Introduction to Ultrasonography in Dentomaxillofacial Imaging

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1.1 Introduction

Sound is pressure changes or vibrations in the frequency range that are emitted in a certain environment and can be detected by the human ear. The upper limit of the sound that the ear can detect is 20 kHz. Any sound above the audible frequency level is defined as ultrasound (ultrasonic sound wave). Ultrasound imaging (USG) is based on the piezoelectric (pressure-electric) effect that was discovered in 1880 by the brothers Pierre and Jacques Curie. The piezoelectric effect working with the expansion of crystals when electrical energy is given, and thus turn electricity into sound waves. Likewise, the sound waves that were returned back after reflection by the organs converted into electrical energy with the same method.

The energy converting materials are called transducers. In USG devices, the transducer is also used as a receiver. Briefly, high sound waves are sent to organs through the skin and each organ reflects these sound waves differently. The reflected sounds are then collected again with the help of the transducer and following a live image is obtained [1]. The transducer in USG imaging is called a probe. The probe produces and emits the ultrasonic waves and transmits to the tissues where the reflected sound waves from the tissue are detected and converted into electrical signals to generate images. High-frequency sound waves lose their energy due to absorption and reflection as they pass through different tissues. Tissue depth is determined depending on the time required for the sound wave to leave and return to the probe [2, 3]. Images are generated according to tissue specifications, depth as well as the amplitude of the echoes returning from the tissues [2, 4]. The rapid vibration, which is transmitted to the patient through a conductive gel, propagates longitudinally into the body as a short, brief series of com-

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K. Orhan (ed.), *Ultrasonography in Dentomaxillofacial Diagnostics*,
https://doi.org/10.1007/978-3-030-62179-7_1

pressions (high pressure) and rarefactions (low pressure). Each ultrasound wave is characterized by a specific wavelength (distance between pressure peaks) and frequency (number of pressure peaks per second). The propagation velocity of a sound wave (i.e., acoustic velocity) is fairly constant.

in the human body (c) and is approximately 1540 meters per second. The process of transmission and reception can be repeated over 7000 times a second and, when coupled to computer processing, will result in the generation of a real-time two-dimensional image that appears seamless. The degree to which the ultrasound waves reflect off a structure and return to the probe will determine the signal intensity on an arbitrary grayscale. Structures that strongly reflect ultrasound generate large signal intensities and appear whiter or hyperechoic. In contrast, hypoechoic structures weakly reflect ultrasound and appear darker [5].

Dense and homogenous structures have little attenuation; waves pass through them and do not lose amplitude. For example, fluid-containing structures—such as vessels, distended bladder, and cysts—have minimal wave attenuation due to the fluid's homogeneity and appear hypoechoic (dark gray) to anechoic (black). In contrast, muscle and visceral organs have higher attenuation coefficients as a result of their heterogeneity and appear hyperechoic (light gray to white). The properties of the various media in human tissue and their respective ultrasound appearances are summarized in Table 1.1. [6].

In general, there are currently four modes of ultrasonography imaging: A-mode, B-mode, M-mode (motion), and Doppler. A-mode uses one transducer to "scan a line through the body with the echoes plotted on screen as a function of depth." In B-mode, 2-D images are created using linear transducers that send waves along one plane of the body. M-mode is a series of B-mode images taken in succession, creating moving images. Doppler mode measures the direction and velocity of blood flow, often used in cardiovascular imaging. The Doppler modality is useful in identifying regions of vascularity in lesions to perform fine-needle aspiration biopsies (FNAB) [7].

Advantages of this imaging technique include:

- Noninvasive.
- Nonionizing radiation is used.
- Simple.
- Real-time imaging.
- Portable machine.
- Can repeat and easy to store.
- Less artifacts.

Disadvantages include:

- Operator and equipment dependant.
- Hard tissue cannot be imaged.
- Deep structures cannot be visualized.
- Restricted to the area of the sensor, i.e., lack of imaging of the organ as a whole (tomographic cross-section only).
- Lower resolution than MR and CT [8, 9].

