Review Article

The Intraoral Ultrasonography in Dentistry

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Abstract

Ultrasonography (USG) is a diagnostic method that the ultrasonic image is created by ultrahigh-frequency sound waves, which have an acoustic frequency above the threshold of human hearing. Compared to other medical imaging methods, USG has several advantages of being real time, portable, inexpensive, radiation free, and noninvasive. In the medicine, most of the USG applications are transcutaneous. However, intraoral USG has been a relatively rare application, it has recently been drawing more interest. Intraoral USG is also used in dentistry for examining the salivary glands and ducts, as well as the mouth floor, the buccal, labial, and palatal mucosa, the tongue, periodontal tissues, and periapical lesions. The main purpose of this review is to provide detailed information about intraoral USG applications in dentistry.

Keywords: *Dentistry, intraoral, ultrasonography*

Introduction

Ultrasonography (USG) is a diagnostic imaging technique based on the application of ultrasound. The principles and application of ultrasound were first discovered by the Curie brothers in 1880, and, in 1937, the Dussik brothers were the first to describe the use of USG imaging.[1] The first data on diagnostic USG in dentistry were reported in 1963 by Baum *et al.*[2] Ultrasound is the acoustic frequency above the threshold of human hearing (20 kHz). In medical practice, high-frequency pulses of sound waves (2.5–10 MHz) are used.[3]

Ultrasonography is used to view internal body structures, such as tendons, muscles, joints, vessels, and internal organs. Ultrasonic images, also known as sonograms, are produced by sending pulses of ultrasound into tissue through the use of a probe, which carries a transducer containing material that produces a piezoelectric effect. According to USG logic, the lower the frequency, the higher the penetration of tissues but the lower the potential image resolution.[3] Depending on the shape and configuration of the probe, different-shaped fields of view are generated. The sound echoes off the tissue; different tissues reflect varying degrees of sound.

These echoes are recorded and displayed as images to the operator. Since ultrasound is blocked by bone, it can be used only if there is a bony defect over the lesion through which ultrasonic waves can traverse.

Compared to other prominent methods of medical imaging, USG has several advantages: it provides images in real time, is portable, inexpensive, radiation free, noninvasive, and unaffected by metal artefacts, such as dental restorations.[2,4,5] It also allows identification of the vascularity of lesions via its power Doppler and color Doppler facilities and is capable of differentiating cystic from solid lesions; it is also helpful in differentiating benign from malignant masses.[4,5] The drawbacks of USG include limitations with respect to its field of view, such as patient cooperation and physique, difficulty in imaging structures behind bone and air, and its dependence on a skilled operator. Oral and nasal cavities, as well as the pharynx, larynx, and trachea, are nearly completely filled with air, and multiple bone barriers further complicate a USG examination.[3,6]

In addition to its use of conventional radiology techniques, modern dental radiology has recently begun to use advanced imaging techniques, such as

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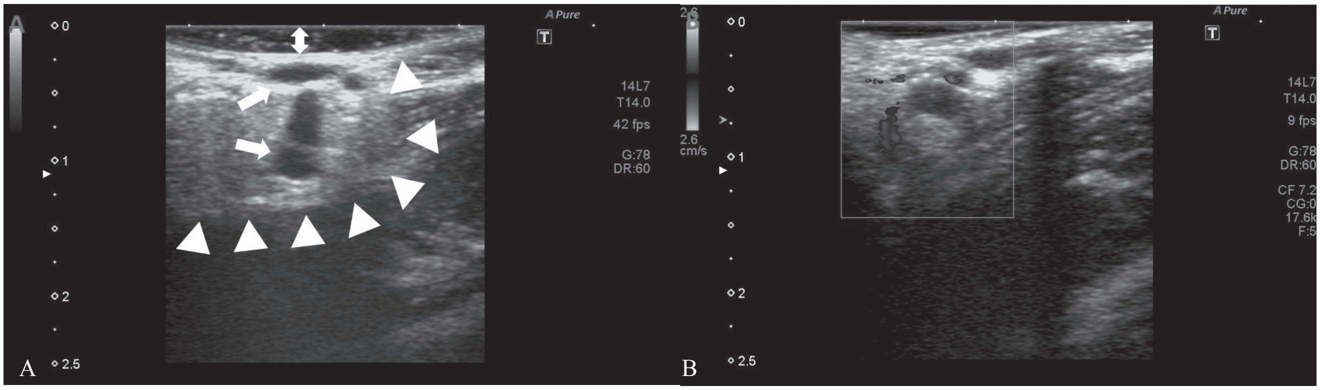

Figure 1: Sublingual gland by intraoral USG. (A) Arrow heads point the sublingual gland parenchyma, arrows point the branches of lingual artery and vein, double-headed arrow points the gel layer. (B) Colored Doppler USG of sublingual gland.

