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Review Article

Ultrasonography In Dentistry – An Overview

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ABSTRACT

Ultrasonography is an advanced real time imaging modality using non ionizing radiation. It is a safe, accurate, cost efficient, technique sensitive modality mainly used to examine soft tissue structures and some hard tissue structures. 'Ultra' means beyond, 'sound' refers to audible sound energy, 'sonogram' is the image formed by ultrasound. At first, they were introduced for its therapeutic effect but now they are mainly used for diagnostic purpose. High frequency sound waves are transmitted to the body using a transducer and echoes are produced. They are detected and displaced on the screen to form image and study the structures. Piezo-electric effect and pulse-echo imaging are the two basic principles to form ultrasound. This technique can be used for the examination of bone and soft tissue, detection of major and minor salivary gland lesions, imaging temporomandibular joint, assessment of fractures and vascular lesions, examination of lymph node, measurement of the thickness of muscles and visualization of vessels of the neck, evaluation of periapical lesions, periodontal pocket depth and follow up for periapical bone healing. Excluding some limitations and executing the further studies may establish it to be a primary imaging modality and therapeutic option for various pathologic conditions of the oral and maxillofacial region.

INTRODUCTION

Ultrasonography is an advanced imaging tool used in the field of medicine for diagnosis and its

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therapeutic effects. Ultrasound is a component of the acoustic spectrum defined by non-ionising high frequency sonic waves that are not audible to humans (above 20 kHz). Ultrasound form echo patterns when transmitted into the body and form a picture called sonogram [(1)]. A frequency of 2-20 MHz is used for differentiating between normal and pathology to diagnose both bone and soft tissue lesions but its role is well established in the diagnosis of various soft tissue lesions. Ultrasonography is most commonly available, cost effective, safe, non-invasive, screening and diagnostic technology that gives "real-time" tomographic images with cross sectional information [(2)]. Administration of radiologic contrast possibly harmful to the ability to recognize and verify various organs and lesions that are located deep within the body having same density on conventional x-ray making it the second most utilized diagnostic imaging technique next to conventional radiography. Another advantage is that it is used to examine both deeper and superficial regions clearly such as tendons, muscles, joints, vessels, and internal organs. So, it is considered as an important diagnostic modality in any medical and dental facility. In dentistry, ultrasonography mainly used for the imaging of soft tissue masses, maxillofacial fractures, cervical lymphadenopathy, temporomandibular joint (TMJ), masticatory and neck muscles, periapical lesions, cyst, benign and malignant tumours and salivary gland diseases.

History

In 1880 Curie brothers were the first to discover the principles and application of ultrasound. In 1937, the use of ultrasound imaging was first described by the Dussik brothers. Use of ultrasound as a diagnostic modality in dentistry was first done by Baum et al in 1963 by scanning the internal architecture of teeth [(3)]. Since then, the clinical uses of USG in diagnostic dentistry are being researched. USG was first introduced in the field of medicine for its effect of heat and acoustic cavitation.

The Ultrasound Machine and Its Principle

The three components of an ultrasound machine are a pulse generator, transducer and an oscilloscope [(4)]. Two basic principles of ultrasound to form an image are the piezo-electric effect and pulse-echo imaging.

The principle of piezoelectric effect is that some materials create pressure when distorted by an applied voltage and some create voltage when distorted by an applied pressure. The lead zirconate titanate crystal present in the transducer can expand and contract in response to electrical pulses due to its piezoelectric properties which causes a rapid motion or oscillation producing sound waves beyond 20kHz audible range of the human ear [(5)]. The acoustical energy of this reflected sound is reconverted into electrical impulses after transmission for analysing these data, as the same crystal generates electrical currents when it is exposed to high frequency reflected waves. The Crystal produces vibrations by receiving electrical energy and transmits it as ultrasound. Thus, converts electrical energy into mechanical energy. The thickness of this crystal determines the frequency of sound produced. Now, the transducer receives the reflected echoes so it can be changed to achieve varying frequency of sound [(6)].