USG was introduced in the medical field in the early 1950s with steady development. The

Table 1.1 Acoustic impedance and attenuation coefficients for various media and their resultant ultrasound appearance (derived from Bakhru and Schweickert, 2013)

Medium	Acoustic impedance (10^6kg/[s × m^2])	Attenuation coefficient (dB/m at 1 MHz)	Ultrasound appearance
Air	0.0004	4500	Hypoechoic (high scatter)
Fat	1.3	60	Hypoechoic
Fluid	1.5	6	Very hypoechoic
Blood	1.7	9	Very hypoechoic
Liver/ kidney	1.7	90	Echogenic
Muscle	1.7	350	Echogenic
Bone	7.8	870	Hyperechoic surface with anechoic posterior shadow

requirement of ultrasound has gained importance in the medical field and slowly its use in dentomaxillofacial and dentistry is also advancing. This method will be a growing imaging modality for these fields because of its advantages such as easy-to-apply, easy to tolerate by patients, includes portable equipment, less artifact, and allows images to be stored.

1.2 What Does the Clinician Need in Terms of USG Imaging in Dentomaxillofacial Diagnostics?

Several different imaging methods have been used in Dentomaxillofacial diagnostics with the progress of technological developments. One of these imaging methods, USG is thought to be having an important potential for maxillofacial region, although not widely used especially intraorally and dentistry [10, 11]. USG is a nonionizing, synchronized, noninvasive, and cost-effective imaging technique used in medical diagnostics and intraoperative guidance in several fields of medicine. Ultrasonography (USG) is also used as a diagnostic imaging modality for the evaluation of head and neck lesions in lymph nodes and salivary glands, as well as facial bone fractures, etc. USG produces dynamic video images depicting muscular dystrophy and denervation in the chewing and striated muscles that produce voluntary contractions, as well as involuntary muscle contractions such as fasciculation [12].

Recently, ultrasound use has a growing demand in dentomaxillofacial area and dentistry for diagnosis and treatment methods. It helps to visualize superficial structures in oral and maxillofacial tissues without ionizing radiation. The anatomy of the head and neck region is complex; therefore, it is necessary to know the normal anatomy very well for the use of ultrasound in this region. Overall, the use of USG in dentomaxillofacial diagnostics are;

- Orofacial swellings.
- Salivary gland disorders.
- Periapical lesions.
- Lymph nodes.
- Intraosseous lesions.
- Temporomandibular joint disorders.
- Examination of chewing muscles.
- Congenital vascular lesions of the head and neck.
- Primary lesions of the tongue.
- Mandibular condyle and ramus fractures.
- Midface fractures.
- Detection of foreign bodies.
- Mandibular bone distraction.
- Suspicious lumps and bumps on the head and neck.

while the therapeutic use of ultrasound in the following areas;

- Myofascial pain.
- Temporomandibular joint dysfunction.
- Treatment of salivary gland stones with baskets and cannulas with/without shock wave lithotripsy.
- Bone healing and osteointegration.
- Oral cancers.
- Treatment of surface skin lesions.

Moreover, USG use in different fields of dentistry is also growing such as in orthodontics. The USG is being used in diagnosis of swallowing models, improvement of orthodontics-induced root resorptions, acceleration of orthodontic tooth movement, and for selection of appropriate mini screw selection in daily clinical applications.

1.3 Conclusion

A close collaboration between clinicians and the radiologists should be made to ensure the correct diagnosis; moreover, standardized terminology and evidence-based guidelines must be taken into consideration for correlation of clinical symptoms and imaging findings in dentomaxillofacial diagnostics. The clinicians should combine the clinical examination and then refer for imaging to the radiologists. The most important part while sending the patient is to provide as much clinical information to the radiologists which allow both sides to have a proposer diagnosis.

Throughout this book, the applications of USG in dental and dentomaxillofacial radiology diagnostics will be discussed in detail. The use of intraoral use of USG is underestimated and not well-known by many radiologists and also dental specialists. Thus, this book will focus more on intraoral and surrounding tissues for the use of USG. The book will provide a detailed discussion of the pathology, treatment, and prognosis of common and rare diseases, congenital/developmental malformations, and more in dentomaxillofacial area.

The chapters that follow fall into two categories: The fundamentals and clinical applications of USG. The technique and fundamentals of this imaging modality will be discussed in Chap. 2–5. Chapters 2–4 briefly review the fundamentals and general considerations of USG imaging. Chapter 5 will be reviewing recently developed advanced USG imaging. The rest of the book will focus on clinical applications in dentistry and dentomaxillofacial diagnostics.

Acknowledgments Some of the researches in this book were supported by Ankara University Scientific Research Projects Coordination Unit (Grant number: 17B0234004 and 18B0234002).

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