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ULTRASOUND IN DENTISTRY-A REVIEW OF LITERATURE

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ABSTRACT

Ultrasound is an oscillating sound pressure wave with a frequency greater than the upper limit of the human hearing range. Ultrasound devices operate with frequencies from 20 kHz up to several gigahertz. Ultrasound has found major applications in the heart, abdomen and pelvis, as well as in the head & neck because of its unique combination of safety and tomographic imaging. Ultrasound is now regarded as the investigation of choice for differentiating between solid and cystic lesions, detection of salivary gland and duct calculi.Its application in dentistry has been used to investigate salivary glands, cysts and tumors in the oral region and in diagnosis of temporomandibular joint disorders, midfacial fractures, fractures of mandibular condyle and ramus, cervical lymphadenopathy and swelling in oro-facial region. Ultrasound guided core needle biopsies recommended as a safe and reliable technique in the diagnosis of cervico-facial masses with a high diagnostic yield. This review focusses on ultrasound and it's major uses in dentistry.

INTRODUCTION

All diagnostic ultrasound applications are based on the detection & display of acoustic energy reflected from interfaces within the body. After the evolution of 2-D ultrasonography systems, the combination of advances in ultrasound image quality with progress in 3D visualization have led to the development of the 3D ultrasound which has demonstrated advantages both for diagnosis of disease and in providing image guidance for minimally invasive therapy. The development of contrast agents for ultrasound has opened new horizons for this non-invasive modality for enhancing the echogenicity of blood and for delineating other structures of the body [1]. Its application in dentistry has been used to investigate salivary glands, cysts and tumors in the oral region and in diagnosis of temporomandibular joint disorders, midfacial fractures, fractures of mandibular condyle and ramus, cervical lymphadenopathy and swelling in oro-facial region.

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Ultrasound guided core needle biopsies recommended as a safe and reliable technique in the diagnosis of cervico-facial masses with a high diagnostic yield. In history, acoustics, the science of sound, starts as far back as Pythagoras in the 6th century BC, who wrote on the mathematical properties of stringed instruments. Sir Francis Galton constructed a whistle producing ultrasound in 1893. The first technological application of ultrasound was an attempt to detect icebergs by Paul Langevin in 1917. The piezoelectric effect discovered by Jacques and Pierre Curie in 1880 was useful in transducers to generate and detect ultrasonic waves in air and water. Echolocation in bats was discovered by LazzaroSpallanzani in 1794, when he demonstrated that bats hunted and navigated by inaudible sound and not vision [2].

PRINCIPLE

Pulse-echo Principle

The transducer emitting ultrasound is held against the body part being examined. The ultrasonic beam passes through or interacts with tissues of different acoustic impedance.

Sonic waves that reflect (echo) toward the transducer cause a change in the thickness of the piezoelectric crystal, which produces an electrical signal that is amplified, processed, and ultimately displayed as an image on a monitor. Typically, the transducer serves as both a transmitter and a receiver.

Definitions [3]

1. *Amplitude* - Amplitude is the peak pressure of the wave (height). This may be simply interpreted as the loudness of the wave.
2. *Period* - Period is the time required to complete a single cycle.
3. *Frequency* - Frequency is the number of times per second the wave is repeated. The range of frequencies typically discussed here is between 2 and 15 MHz.
4. *Spatial Pulse Length* - Spatial pulse length is the distance or length of each pulse that is determined by the frequency and pulse duration.
5. *Reflection*is a form of attenuation. Reflection is the foundation upon which ultrasound scanning is based. The ultrasound beam should evaluate the anatomy of interest at 90 degrees to maximize the reflection and visualization of the anatomical structures.
6. *Refraction*is the redirection of part of the sound wave as it crosses a boundary of mediums possessing different propagation speeds.
7. *Echogenicity* refers to the amplitude or brightness display of the returning echoes.
8. If a structure presents as *HYPERECHOIC*, it is said to be more echogenic (of increased amplitude) than the surrounding anatomy.
9. *HYPOECHOIC* structures appear less echogenic (of decreased amplitude).
10. *ISOECHOIC* information has the same echogenicity as the surrounding structures.
11. *ANECHOIC* refers to the absence of echoes. Typically, fluid-filled structures appear anechoic.
12. *Axial Resolution* - It is the ability to differentiate two closely spaced echoes that lie in a plane parallel to the direction of sound wave propagation.
13. *Lateral Resolution* - Lateral resolution is the ability to differentiate two closely spaced echoes that are positioned perpendicular to the direction of propagation of the ultrasound beam.
14. *Temporal Resolution* - Temporal resolution refers to the acquisition rate of a composite frame expressed as frame rate (frames per second) or sometimes expressed as Hz (cycles per second).
15. *Contrast Resolution* - Contrast resolution refers to the ultrasound system's ability to assign a grayscale value to returning echoes of varying amplitudes.
16. *A Mode***,** or "*Amplitude*," provides one of the original evaluations of the human body using sound.
17. *B Mode***,** or "*Brightness*," converts amplitude waveforms into an image allowing better correlation with anatomical structures.
18. *M Mode***,** or "*Motion*," permits a simultaneous display of the two-dimensional (2-D) B Mode image and a characteristic waveform.
19. *D Mode***,** or "*Doppler*," is presented in a few different forms. It interprets the "frequency shift" that exists between the transmitted and received Doppler signal, while the anatomy (blood within the vessel) is moving as it is imaged.

