle appears as a single, homogenous component close to the mandible. Because of its increased size and characteristic band shape, the sternocleidomastoid muscle is easily visible on USG as a solid hypoechogenic pattern. The USG method was proven to be effective in determining the thickness of the masseter muscle. In adult patients with facial palsy, Ultrasonography can be utilized to quantify the static and dynamic alterations of the face muscles. As a result, establishing a method for quantitative measurement of facial muscles in children with facial palsy would be beneficial. It was discovered that on the paralyzed side of the face, there was a reduction in muscle size during rest and contraction, as well as a higher echo intensity. As a result, facial muscle Ultrasonography is also possible in youngsters, facilitating diagnosis in children with facial palsy.[19]

7. Inflammation

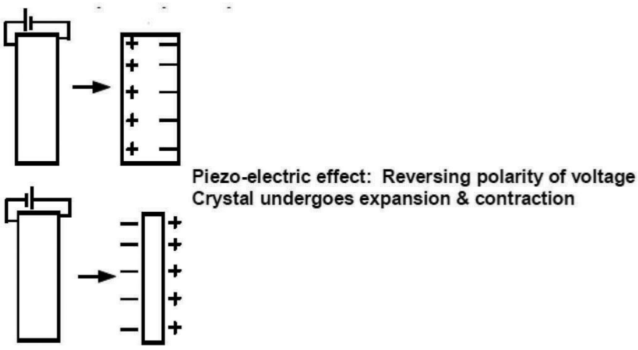
By giving direct imaging of a fluid collection, Ultrasonography can help rule out a suspected abscess. The closeness of the infection to other structures can also be assessed, assisting clinical decision making. An abscess is a soft tissue swelling surrounded by a hypoechoic region. Subcutaneous tissue swelling, increased fluid collection, and fat lobules all contribute to a cobblestone appearance in Cellulitis. Ultrasound enables for a quick decision-making and successful soft tissue infection treatment.[20] In inflammatory swellings, USG has a sensitivity and specificity of 100%, whereas clinical diagnosis has a sensitivity and specificity of 85.7 %.[10]

8. Midfacial Fractures

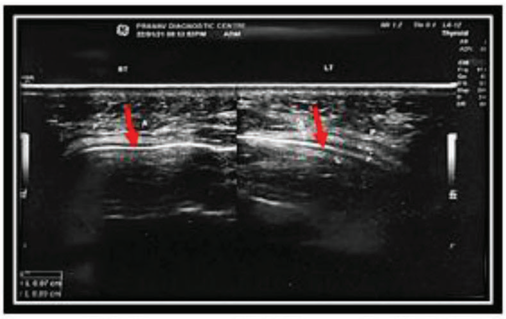
In trauma cases, USG has proved to be helpful in determining the location of a midfacial fracture. The zygomatico-orbital complex, including the infraorbital boundary, orbital floor, frontozygomatic suture, lateral or medial wall of orbit, and body of zygoma, was studied by Sinha P and David MP. They noticed that USG was accurate and reliable in imaging zygomatico-orbital fractures.[21] Ultrasound was found to be most beneficial in the imaging of the front wall of the frontal sinus and the zygomatic arch in midfacial fractures. Non-dislocated fractures, on the other hand, were difficult to identify. In some planes, the soft tissue covering of the tissues obstruct the scanning of fracture. For identifying fractures of the mandibular ramus and condyle, USG is not an additional technique along with properly obtained X-ray imaging.[10]

9. Temporomandibular disorders

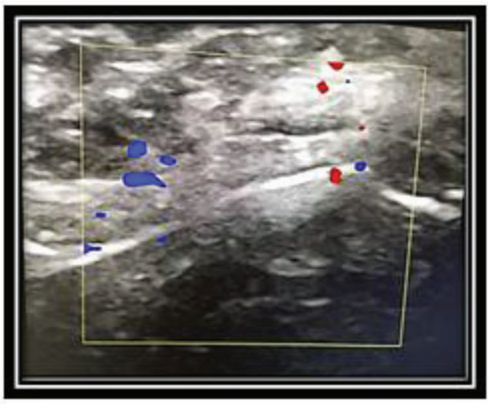
The TMJ is a complex structure that reflects sound waves in a variety of ways. The condyle head and articular eminence are hypoechoic and look black on USG, whereas the bone border is hyperechoic and appears white. Connective and muscle tissues are isoechoic, but the condyle and glenoid fossa are hyperechoic. The surface of the joint capsule, on the other hand, strongly reflects sound waves, resulting in a hyperechoic line. Hypoechoic spaces are present in the superior and inferior joint compartment. The radiologist should constantly modify the location of the transducer during imaging when the condyle translates from closed mouth to open mouth position for better visibility of the articular disc.[10] Ultrasonography has shown good specificity and can be utilized as a potential diagnostic imaging tool in patients with TMJ issues to augment clinical examination. It cannot, however, detect complex TMDs where the disc's integrity is in question.[22]