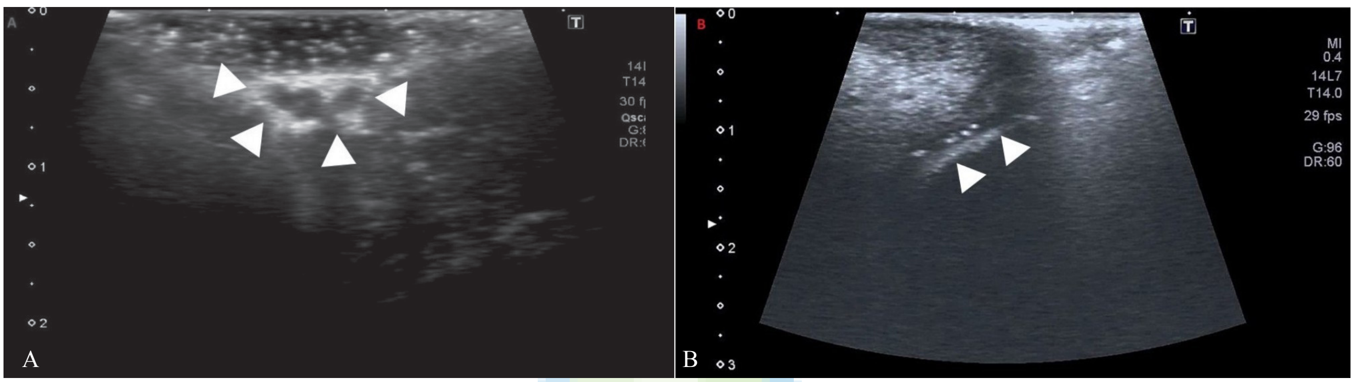

Figure 2: Wharton duct by intraoral USG. (A) Arrow heads point the orifice of the Wharton duct on caruncula sublingualis. (B) Arrow heads point the middle part of the Wharton duct and air bubbles in the saliva are seen.

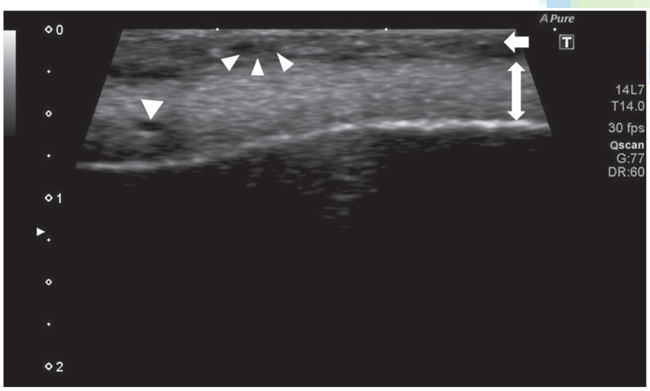

Figure 3: The labial mucosa by intraoral USG. Arrow points the epithelial layer, double-headed arrow points the muscular layer, three arrow heads point the labial gland, and arrow head points a vessel.

computed tomography (CT), magnetic resonance imaging (MRI), radionuclide imaging, and USG. Modern USG devices with high-frequency linear probes (7.5–12 MHz) provide high-resolution images in multiple planes in the head and neck regions.[4] In dentistry, USG is generally used in the imaging of maxillofacial fractures,[7] cervical lymphadenopathy,[8] various soft tissue masses,[9] masticatory and neck muscles,[10,11] temporomandibular joint (TMJ),[12] periapical lesions,[13,14] and salivary gland diseases. However, most dental radiologists do not know how to utilize USG in the diagnosis of various kinds of oral diseases, which is very disadvantageous for patients with any of the aforementioned diseases.[5]

Transcutaneous USG is used in many of the areas in medicine. In dentistry, intraoral ultrasound is rare; however, it has recently begun to draw more interest. In 1987, Yoshida *et al*.[15] described the use of intraoral ultrasonic scanning with a small intraoral transducer. The authors used it in the clinical diagnosis of oral soft-tissue lesions and reported that intraoral ultrasonic scanning was useful for that purpose. Intraoral USG makes it possible to visualize oral cavity organs, such as the sublingual gland and the submandibular duct, as well as the tongue, lips, tonsils, and soft palate, which are virtually impossible to image via conventional USG.

