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Review

Dentistry Under the Gaze of Ultrasonography

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Abstract: Ultrasonography is a non-invasive imaging technique based on the emission and reception of high-frequency sound waves, enabling real-time analysis of examined tissues. In dentistry, its application has expanded to include the diagnosis of soft tissue alterations in the head and neck region, such as inflammatory processes, superficial lesions, and temporomandibular disorders. The technique allows differentiation between cystic and solid lesions in the mandible, as well as precise evaluation of the submandibular and sublingual salivary glands. Intraoral examinations are also feasible with this technology. The sensitivity for detecting zygomatic fractures is 88.2%, with a specificity of 100%. In periapical lesions, ultrasonography distinguishes cysts from granulomas, especially when using color Doppler, which identifies vascular structures and assesses blood flow and resistance. Beyond its diagnostic value, ultrasound has therapeutic potential, being used as an adjuvant in pain, inflammation, and edema control, and in promoting healing. Being painless, accessible, radiation-free, and low-cost, ultrasonography stands out as a promising tool in dental practice.

Keywords: Ultrasonography; Diagnostic Imaging; Dentistry.

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1. Introduction

With the aim of expanding both the quantity and quality of information obtained for more accurate diagnoses and therapeutic planning—especially in the healthcare field and, in particular, in dentistry—various imaging technologies have been widely studied. Among the main methods are computed tomography, magnetic resonance imaging, and ultrasonography (US), each with specific characteristics and advantages. US is an imaging diagnostic technique based on the emission and reception of high-frequency sound waves (ultrasound). The physical foundations of this technology were described in 1880 by the Curie brothers, who discovered the phenomenon of piezoelectricity, essential for the functioning of ultrasonic transducers. In 1937, the Dussik brothers conducted the first attempts at obtaining images using ultrasound, marking an important step in the application of the technique [1]. However, only from the 1950s onwards did consistent reports of the clinical use of US in medicine begin to emerge [2].

According to Kocasarac & Angelopoulos [3], ultrasound refers to oscillating sounds with frequencies ranging from 2 to 20 MHz, which exceed the threshold of human hearing. US, also known as echography or sonography, is an imaging technique based on the propagation and reflection of ultrasound waves in tissues. The transducer includes a piezoelectric crystal that, when stimulated, converts electrical impulses into high-frequency sound waves that are transmitted to the examined tissues. As these sound waves pass through tissues with different acoustic impedances (e.g., blood and muscle), part of the wave is absorbed and another part continues to travel through the tissues. Along this path, a portion of the sound is reflected back to the transducer, while smaller portions are scattered and lost. An echo is the part of the sound wave reflected back to the body surface, where it is collected by the transducer, reconverted into electrical impulses, amplified, processed, and displayed as grayscale images on the computer screen [3].

The diagnostic US method can be used to study soft tissues in the body without the use of radiation. It is non-invasive, considered harmless, and accessible worldwide due to its low cost [4]. In addition, US provides excellent spatial resolution and does not restrict scanning spaces, allowing the evaluation of lesions with complex geometry [5]. US is a viable option for studying the oral and pharyngeal pathways and the structures involved in swallowing. Some additional advantages include the possibility of using regular food without the need for contrast agents and/or dyes, and the portability of the device, which allows the test to be performed at the patient's bedside, for example [6].

The first report on the ultrasonographic visualization of tooth structures was published in 1963. Currently, US is used in both clinical and investigative dentistry in various situations: detection of proximal caries; assessment of periodontal space; evaluation of periodontal bone defects; measurement of tooth enamel thickness; differentiation of periapical lesions; determination of gingival thickness; and monitoring of periapical healing after endodontic surgery [7]. In recent years, ultrasound examinations have become widely applied in the head and neck region. In dentistry, US has been used in the field of endodontics, where it has become a promising tool for detecting and tracking non-invasive sinus tracts and in the temporomandibular joint (TMJ) [2, 8].

In this context, the objective of this study was to conduct a literature review addressing the feasibility of using US in dentistry.