Figuer-1: Piezo electric effect

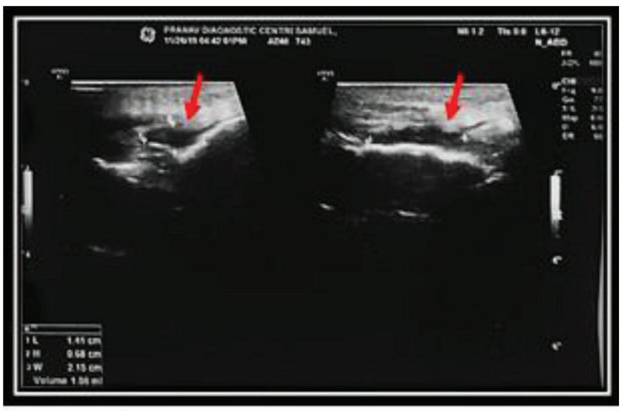


Increased submucosal thickness in OSMF



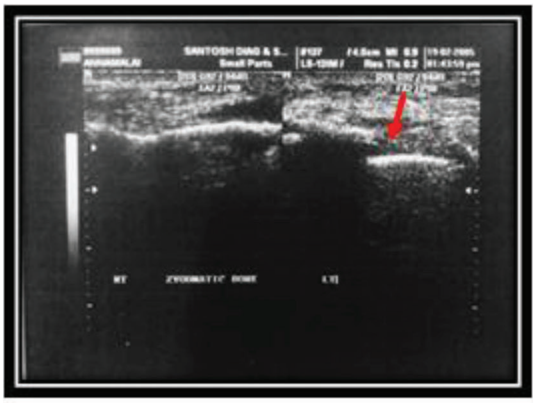
Decreased submucosal thickness in OSMF

Figuer-2: Oral Submucous Fibrosis



Submandibular Lymphadenitis

Figuer-3: Lymph nodes



Zygomatic bone fracture

Figuer-4: Midfacial Fracture

10. Oral cancer thickness

For the detection of oral cancer, intraoral Ultrasonography has been stated as an useful diagnostic technique. When a transducer was placed directly on the surface of tumors in the oral cavity, along with the lower frequency (7.5 MHz), the signal was able to penetrate deeper into the tissue. The extent of the oral cavity lesion was determined by intraoral Ultrasonography. The measurements of tumor thickness obtained from intraoral Ultrasonographic images and histological sections have a significant association. As a result, intraoral Ultrasonography might be considered as a significant diagnostic tool for evaluating lesions before to surgery and assisting in more precise surgery.[23]

11. Odontogenic tumor and cyst

Odontogenic tumors are hyperechogenic because of the homogeneity of the tumor mass.[10]A calcified mass appears hyperechoic, while cysts appears anechoic. Ultrasonography was able to correctly diagnose all cystic lesions with a diagnostic accuracy of 100%. With cysts, the USG can be utilized with the greatest precision, whereas it can be used as an adjunctive imaging modality in benign and malignant tumors. [24]

12. Implantology

USG may be useful in locating inundated implants.[10] Ultrasound could be beneficial in all three stages of treatment. During the planning phase, Ultrasound could be used to assess important structures, tissue biotype, ridge width/ density, and cortical bone thickness. It can offer feedback during surgery by detecting critical organs and bone. During follow-up visits, it might assess marginal bone level and implant firmness.[25]

13. Periodontal US

Periodontal Ultrasonography is a reliable technique for visualizing the anatomical elements necessary to assess periodontal health, even though the ultrasonic waves cannot penetrate the cortical bone with a thickness more than 1.1mm when working at 6–12MHz with a 40-millimeter linear probe.[26]

Recent Advances in Ultrasonography

Recent years have seen the introduction of 3 Dimensional

Ultrasound (3D US), which combines 2 Dimensional Ultrasound (2D US) images with a computer to create an objective 3D image that can be viewed, modified, and measured in 3D by radiologist.[5] Fusion Imaging, a combination of two imaging modalities, Ultrasound and Computed Tomography (CT) or Magnetic Resonance Imaging (MRI), as well as a combination of anatomical (CT or MRI) and molecular (SPECT or PET) imaging modalities, is another innovation in USG. [27] Ultrasound Elastography (USE), an imaging technique which is sensitive to tissue rigidity, has been developed and modified in recent years to provide quantitative measurements of tissue stiffness.[28] It can distinguish between benign and malignant salivary gland tumors, as well as identify muscular stiffness, which can be used to estimate muscle force during contraction. As a result, Fusion Imaging and Elastography have a wide clinical application in the detection of lymph nodes, salivary gland tumors, and tumor thickness assessment, providing a more specific, comprehensive picture of the disease. Modification of existing techniques for a wide variety of practical applications may serve to further expand the applications of Fusion Imaging and Elastography.[29]

CONCLUSION

Ultrasonography is a non-invasive, low-cost imaging modality that has been broadly utilized in Oral Medicine for the examination and diagnosis of many oral and maxillofacial pathologies. With recent advancements, USG will prove to be a valuable radiation-free advanced diagnostic imaging tool in Oral Medicine, with a bright future.

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