Intraoral USG procedures most commonly used in general medicine are performed to examine the peritonsillar area,[16–21] the retropharyngeal wall,[22] and the carotid artery.[23–25] At the present time, there are no plans for the manufacturers of USG devices to produce probes specifically for intraoral usage. High-frequency small-footprint transducers which are produced for various purposes are typically used for

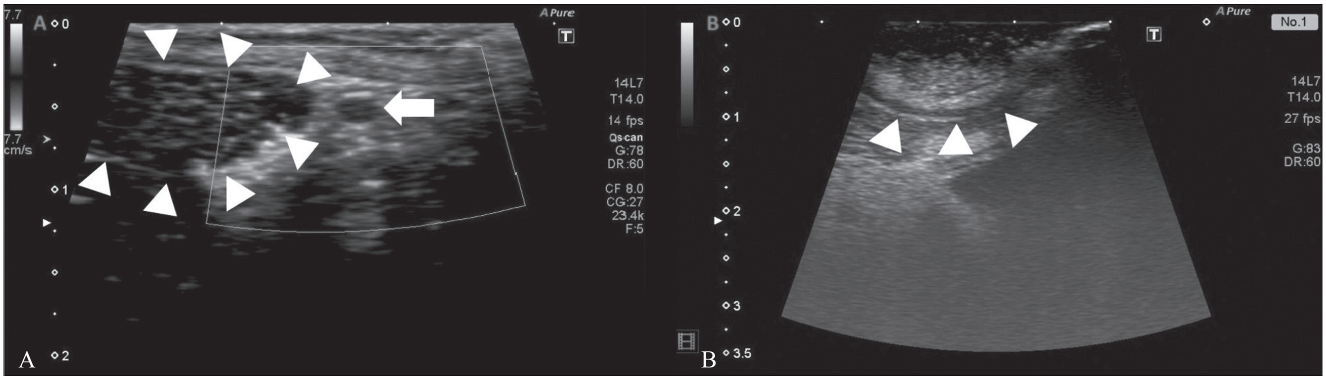

Figure 4: Buccal mucosa by intraoral USG. (A) Arrow points the orifice of the Stensen duct. Arrow heads point the adipose tissue. (B) Arrow heads point the middle part of the Stensen duct.

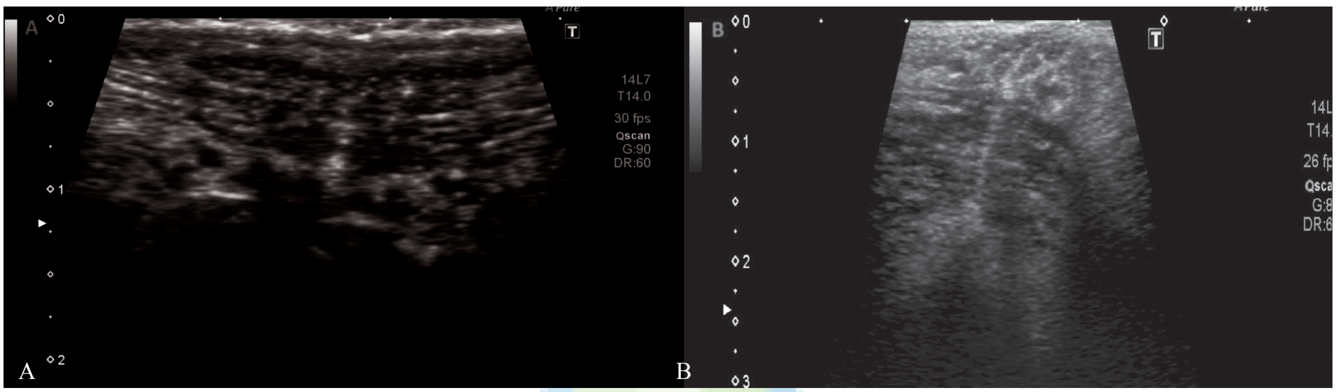

Figure 5: The tongue by intraoral USG. (A) From longitudinal plain. (B) From transversal plain.

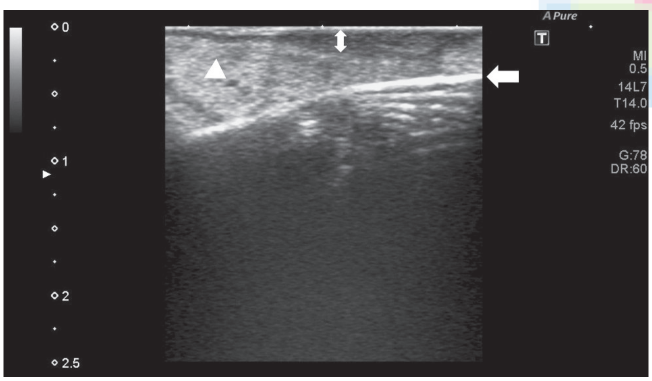

Figure 6: The hard palate by intraoral USG. Arrow points the palatal bone, double-headed arrow points the epithelial layer, and arrow head points the minor salivary gland.

intraoral USG. Therefore, applications using the existing probes may not always permit an ergonomic intraoral approach. It may be difficult for patients and physicians. Before initiating the intraoral USG examination, the patient must be sprayed with topical 1% lidocaine, and the transducer surface must be covered with ultrasound gel and wrapped with a disposable clingy wrap.[26] When performing an intraoral ultrasound scan, it is advisable start from the buccal mucosa. Starting the procedure this way will cause less discomfort to patients and minimize the gag reflex.