PHYSIOLOGICAL EFFECTS OF ULTRASOUND[4]

Effect on blood flow

Continuous US can increase the blood flow up to 45 minutes after treatment because of:

- Thermal effect
- Alteration of cell permeability
- Histamine release

Pain control

a) ***Direct effect:***

- Increase pain threshold
- Decrease transmission of pain impulse along nerve fibers produce counterirritant effect (gate theory for pain inhibition)

b) ***Indirect effect*:**

It results from the other effect of US which could lead to removing the source of pain such as:

- Removing waste products and edema reduction
- Improving tissues healing
- Decrease muscle spasm
- Breaking down adhesion

Effect on Adhesion and scar tissues

Collagen has high US absorption coefficient. The thermal effect of US lead to increasing extensibility of collagen rich tissues. Thus US could be used prior to range of motion exercises and stretching exercises. Also, US is used to help improving the quality of the scar, resulting in a slightly stronger & more elastic scar.

Effect on wound healing

Pulsed ultrasound at low intensity (0.8 W/cm²) enhance healing of wound by:

- Stimulating collagen production by fibroblasts, increases the intracellular calcium ion levels improve the local blood supply
- Encouraging the growth of new capillaries
- Stimulating the MYOFIBROBLASTS to contract, giving rapid initial wound strength.

Fracture healing

The use of ultrasound accelerates the rate of fracture repair when it is delivered at low intensity (0.03 W/cm²) at 1.5MHz pulsed at a ratio of 1:4. for 20 minutes. Using higher ultrasound doses (1 – 2 W/cm²) could have an adverse effect on the fracture healing process.

CLINICAL APPLICATIONS [5]

SALIVARY GLAND IMAGING

- Usually, for normal imaging 5–12-MHz wide-band linear transducers (median frequency, 7–7.5 MHz or more) are used.
- In assessment of large tumors and lesions located in deep portions of the glands, 5–10-MHz transducers may be useful.
- Probes with a median frequency above 10 MHz may be useful in evaluation of the internal structure of salivary glands.

a) Parotid Gland

The retromandibular vein, which usually lies directly above the trunk of the facial nerve, is used as a US landmark separating the superficial and deep lobes of the parotid gland. The deep parotid lobe can be visualized only partially at US. Some areas of glandular parenchyma and possible lesions may be hidden in the acoustic shadow behind the mandibular ramus. (figure 1)

b) Submandibular Gland

The submandibular gland lies in the posterior part of the submandibular triangle created by the anterior and posterior bellies of the digastric muscle and the body of the mandible.Generally, the shape of the submandibular gland in longitudinal and transverse sections is close to a triangle.The submandibular gland may be connected with the parotid or sublingual gland by the glandular processes.

c) Sublingual Gland

On transverse sections, the shape of the sublingual gland is close to an oval. On sections parallel to the body of the mandible, the shape is longitudinal and lentiform. Along its medial part runs the excretory duct of the submandibular gland.

d) Inflammatory Disorders

In acute inflammation, salivary glands are enlarged and hypoechoic. They may be inhomogeneous; may contain multiple small, oval,hypoechoic areas; and may have increased blood flow at US. Enlarged lymph nodes with increased central blood flow may be observed in acute inflammation of salivary glands

e) Salivary Gland Abscess

At US, abscesses are hypoechoic or anechoic lesions with posterior acoustic enhancement and unclear borders. Central liquefaction may be distinguished as an avascular area or identified by means of moving debris. Hyperechoic foci due to microbubbles of gas may be seen within the abscess. Organized abscesses may be surrounded by a hyperechoic “halo”.

f) Sialolith

Sialolith in the proximal portion of the duct or in the parenchyma of salivary glands may be demonstrated only radiologically.US features of sialolithiasis include strongly hyperechoic lines or points with distal acoustic shadowing, which represent stones. In symptomatic cases with duct occlusion, dilated excretory ducts are visible.