2. Literature Review

Ultrasonography (US) was initially used as a therapeutic aid; however, it has now become one of the most common imaging methods. The use of US in dentistry has recently gained popularity due to increasing concerns about radiation doses and the high costs of imaging exams [9]. In dentistry, US—also known as real-time echography—operates at frequencies between 3 MHz and 12 MHz. The most commonly used dental display modes are amplitude mode (A-mode) and brightness mode (B-mode). A-mode ultrasound is the most basic display format, where the radiofrequency signal is plotted using a single crystal to generate a one-dimensional image, displaying echo amplitude vertically and time horizontally.

Currently, standard screen images use B-mode, in which real-time images are updated several times per second (approximately 16 scans per second), allowing for the display of moving images on the screen. By moving the ultrasound probe (transducer) across the area of interest, the anatomical plane is altered, and radiofrequency echo signals are received at each probe position, providing a real-time three-dimensional impression of the space. The transducer converts electrical energy into points of light using grayscale imaging on a monitor. A marker on the probe helps guide the user in determining image orientation, and the operator adjusts the console controls to optimize the system for different anatomical targets [3,10].

Sonograms (US images) are generated by a probe or transducer that sends ultrasound pulses into the area of tissue being examined. The lower the frequency, the greater the tissue penetration, although with reduced image resolution. Depending on the shape and configuration of the probe, different display field formats are generated. Sound waves echo through different tissues, reflecting varying degrees of sound that are recorded and displayed to the operator [1]. Lavanya et al. [11] describe ultrasound echogenicity in comparison to adjacent structures: hyperechoic (brighter), hypoechoic (darker), isoechoic (similar), and anechoic (no internal echoes) or mixed signals [11].

US can be used to diagnose various inflammatory diseases of the soft tissues in the head and neck region, superficial tissue disorders, and temporomandibular disorders. With high-resolution transducers, US can visualize internal muscle structures more clearly than computed tomography (CT). Moreover, US can safely replace CT in contraindicated cases, such as in pregnant women or patients with cervical spine injuries [12].

Compared to conventional radiography, US has proven to be a valuable technique with greater capability for differentiating cystic and non-cystic lesions in the mandibular region, as well as higher sensitivity and specificity than conventional or digital radiography and greater accuracy in identifying the pathological nature of lesions [13]. US can also be used to evaluate the submandibular and sublingual salivary glands, making it possible to diagnose parotid gland sialolithiasis, which appears as echo-dense spots with characteristic acoustic shadowing on the scan [12]. Intraoral US exams are also feasible and can be applied to assess the floor of the mouth, buccal, labial and palatal mucosa, the tongue, and lesions [1].

According to Bhaskar et al., several studies have shown that US has the potential to evaluate both hard and soft tissues around teeth, not only during treatment but also during surgery and follow-up visits. Using cross-sectional images that can be repeated over time, US allows, for example, monitoring of marginal bone levels after implant placement [14]. Additionally, US is the only available imaging technique that can be used for routine monitoring of cervical lymph node metastases. Ultrasound-guided core needle biopsy is recommended as a safe and reliable technique for diagnosing cervico-facial masses with high diagnostic yield. US is also helpful for visualizing the zygomatic arch immediately after closed reduction in midfacial trauma cases [12].

In trauma cases, US can be used to investigate possible fracture lines in the affected bone. Compared to CT and submentovertex films, US can assess zygomatic fractures with 88.2% sensitivity and 100% specificity. In orbital trauma cases, US has shown 77% sensitivity, 89% specificity, and 97% accuracy for infraorbital rim fractures, and 57% specificity and 96% accuracy for orbital floor fractures. These results indicate that US can accurately detect bone fractures, offering real-time information without radiation exposure [15].

In cases of superficial tongue carcinoma, intraoral US is particularly useful because it can estimate the depth of tumor invasion. Increased depth of invasion and microvascular proliferation from tumor growth influence the proximity to blood and lymphatic vessels, potentially increasing the risk of metastasis [16]. In endodontics, US imaging has been used to diagnose periapical lesions and differentiate cysts from granulomas. In addition to identifying the extent of the lesion, the scan can provide further information using Doppler ultrasound, helping to distinguish endodontic bone lesions from other maxillofacial bone lesions [17].