In the examination of oral lesions, transcutaneous USG is carried out by placing the transducer on an extraoral site. However, it is difficult to obtain high-quality images via this method. Placing the transducer directly on the surface of tumors in the oral cavity, combined with a lower frequency for deeper lesions and a higher frequency for superficial lesions, as used in this technique, allows evaluation of the thickness, echogenicity, and in addition, vascularity of lesions on Doppler application. Accurate measurement of the size and extension of tumors of the tongue, mouth floor, and buccal mucosa can easily be accomplished preoperatively with the help of intraoral USG.[27]

The main purpose of the present article is to provide information about intraoral USG applications in dentistry.

Method

A literature search was conducted via the electronic database MEDLINE (PubMed), without any time restrictions and using the term *intraoral ultrasound.* A total of 154 articles were examined individually, and only those that included the full text were reviewed. Overall, 56 articles were included in the study. These articles were carefully read, and detailed information about the intraoral USG procedures was noted. Figures have been added to the article to visually support

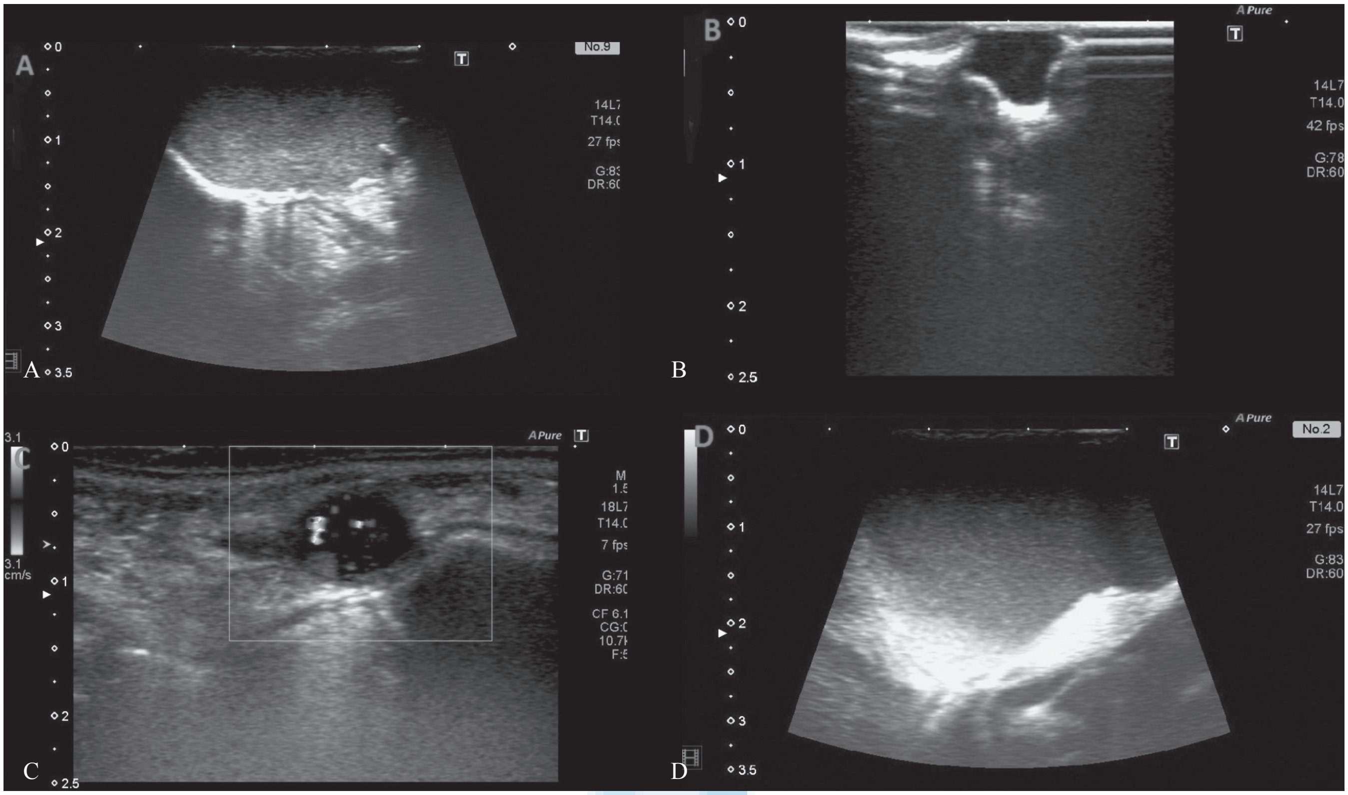

Figure 7: Various pathologies detected by intraoral USG. (A) A central giant cell granuloma on mandibular premolar region. (B) A lateral periodontal cyst on mandibular canin region. (C) A hemangioma on buccal mucosa. (D) A ranula on mouth floor.