g) Chronic Sialadenitis

Chronic sialadenitis is clinically characterized by intermittent swelling of the gland, often painful, that may or may not be associated with food. In chronic inflammation, salivary glands are normal sized or smaller, hypoechoic, and inhomogeneous and usually do not have increased blood flow at US.

h) Sjögren Syndrome

It is a chronic auto-immune disease characterized by symptoms of oral and ocular dryness and lymphocytic infiltration and destruction of exocrine glands. US features of advanced Sjögren syndrome include inhomogeneous structure of the gland with scattered multiple small, oval, hypoechoic or anechoic areas, usually well defined, and increased parenchymal blood flow. Hypoechoic or anechoic areas are believed to represent infiltration by lymphatic cells, destroyed salivary parenchyma, and dilated ducts.

i) Pleomorphic Adenomas

Pleomorphic adenomas occur most often in the parotid gland (60%–90%) in people in the fourth and fifth decades of life but may arise at any age.At US, pleomorphic adenomas are hypoechoic, well-defined, lobulated tumors with posterior acoustic enhancement and may contain calcifications.

j) Warthin’s Tumor

Warthin’s tumors appear oval, hypoechoic, well-defined tumors and often contain multiple anechoic areas. Warthin’s tumors are often hypervascularized but may also contain only short vessel segments.

ULTRASOUND OF TMJ

The imaging protocol includes transverse and longitudinal scans so the antero-superior joint compartment can be examined in coronal, axial and oblique views. A linear probe, with a frequency of 7.5–20 MHz is placed over the TMJ, perpendicular to the zygomatic arch and parallel to the mandibular ramus and tilted until the best view is achieved. When a satisfactory view is obtained, static and dynamic evaluations are usually performed at different mouth opening positions.

ULTRASOUND GUIDED BIOPSY

The use of ultrasound guidance (dynamic guidance) or ultrasound assistance (static guidance) to perform certain procedures can decrease complications when utilized correctly. Before performing any procedure under ultrasound guidance, it is imperative that clinicians have a thorough understanding of sonographic anatomy, the basic principles of ultrasound, and have practical training with phantoms or models to develop the hand- eye coordination required.

PRIMARY LESIONS OF THE TONGUE

Tumor thickness in oral squamous cell carcinoma of the tongue is highly related to the occurrence of cervical metastasis. Particularly in cases of tongue cancer, US imaging is often used to accurately estimate tumor size or thickness and to define adequate resection margins with tumor extension and deep infiltration.

DENTAL CARIES DETECTION

Tagtekin et al. compared the use of ultrasound for caries detection. All ultrasound measurements were accurate, reliable, and positively and significantly correlated between examiners. The authors showed that both methods demonstrated high repeatability and accuracy.

Matalon et al. compared traditional bite-wing radiography with ultrasound for diagnosis of proximal caries. These results showed that under in vitro conditions, ultrasound is reliable for detecting proximal carious lesions, and has a similar level of accuracy to that of bite-wing radiographs, with the advantage of not promoting ionizing radiations as is the case with X-rays.

PERIAPICAL PATHOLOGY

Cotti et al. used sonography for the study of periapical lesions. The study was conducted in 12 patients with periapical lesions of endodontic origin, diagnosed with conventional clinical and radiographic examination, and further examined using sonography at the site of the diagnosed lesions. A multi frequency (7-9 MHz) ultrasound was used.

TOOTH FRACTURE AND CRACKS

Based on the same principle used to evaluate enamel thickness and carious lesions, ultrasound imaging can also be used to detect. Dental fractures and cracks at the dentinoenamel junction (DEJ). A simulated crack was located at the DEJ. A 130 mm-thick transducer with a resonance frequency of 19 MHz was used to detect cracks in gold, amalgam and porcelain restorations. A 19 MHz transducer was used and the relative return echo amplitude from restoration surfaces was measured.

SOFT TISSUE SWELLINGS

The ultrasound features considered were shape, echo intensity, boundary, ultrasound architecture of lesion, posterior echoes, and ultrasound characteristic of tissues. Doppler ultrasound images were taken in the B-mode scan, with a 7.5-10 MHz linear array transducer.

Intergroup comparisons can be made between four different types of swellings:

1. Inflammatory
2. Cystic
3. Benign
4. Malignant.

A comparison can be made between benign and malignant neoplasms by using the criteria of boundary, echo intensity, and ultrasound architecture of lesions using ultrasound.