Color Doppler US was developed in 1842 by Austrian physicist Johann Christian Doppler and is used to identify vasculature and evaluate blood flow velocity and vessel resistance, along with surrounding morphology—especially in periapical lesions. Frequency shifts between emitted ultrasound waves and their echoes are used to measure the velocity of moving objects, based on the Doppler effect principle. The waves can be continuous or pulsed [1,12,18].

A study conducted by Saeed et al. [19] aimed to evaluate the effectiveness of ultrasound and color Doppler ultrasound in diagnosing periapical lesions in 26 patients aged 8–40 years. In all cases, it was possible to differentiate the lesions as cysts, abscess granulomas, or granulomas with acute exacerbation (Phoenix abscess) using US and color Doppler US. It was also possible to measure the lesions, evaluate their content, and assess vascularization in the anterior region of the maxilla and mandible and in premolar teeth. After the US exam, patients underwent surgical treatment, confirming that US and Doppler US are reliable diagnostic techniques for differentiating periapical lesions [19].

2.1 Ultrasound-Guided Drainage of Deep Neck Spaces

Infections are among the most significant emergencies a dentist may encounter, particularly in oral and maxillofacial surgeries, where they can spread through fascial planes and compromise vital structures in the head and neck region, potentially resulting in mortality. As a therapeutic option, drainage guided by ultrasound imaging has become highly promising, as it allows vital structures to be preserved—something that would not be possible during blind abscess exploration—and results in minimal to no scarring, with the procedure performed under local anesthesia or conscious sedation [20]. Biron et al. (2013) conducted a randomized controlled clinical trial comparing incision and drainage versus ultrasound-guided drainage in cases of deep cervical spaces and concluded that ultrasound-guided drainage led to reduced hospital stay, increased safety, and a 41% reduction in overall costs compared to conventional incision and drainage [21].

2.2 Ultrasound-Guided Biopsy

During fine-needle aspiration biopsy (FNAB) or cytology, ultrasound can be used to guide the procedures, enabling sample collection from non-palpable lesions, providing access to different regions of the lesion, and allowing visualization from multiple angles. This procedure is highly valued for assessing tissue conditions in the head and neck region and superficial tissue disorders of the maxillofacial area. The accuracy of ultrasound-guided FNAB ranges from 89% to 97%. Additionally, ultrasound-guided needle biopsy is considered a safe and effective diagnostic procedure [22].

Ultrasound-guided core needle biopsy (CNB) is an important technique in diagnosing salivary gland masses. US is used to guide the placement of a spring-loaded portable device that collects core tissue samples from salivary gland lesions. Compared to FNAB, ultrasound-guided CNB can provide biopsy samples with preserved architecture, enabling immunohistochemical staining and allowing for the staging and classification of neoplasms. These features are especially relevant for diagnosing lymphomas, where histopathological analysis is essential. With this diagnostic method, the sensitivity and specificity for identifying malignant salivary gland lesions can reach 96% and 100%, respectively [23].

A study conducted by Baer et al. [24] using ultrasound-guided CNB to evaluate salivary gland abnormalities suspected of lymphoma in 24 patients with Sjögren's syndrome (SS) concluded that none of the patients reported complications from the procedure. Moreover, surgical excision was avoided, along with associated risks such as facial nerve injury, fistula formation, sialocele, or unacceptable aesthetic deformity. This diagnostic protocol using CNB provided sufficient material to differentiate a range of expected pathological findings in a cohort of SS patients and helped target lesions suspected of lymphoma [24].

2.3 Ultrasound-Guided Bichectomy

In bichectomy procedures involving anatomically challenging positions of the buccal fat pad, US minimizes the risk of complications by providing real-time imaging. In a case report involving a 25-year-old patient referred for bichectomy on the left cheek, US revealed that the buccal fat pad was located deep in the masseteric region and near branches of the facial vein and transverse facial artery. Real-time ultrasound imaging allowed for guided incision and excision with maximum safety, resulting in a procedure with minimal chances of complications [25].