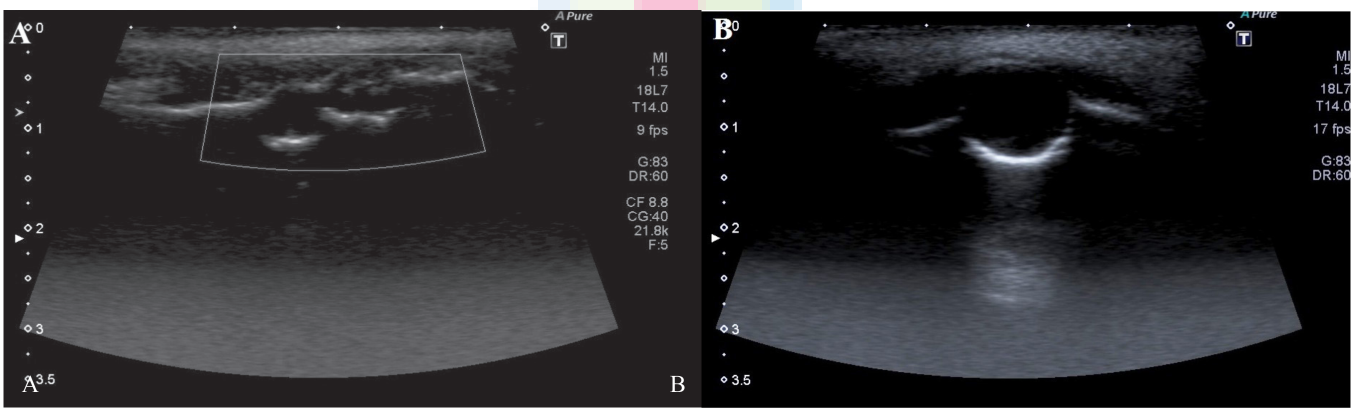

Figure 8: Periapical lesions detected by intraoral USG. (A) Two periapical granulomas associated with upper central incisors, representing a solid lesion appearance. (B) A periapical cyst with posterior acoustic enhancement.

the provided information. Images were obtained intraorally with an Aplio 300 (Toshiba Corporation, Tokyo, Japan) USG device and a 12-MHz, center frequency, hockey-stick, linear-array, intraoperative probe in the transversal and longitudinal planes.

Discussion

Intraoral USG procedures most commonly used in general medicine are performed to examine the peritonsillar area,[16–21,28] the retropharyngeal wall,[22] and the carotid artery.[23-25] Intraoral ultrasound should be considered a first-line imaging modality to confirm and to differentiate peritonsillar swelling from peritonsillar abscesses or cellulitis[17–19,21] and also tonsilloliths.[28,29]

Transoral ultrasound can also be used to visualize, sample, and localize abnormal masses in the retropharyngeal space, such as metastatic nodes in patients with a history of head and neck cancer.[6,22,30,31] Another indication for the use of transoral USG in medicine is in carotid artery examinations.[23–25,32–35] Conventional ultrasonographic assessment of the distal extracranial internal carotid artery is limited by the mandibular bone, even in patients with a low bifurcation.[23,34]

Intraoral Ultrasound Scanning Procedures In Dentistry

Examination of the salivary glands, parenchyma, and ductal systems

Patients are usually not uncomfortable during an examination of the sublingual region with a transducer. To find the sublingual gland, scanning must be started from the orifice of Wharton duct to the mouth floor [Figure 1]. Inflammatory lesions, cysts, or neoplasm can be clearly detected.

To examine Wharton duct, the transducer must be turned a bit inside from the region of sublingual gland [Figure 2]. The conventional transcutaneous approach is more limited at visualizing Wharton duct, which, in most cases, is not easily detected if it is depressed when placing the probe. Intraoral USG can visualize the submandibular duct and detect the presence of small calculi.[36,37] In addition, intraoral USG enables one to detect even the thickness of stones.