In pulse echo imaging, a narrow beam path of short impulses is sent and the echoes returned are collected from the structures in its path and are assembled to form an image that can be recorded and visualized [(6)]. Transducer influences the quality of image as it generates and receives these sound pulses. The site, size and quality of object to be captured determines the size, shape, type, and frequency of the transducer required. The time duration of delay between the sent impulse and received echo determines the depth of interface.

These detected echoes are displayed in four ways as A-mode, B-mode, M-mode. and B-scan mode. In the A-mode, oscilloscope displays electrically converted echo pattern as a vertical deflection. The transducer receives the reflected energy that is proportional to the amplitude of each deflection. On a calibrated tracing, deflection occurs at different points corresponding to the distance between reflecting surface and face of the transducer. In B mode, the oscilloscope shows echoes which appears as dots of light with varied brightness due to the intensity of the reflected waves. These dots are registered as linear traces. M-mode is also called as Motion-mode [7]. The B- mode tracing is moved at pre-selected speed to record the motion of the pulsatile structure. The modification of amplitude of echoes is possible and it is called intensity modulation. B-scan mode is produced by moving the transducer across the area of interest which allows cross sectional study of the body.

Interaction of Ultrasound with Tissue

When the sound beam travel across tissues within the body, their amplitude and intensity is reduced due to loss of energy. This phenomenon of loss of energy of a sound beam is called as attenuation. The four main cause for attenuation are Reflection, Refraction, Absorption and Scattering. All these factors affect the transmitted beam and echoes returning to the transducer [7].

The generation of echoes and acquisition permits to analyse physical characteristics of various materials by evaluating the depth of tissues at the level of their interface, this is studied as acoustic impedance. The term 'Acoustic impedance' is used to define the resistance of a material for propagation of the ultrasound waves and it depends on the density of the material. The difference between the acoustic impedances of neighbouring structure determines the number of reflected echoes. When the beam passes through a media with acoustic impedance similar to that, reflection does not occur. So, there is no formation of echo [8]. If the interface is between two structures with huge difference in their densities, it is very difficult to study them.

In solid materials, particles are denser and the waves are reflected more transmitting only fewer sound waves. In case of fluids less waves are reflected and more waves are transmitted in comparison to solids. Therefore, the resultant image produces an echogenic 'black' image for fluids and bright 'white' image for solids like stones and bones. A black acoustic shadow is present behind the white image as the sounds cannot pass through them [9]. In semi-fluid media, echo production is inversely proportional to the transmission of sonic waves. Air is a strong reflector of ultrasound waves making it difficult to visualize the structures.

Interpretation of Image

Echogenicity is the ability of a tissue to reflect ultrasound waves in the perspective of surrounding tissues. When structures with varying echogenicity are studied, obvious difference in their contrast will be displayed on the screen. Based on echogenicity, a structure can be classified as hyperechoic (appears white on the screen), hypoechoic (appears grey on the screen), or anechoic (appears black on the screen) [10].

Bone appears hyperechoic on the screen with a brilliant anechoic rim. Cartilage appears hypoechoic or anechoic as it is more permeable than bone. Muscle appears anechoic with few hyperechoic speckles within the structure giving it the 'starry night appearance' [11]. Fascia appears as linear hyperechoic lines. Lymph nodes are anechoic or hypoechoic. Blood vessels appear black or anechoic. Veins can be easily collapsed by the external pressure exerted by the transducer but arteries are pulsatile so, they can withstand this moderate pressure. On colour doppler method of ultrasound, blood vessels have a unique appearance. The flow towards probe appears as red and the flow away from probe appears as blue. The proximal nerves appear hypoechoic while distal nerves are hyperechoic with 'honeycomb' appearance.

Scanning Planes and Views:

They are same as the anatomical planes such as axial or transverse plane, sagittal plane, parasagittal plane and coronal plane. These standard planes can be combined with oblique direction. From a two-dimensional approach except cubes and spheres, all objects have a long axis and a short axis. Viewing a structure in long axis and short axis will provide long-axis view and short axis view respectively. Blood vessels and nerves are most commonly viewed in the short axis when the lateral–medial perspective is lost. A short axis view is changed to a long axis view by rotating the probe to 90°. An oblique view is achieved by rotating the probe between the true short axis view and long axis view.