SPACE INFECTIONS

USG is a diagnostic tool to confirm abscess formation in the superficial facial spaces and is highly predictable in detecting the stage of infection. It has the ability to pinpoint the relation of the abscess to the overlying skin, accurately measure the dimensions of the abscess cavity, and its precise depth below the skin surface. No echoes are returned by fluids and thus USG is very sensitive in detecting fluid collections as in case of maxillofacial infections.

MAXILLOFACIAL FRACTURES

Besides the fact that computed tomography (CT) and cone-beam CT (CBCT) are the most used methods to diagnose mid-facial fractures, ultrasonography has also been explored. Ultrasound proved to be a reliable first-line imaging modality for the investigation of suspected mid facial fractures, resulting in decreased exposure to radiation. Ultrasonography was important and useful for evaluating and repositioning nasal bone fractures. A 10 MHz broadband linear array transducer is used.

PERIODONTIUM

The ultrasound energy received from the periodontal ligament is received by the transducer and the pulse-echo measurement was intuitively able to match the current method of periodontal probing. However, it results in a small echo because the acoustic impedance mismatch between the gingiva and the periodontal ligament is small. Nevertheless, there has been a report of ultrasound being limited when visualizing the interdental septum. Due to the increased frequency of ultrasound, there is low penetration in the interdental area. Bone defects: single-element focused ultrasound transducers with center frequencies ranging from 30 to 60 MHz.

MUSCLE THICKNESS [6]

Ultrasonography has been described as being capable of providing uncomplicated and reproducible access to the parameters of jaw muscle function and interaction within the cranio-mandibular system. 12-MHz-wide bandwidth linear active matrix transducer (ranging from 6 to 14 MHz). Ultrasound examination is usually applied only to the superficial tissues in the maxillofacial region because the facial skeleton shields the deep tissues.

ADVANTAGE: It can be easily performed, is non-invasive and can be repeated several times.

DENTAL IMPLANTS

Determination of tissue thickness over implants is crucial for the selection of appropriate abutments, restorative components, and treatment planning. Ultrasonic imaging, including a soft tissue matched transducer with a customized transceiver and signal processing. It is capable of measuring soft tissue thickness over bone and implants placed in bone submerged beneath soft tissue.

THERAPEUTIC USES OF ULTRASOUND

- Myofacial pain dysfunction syndrome
- Silolitotripsy of salivary calculi
- Craniofacial deformities
- Scaling of teeth
- Root canal procedure
- Amalgam packing
- Extraction of teeth
- Cleaning of instrument prior to sterilization and dentures.

DOPPLER ULTRASOUND

Doppler ultrasound is based upon the Doppler Effect. It was developed by Christian Andreas Doppler, an Austrian mathematician and physicist, in 1841. Doppler used analogies based on the transmission of light and sound. The Doppler Effect, as the theory became known, is defined as "the observed changes in frequency of transmitted waves when relative motion exists between the source of the wave and an observer".

3D ULTRASOUND IMAGING

In a 3D ultrasound examination, the 2D ultrasound images are combined by a computer to form an objective 3D image of the anatomy and pathology. This image can then be viewed, manipulated and measured in 3D by the physician on the same or another computer. Also, a 2D cross-sectional image can be generated in any orientation, without restriction, at any anatomical site, which may easily be registered with a previous or subsequent 3D image.

OTHER ADVANCES IN ULTRASOUND IMAGING: SONOPORATION

It is defined as the interaction of ultrasound with contrast agents. Ultrasonic contrast agents are used to temporarily permeabilize the cell membrane allowing for the uptake of various substances such as DNA, drugs, and other therapeutic compounds, from the extracellular environment.

DIGITAL ULTRASONIC IMAGING:

Digital control of the transducer array is used to steer the US beam and allows dynamic changes in both focusing and aperture to be made while receiving US echoes. This provides higher spatial resolution and, by reducing artifacts, improves image contrast.

ELASTOGRAPHY

Using this technique, known as elasticity imaging, or elastography, the difference between pathological tissue and surrounding normal tissue can be quantified. The images produced have very high contrast and may significantly improve lesion detection within the breast, prostate, blood vessels, and liver.

FUTURE DIRECTIONS [7]

- Gene delivery
- Osteoinduction
- Induction of dental pulp stem cell differentiation into odontoblasts
- Site specific gene delivery
- Local Drug delivery
- Targeted Drug delivery

CONCLUSION

Ultrasound imaging in dentistry has been increasingly developed and studied in recent years and it seems that this technology will gain even more space in dental practices. Nevertheless, most dentists are still unaware of the full utility of this technology. Some of it's advantages like non- ionizing radiation, non-invasive method, painless, accuracy, visualization of hard and soft tissue, and good acceptance by patients, which makes it very interesting and capable of being used in all specialties.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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