The submandibular gland is the most common site for calculi formation (about 80% among major salivary glands) because it produces particularly viscous, mucous, and more alkaline saliva with a relatively high concentration of hydroxyapatites and phosphates. The opening of the main salivary duct of the submandibular gland is narrower than the diameter of the entire duct. In addition, the duct ascends toward its opening, which leads to saliva stagnation and retention. About 85% of submandibular gland calculi are located in Wharton duct, whereas the remaining 15% lie in the gland parenchyma.[36,38] The most common site of the submandibular duct for calculi formation is the proximal segment, where the duct wraps around the posterior edge of the mylohyoid muscle at a steep angle and where 35% of the deposits are located. Of the calculi, 30% are located near the opening of Wharton duct, and 20% are located in its mid-portion.[36]

When sialolithiasis of the submandibular gland is suspected, USG might show whether the stone is located in the glandular parenchyma or in Wharton duct.[37-39] This distinction is essential in choosing the method of treatment. With respect to sialolithiasis, USG features include strongly hyperechoic lines or points with distal acoustic shadowing. In symptomatic cases with duct occlusion, dilated excretory ducts are also visible.[36,38] Some authors claim that sialoliths smaller than 2–3 mm may be overlooked because of the absence of acoustic shadow and that hyperechoic air bubbles mixed with the saliva may sometimes mimic stones.[36,38] Tiny calculi, especially in the region of the salivary duct opening, are hard to visualize during conventional USG examination of the neck. However, intraoral USG can reveal stones within the proximal portion of the submandibular duct.

Although conventional transcutaneous USG works well with intraparenchymal calculi, its sensitivity decreases for ductal stones. Via the use of classical transcutaneous USG, stones located near the duct orifice or in the mid-portion of Wharton duct may sometimes be better demonstrated when additional pressure is applied from inside the oral cavity during USG examination. When the direction of probe is shifted deeper from Wharton duct, the hilum of the submandibular gland can be visualized. Bimanual palpation can be used to find stones in the submandibular gland duct or hilum.

Examination of the lingual artery and nerve

When we go deep inside along Wharton duct, we can find various vessels on the mouth floor [Figure 1] A recent experimental study on pig cadavers demonstrated that ultrasound is well able to visualize the position and status of the lingual nerve.[3] The course of lingual nerve can be detected by intraoral USG.[40,41] A hockey-stick transducer may be used to image the lingual nerve in relation to the retromolar triangle, the ramus, and the medial aspect of the alveolar bone along the second and third mandibular molars. The prevalence of damage to the nerve as a result of extraction of third molars ranges between 0.6% and 11%. The lingual nerve does not migrate inferiorly, however, because of the alveolar bone resorption in edentulous patients; second molar implants may also cause lingual nerve injuries. It should be noted that ultrasound cannot penetrate the mandibular cortex; its role in preoperative imaging of the relationship between the lower third molars and mandibular canal thus remains obscure.[41]

Examination of the minor salivary glands, buccal mucosa, and lips

The minor salivary glands are clearly seen when the transducer is placed near the lip, and the the depth and size of any ulceration on the lips can be precisely evaluated [Figure 3]. A detailed scan can be conducted along the rest of the oral cavity because the patient feels minimal discomfort. A normal pattern of the buccal mucosa consists of homogenous echoes with a hyperechoic aspect due to the thick cortical bone of the mandible. The buccinator muscles, superficial minor salivary glands, the orifice of Stensen duct, and any soft-tissue lesion on buccal mucosa can also be detected [Figure 4].

Examination of the tongue

The tongue is a muscular organ and is scanned in a way that is similar to the scanning of other muscles.

Lesions can easily be scanned through the mobile tongue anteriorly and the tongue base posteriorly. High-resolution 7–15 MHz, linear, hockey-stick probes are often used for intraoral USG tongue evaluations[42] and the probe is placed directly on the surface of the tongue. Patients are able to tolerate a transducer placed at the anterior aspect of the mobile tongue, and they are instructed to protrude the tongue and, while it is gently held with gauze, to keep it as still as possible. The wrapping film is used for hygienic purposes; the gel is placed on the probe and plays an essential role in preventing the accumulation of air between the surface of the probe and the wrapping film. The scan direction is usually parallel to the longitudinal axis of the tongue, and a normal intraoral ultrasonographic pattern of the tongue shows homogenous echoes.[43] The transverse muscle of the tongue is located at a deeper site, and it could be well depicted with hypoechoic lines on intraoral sonography [Figure 5].[44]