Angle of incidence is the angle at which the ultrasound waves come across the surface of structure. Better quality of image is achieved, when the angle is placed perpendicular, or closer to perpendicular [12]. So that the reflected waves to transducer increases and only few waves are scattered away. When the waves are more parallel to the surface of the object, the image produced has less definition. The probes are tilted or rotated to produce high-definition images of the structure. This property has significant effect in clinical evaluation of produced image. When the sound beam hits the border obliquely, it gets reflected partially and the probe does not receive part of this echo making the tissue interaction more complex.

Even mild changes in the angle of incidence cause anisotropy in ultrasonography, which can be defined as the property of tissue that is responsible for dramatic changes in the reflection of ultrasound waves. This creates the well-known phenomenon called 'now-you-see-me-now-you-don't'. Degree of anisotropy varies with different structures.

DIAGNOSIS

Salivary Gland Disorders

Ultrasound is the first imaging modality of choice for diagnosing acute inflammation, chronic inflammation, sialolithiasis, tumour and Sjögren syndrome of salivary glands. The normal echogenicity of all major salivary glands is usually homogeneous and it varies from very bright to only slightly hyperechoic compared to adjacent muscles [(13).] Transcutaneous extra-oral ultrasound is used for the detection of calculi in the salivary glands. An echogenic, round or oval structure of a salivary stone appears in image. Ultrasonography is a reliable method in the diagnosis of salivary gland stones. Study of opposite asymptomatic glands is possible simultaneously. It can detect radiolucent stones which are up to 2mm. Stones > 2mm is detected as echo-dense spots with the characteristic acoustic shadow.

Oral Sub Mucous Fibrosis

Demonstrates the number, length, and thickness of the fibrotic bands and pattern of overall vascularity in the affected area. Oral submucous fibrosis shows increased hyperechoic areas representing fibrous bands or diffuse fibrosis with normal/ decreased vascularity and peak systolic velocity [(13)].

Neck and Cervical Lymph Nodes

Lymph nodes assessment in neck region is essential in head-and-neck cancer to predict the prognosis and provide appropriate treatment. Can be used to differentiate between benign lymph nodes and malignant lymph nodes [(13)]. Malignant lymph nodes appear hypoechoic with irregular margins or blurred margins which indicate frank invasive contour extracapsular and extra nodal spread with the absence of hilum.

TMJ Disorder

Articular eminence and mandibular condyle are hypoechoic, margins of the bone, surface of the joint capsule and muscles appear hyperechoic, articular disc may appear hyperechoic/hypoechoic/isoechoic. Used as diagnostic instrument in the study of TMJ disc displacement and TMJ effusion [(14)].

Joint effusion

Presence of joint effusion was detected by direct visualization of a hypoechoic area within the articular capsule or by an indirect measurement of the capsular distention, which was taken as the distance between lateral surface of the mandibular condyle and the articular capsule [(14)].

Odontogenic tumour and cyst

Odontogenic tumours are hyperechogenic and calcified mass appears hyperechoic, while cysts appear anechoic. Ultrasonography was able to correctly diagnose all cystic lesions with excellent diagnostic accuracy, 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 tumours. Benign lesions usually look well defined, homogenous and hypoechoic, while malignant lesions appear as ill-defined hypoechoic with heterogenous internal architecture

Colour Doppler USG

Measures speed of blood and its flow. Two methods used are Spectral Doppler and Colour flow mode. The spectral mode examines speed of blood in particular arteries. Colour flow mode evaluates vascularity [(14)].

Tongue carcinomas

The precise evaluation of the extent of tongue carcinoma is necessary to estimate the depth of invasion in order to predict cervical lymph node metastases. Increased depth of tumour invasion and the microvascular proliferation caused by neoplastic growth might determine proximity to blood vessels and lymphatics facilitating the tumour's ability to metastasize [(14)].

THERAPEUTIC AID

High Intensity Focused USG

This non-invasive technique uses high power transducers to emit focused high intensity beam. They target tissue volume and increase focal temperature to cause coagulative tissue necrosis. Two principles are Hyperthermia and Acoustic cavitation. Used for treating benign and malignant tumours. This technique can overcome multidrug resistance of tumour cells [15].