2.4 Ultrasound in Orofacial Harmonization Complications

Orofacial fillers have become increasingly popular in recent years due to advances in technology and new product formulations, with hyaluronic acid (HA) being one of the most commonly used. However, injecting HA or other fillers into orofacial regions may result in severe complications due to the complex facial vascular network—for instance, embolization. This can occur either from inadvertent injection into a blood vessel or from external compression due to filler expansion, which obstructs the blood supply to the region [26].

In this context, it is crucial to prevent or detect these cases early, and US proves to be an efficient method for evaluating the injection area and monitoring the dynamics of the synthetic material. With US, it is possible to observe the location and relationship of important structures—such as vessels, muscles, and glands—that may influence the injection procedure, as well as track the movement of the filler through the tissues [27].

2.5 Limitations of Ultrasonography (US)

US offers numerous advantages as a diagnostic imaging method, being non-invasive, widely accessible, and free from ionizing radiation. However, it also presents some limitations that must be considered. Among them are a restricted field of view, the possibility of low patient cooperation during the exam, and difficulty visualizing structures located behind bone tissue or in areas containing air-filled cavities. Additionally, the quality of the exam is highly dependent on the operator's skill, requiring specific training for proper image acquisition and interpretation. In deep lesions or areas surrounded by dense bone, ultrasound waves can be significantly absorbed, reducing image quality. Another challenge lies in image archiving, which can complicate orientation and subsequent interpretation. In the context of temporomandibular joint (TMJ) evaluation, the limitations are even more evident, particularly due to the difficulty of accessing deep structures such as the articular disc, whose visualization is hindered by sound wave absorption in the lateral portion of the mandibular condyle head and the zygomatic process of the temporal bone [1,9].

There are also some contraindications to US mentioned in the literature, such as: detailed evaluation of the ductal gland architecture; large or deeply growing tumors; complete visualization of the parotid gland; accurate differentiation between benign and malignant lesions; and assessment of the relationship between the lesion and the facial nerve [28].

3. Discussion

US is used to visualize internal body structures such as tendons, muscles, joints, blood vessels, and organs. In dentistry, it stands out for offering real-time imaging and being unaffected by metal artifacts from dental restorations. Another important advantage is the possibility of frequent use at short intervals when needed, especially in surgical contexts [1,3]. The main clinical applications of US in dentistry include evaluation of major salivary glands, detection of sialoliths in the ducts, examination of cervical tumors, and analysis of the vascularization of glandular inflammatory masses. Its greatest utility is related to the assessment of soft tissues, allowing for the localization and measurement of the height, width, and depth of involved anatomical structures [28].

US has also proven effective in the early detection of lymph node metastases, with monitoring recommended at intervals no longer than one month. In the therapeutic planning of tongue carcinomas, intraoral US should be considered a standard method for assessing the depth of tumor invasion. For periapical lesions, US can provide important complementary data, especially when cortical bone surface erosion is present, enabling visualization of the lesion's extent and the location of root apices [4].

Despite its diagnostic potential, the use of US in dentistry remains limited. One of the main obstacles is the lack of familiarity among dentists with this imaging modality, reflecting the absence of a solid theoretical foundation on the subject in general dental education. This gap hinders understanding of indications, image interpretation, and especially the incorporation of US into clinical routine. As a result, many professionals miss out on benefiting from an accessible, accurate, and non-invasive tool with wide applicability across various dental specialties.

4. Conclusion

Ultrasound is an evolving imaging technology that has been progressively integrated into dental research and practice. It is a non-invasive, accessible, economical, painless diagnostic tool that is free from ionizing radiation. The use of color Doppler further enhances its applicability by enabling the detection of intra- and perilesional blood flow. Ultrasonographic images exhibit high specificity for soft tissues, being capable of detecting, delineating, and characterizing alterations in structures of the dento-maxillo-cervico-facial complex, with potential applications in various specialties. Furthermore, US is also being explored as a therapeutic resource for head and neck disorders, showing promising results.

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