Intraoral tongue USG is often used for benign or malignant tongue tumors.[6,42,44–48] The probe is gently placed on the lesion so as not to distort the mass and is moved along the tumor surface until the deepest hypoechoic region, correlating to the greatest tumor thickness is visualized. Via USG, one is able to detect the lesion apart from the normal tongue parenchyma as a well-defined hypoechoic area in comparison with the echogenic area of surrounding normal tongue tissue, and its reliability in evaluating tumor thickness against histological specimen measurement has been demonstrated.[42–44,46,47] Several studies have reported that USG is useful in evaluating the thickness of primary lesions in tongue carcinoma.[6,42,44,46–49] The difficulties in assessing oral tumor size with extraoral ultrasound measurements in some early studies have now been overcome by using high-resolution intraoral USG. Transcutaneous USG is now considered inferior to intraoral USG in tongue-tumor examinations.[50] Many reports have noted the importance of the invasive depth of a tumor as a predictive factor for cervical lymph-node metastasis.[43,46] Cases with a tumor invasive depth of greater than 3 mm had rates of lymph-node metastasis that were higher than cases having a depth less than 3 mm.[46] Patients with cervical lymph-node metastasis from oral squamous cell carcinoma have poor prognosis and will generally receive surgical excision of the primary tumor and therapeutic neck dissection. Tumor thickness should be assessed preoperatively in oral carcinoma. Palpation is also a useful evaluation, but it presents certain problems in terms of objectivity and correctness. A noninvasive and accurate method to detect the lesion and measure tumor thickness before starting therapeutic procedures will be useful. A study by Shintani *et al*.[48] showed good correlation between thickness determined by intraoral ultrasonographic measurement and histologically proven thickness. Other methods for evaluating the extent of oral carcinoma include CT and MRI, and intraoral USG;[43] however, the superiority of USG over CT and MRI to measure tumor thickness within 1 mm has been shown.[42,43,48] The tumor's vertical depth of invasion, like an iceberg, is much more difficult to assess both preoperatively with CT or MRI and clinically at surgery, thus inadequate resections may occur.[50] However, occasionally the exact thickness cannot be measured by intraoral USG due to the position of the probe and the orientation of the lesion.[43]

While examining tongue lesions via intraoral USG, blood flow response during posterior echo strengthening and Doppler USG may indicate infiltration of blood vessels, lymph ducts, or both. The major focus of the studies using intraoral USG has been the measurement of tumor thickness. Not only is the invasive depth of the tumor useful as a predictor of cervical lymph-node metastasis, but the presence of blood vessel infiltration and lymph-duct infiltration can also be considered factors in the prognosis of cervical lymph-node metastasis.[46] Few studies have described the use of USG (including intraoral USG), and the assessment of internal echo and marginal echo, as well as optimal assessment methods for this practice, have yet to be established.[46] The relationship between the ultrasonic images of oral tongue cancer and histopathological features has not been elucidated. Another drawback to USG is its status as a highly operator-dependent technique. Therefore, some researchers have attempted to develop computer-aided diagnostic systems that can assist inexperienced operators to avoid misdiagnosis.[48]

Tongue cancer frequently occurs in the margin of the tongue;[44] in such cases, the probe can easily be placed at the lesion by pulling the tongue to anterior and opposite side of the lesion. The ventral aspect close to the lingual frenulum can also be readily evaluated by elevating the tongue. If the tumor exists posterior to the vallate papilla, it is impossible to perform intraoral USG. If patients have limitations associated with mouth opening, intraoral USG is also difficult to perform. However, tongue cancer, unless it invades the masticatory muscles, usually does not cause limitations of jaw opening.[44]

Intraoral USG could demonstrate sequential change of the primary site of the tongue cancer, and it has also been found useful in detecting recurrent tumors and posttreatment changes. It can depict the sequence changes of the tongue after radiotherapy, and it is thus beneficial in the confirmation of clinical findings associated with either radiation ulcers or recurrence.[44]

Examination of the Hard/Soft Palates

We can examine the mucosal lining and its depth, as well as changes affected by neoplasm or ulcers by scanning the gingiva and adjacent parts in addition to the hard/soft palates. Both B-mode and A-mode images scanning yield images of sufficient quality for measurements of mucosal thickness with intraoral USG [Figure 6].[51] The tissue-reflected signals vary with the keratinized nature of the epithelium (gum or mucosa) and may reflect the epithelial projection in connective tissues (epithelial rete pegs). The keratinized gingiva reflection appears to have a distinct echogenicity compared to the mucosa.[52] Considered the best initial investigation technique for the evaluation of palatal masses, USG is also acknowledged to be quite useful in conducting preoperative evaluation in patients with small palatal tumors less than 3 cm in diameter.[30] USG imaging of palatal regions leads to measure the thickness of the potential donor site for subepithelial connective tissue graft or to choose a suitable orthodontic anchorage screw.[52]

Intraoral USG is also a useful imaging technique in evaluating the nature of suspicious masses of the palatal minor salivary gland. The ultrasonic, well-delimited margins of the palatal tumors are related to the presence of a histological capsule, and posterior echo enhancement shows defects in the palatal bone.[53] Regarding salivary gland tumors, the smaller the gland, the higher the proportion of malignant tumors: the rate of malignancy in the parotid is 20–25%; it increases to 40–50% in the submandibular gland and to 51–80% in the sublingual and minor salivary glands.[27] However, intraoral USG of the palate is problematic because of the dome shape. Moreover, it is difficult to perform a full approach with linear probes to in this region, particularly in patients with narrow palates; small-footprint convex probes may be more appropriate. However, their frequency remains too low for use in superficial examinations.