Magnetic Resonance Imaging-Guided Focused Ultrasound Surgery

Combination of both MRI and USG. MRI has the ability to capture temperature and provide temperature sensitive contrast which helps in guided therapy delivery system [15].

Sonoporation

Interaction between ultrasound and contrast agents temporarily permeabilize the cell membrane and allows better penetration of substances like DNA, drugs, and other therapeutic agents, from the extracellular environment [15]. Used in DNA transfer, local and targeted drug delivery, tumour cell killing, induction of apoptosis, and gene transduction.

Ultrasound-Guided Drainage of Deep Neck Space

Infections which can result in significant morbidity with potential mortality are the most common threat. Drainage using USG has become a promising therapeutic aid as vital structures are preserved during blind exploration of an abscess [15].

Extracorporeal Lithotripsy

Used to diagnose radiolucent stones. Extracorporeal lithotripsy is a non-invasive method that avoids any surgical procedure including a minimal incision of papilla or duct during interventional sialendoscopy [15]. Extracorporeal shock wave lithotripsy uses high energy shock waves to pulverizes the stones.

Ultrasound Therapy in Temporomandibular Joint Disorders

High-frequency sound waves are used to reduce pain, swelling, inflammation, promote muscular relaxation, and increase blood flow by altering capillary permeability. Low-intensity waves are used for a short duration to provide anti-inflammatory effects. Further, it increases vascular and fluid circulation, increases pain threshold, cell permeability and break in pain cycle [15].

Advantages

1) No harmful radiation exposure to both the operator and patient as it uses non-ionizing radiation [15].
2) Realtime imaging can be achieved.
3) No adverse effects produced by usage of diagnostic dosage on physiological tissues.
4) Inflammatory soft tissues and Muscle structures appear clearly compared to computed tomography.
5) When CT or plain films are contraindicated in conditions like pregnancy and patients with cervical spine injuries, ultrasound images are suggested.
6) Heavy sedation is not necessary.
7) Easily available, affordable, safe and non-invasive procedure.
8) Repeated examinations are possible.
9) Mainly useful for soft tissue examination.
10) Fewer occurrence of artifacts.
11) Patient compliance is excellent.
12) Easily transportable.
13) Convenient and fast.
14) High-definition sensitive images provide proper discrimination between normal and pathological soft tissues [15].

Disadvantages

1) Impossible to delineate complex multiple facial fractures and to distinguish between old and new fractures.
2) Ultrasound has limited use in the head and neck region because of inaccessibility of deep-seated lesions, its inability to penetrate bone.
3) Unable to Identify intracapsular fracture of mandibular condyle due to zygomatic arch overlap.
4) Difficulty in visualization of bone in acute conditions with facial oedema and empyema.
5) The images are difficult to orient and interpret as specific scan planes are not reproduced.
6) The images suffer from anatomic noise making interpretation difficult.
7) Difficulty in visualising articular disc as it is present in between two hard tissues.
8) Technique sensitive and only a radiology expert can interpret images clearly.
9) Hard tissue examination shows poor details.
10) At high exposure therapeutic dosage levels, tissue damage can occur.
11) Teratogenicity of heat and acoustic cavitation.
12) Artefacts may produce blurred image.

13) Limited field of view and lack of easily identifiable anatomic landmarks.
14) Inter observer variability
15) No quantification of function.

Artifacts

They are responsible for untrue images that does not exist in reality or false images. Some artifacts are reverberation, mirror image, or acoustic enhancement artifacts.

Recent Advances in Ultrasonography

Introduction of 3-Dimensional Ultrasound (3D US), that 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 [(16)].

4D ultrasound is also introduced recently. It allows visualization of embryonic movements two weeks earlier than 2D ultrasound [(17)]

Fusion Imaging is combination of two imaging modalities like 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.

CONCLUSION

Ultrasonography is an innovative, safe, rapid, cost efficient and portable imaging technology that has been broadly utilized in Oral Medicine for the examination and diagnosis of many oral and maxillofacial pathologies. With recent advancements and studies, it will prove to be a valuable radiation-free advanced diagnostic imaging tool with a bright future. Although some limitations did exist with USG they have been largely overcome with modifications in the apparatus and machine.

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