Examination of periodontal tissues

The evaluation of periodontal tissues can be done through clinical examinations, such as probing depth, assessment of gingival recession, and tooth mobility, as well as through complementary methods, such as radiological examination, blood tests, and microbiological analysis. Radiological examinations, such as bitewing and panoramic radiography, are cost-effective; however, exposure to ionizing radiation and the lack of information about bone resorption from the buccal and lingual surfaces of the teeth represent significant.[54] Periodontal changes can be assessed more accurately using new imaging techniques, such as cone-beam CT, optical coherence tomography, optical spectroscopy, and USG.[52,54,55] Disadvantages of cone-beam CT includes its relatively high level of radiation exposure and lack of information about soft tissues. Optical coherence tomography is rather limited due to reduced penetrability into the tissues.[55]

Periodontal USG is a reliable, noninvasive, and cost-effective method for identifying anatomical elements necessary for obtaining accurate periodontal diagnosis of the examined area.[47] Recent studies have shown the validity and reliability of USG in the measurement of not only gingival thickness but also of other periodontal structures that cannot be assessed through inspection and palpation.[52,54–56] Linear, small-footprint, high frequency (40 MHz) transducers are used for periodontal USG.[54,55] On the ultrasound image, the following micrometric level measurements may be performed: gingival sulcus depth, free gingival thickness, width of the periodontal space in the most coronal position, distance between marginal gingiva and alveolar crest, height of the clinical crown, and height of the anatomic crown.[55] Furthermore, with respect to implantology, the bone level and the thickness of soft tissue around implants are measurable by intraoral USG.[52]

On buccal surfaces, it is quite easy to obtain the necessary information for periodontal diagnosis, whereas on the lingual surfaces, if the size of future transducers are better adapted, the necessary information will very likely be obtained. For now, with the existing ultrasound devices, it is difficult, or even impossible, to examine the periodontal tissues on proximal surfaces.

Examination of periapical diseases

Conventional and digital radiography enable the diagnosis of periapical diseases but not their nature, whereas USG imaging with color Doppler and power Doppler is superior to conventional intraoral radiographic methods for diagnosing the nature of periapical lesions in the anterior jaws, which is of importance in predicting treatment outcome.[13,25] Conventional root-canal therapy is the main treatment modality for periapical granuloma, but it has no benefit for periapical cysts because true cysts are less likely to be resolved by conventional root-canal therapy and require surgical intervention.[13] Linear, regular-size, multifrequency USG probes at an average frequency of 8–11 MHz may be used for this purpose.[13,57] Possible fenestration and thin anterior bone permits the capture of USG images in intraosseous jaw lesions [Figure 7]. Both transverse and longitudinal scans may be obtained by placing the ultrasound probe intraorally in the buccal sulcus overlying the apical area of the affected tooth. However, intraoral scanning is not possible if the patient's vestibule is too shallow.

Periapical cysts are viewed as hypoechoic, well-contoured cavities surrounded by reinforced bone walls and filled with fluid, with no evidence of internal vasculature on color and power Doppler examinations. Periapical granulomas are viewed as poorly defined solid lesions that are clearly corpusculated (hyperechoic/echogenic) or have both corpusculated and hypoechoic areas, and that exhibit a rich vascular supply on color and power Doppler examinations [Figure 8]. However, intraoral USG examination is limited to the anterior aspects of the jaws, as the presently available probes are not ideal for use in the posterior jaws in areas of thick cortical plates. Further research is required for the development of suitable probes for the posterior jaws.[13,57]

Conclusion

USG is a noninvasive and easy-to-use diagnostic tool. It can create remarkable images. Intraoral USG makes it possible to visualize oral cavity structures, such as the sublingual gland and the submandibular duct, lingual artery and nerve, the tongue, lips, tonsils, and soft palate, which are virtually impossible to image via the use of conventional USG. Thus, intraoral USG can be used to imaging of oral cavity structures.

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Conflict of interest

There are no conflicts of interest.

Human and animal rights statement

This article does not contain any studies with human or animal subjects performed by any of the authors.

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