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Diagnostic applications of ultrasonography in maxillofacial region

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Abstract
Ultrasonography (USG) as an imaging modality in dentistry has been extensively explored in recent years due to several advantages that diagnostic ultrasound provides. Ultrasonography is a technique based on sound waves that acquires images in real time without the use of ionizing radiation. Ultrasonography is used as an imaging modality for diagnosing many maxillofacial diseases and disorders. It is an inexpensive, easy to use and non-invasive technique, thereby eliminating the harmful effects of ionizing radiation. The application of USG in diagnosing cervical lymph node metastasis, oral sub mucous fibrosis, soft tissue calcifications in carotid region, temporomandibular disorders and salivary gland pathology etc. has been explored in recent years.

USG has a promising future as a diagnostic imaging aid in all specialties in dentistry. This review will enlighten the diagnostic applications of USG in maxillofacial region.

Keywords: Ultrasonography, Diagnostic aid, Maxillofacial applications

Introduction
Imaging has an important role in diagnosis of maxillofacial diseases. Various modalities used for maxillofacial imaging are Conventional Radiography, Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Ultrasonography (USG) etc. More advanced techniques include Nuclear Medicine, Positron Emitting Tomography (PET), Single-photon emission computed tomography (SPECT). Of these modalities, USG is an easy to use technique for detection of superficial soft tissue pathologies in Oral and maxillofacial region. It is recognized as one of the most risk free and easy to use methods of evaluating any disease affecting the human body.

Principle
Ultrasonography is a technique based on sound waves that acquires images in real time without the use of ionizing radiation. The phenomenon perceived as sound is the result of periodic changes in the pressure of air against the eardrum. The periodicity of these changes lies anywhere between 1500 and 20,000Hz. By definition, ultrasound (US) has a periodicity greater than the audible range. Diagnostic ultrasonography (sonography) uses vibratory frequencies in the range of 1 to 20MHz.

The ultrasound signal transmitted through a patient is attenuated by a combination of absorption, reflection, refraction and diffusion. When the frequency of the sound waves is higher, the image resolution will also be higher but there will be less the penetration of the sound through soft tissues. Fraction of the beam that is reflected to the transducer depends on the acoustic impedance of the tissues, which is a product of its density (and thus the velocity of sound through it) and the beam's angle of incidence. Because of its acoustic impedance, a tissue has a characteristic internal echo pattern.(1)

Tissues that do not produce signals, such as fluid-filled cysts, are said to be anechoic and appear black. Tissues that produce a weak signal are hypoechoic such as malignant metastatic lymphnodes, whereas tissues that produce intense signals such as ligament, skin, needles or catheters are hyperechoic and appear bright. Areas with the same acoustic properties of the surrounding tissues are isoecoic.

There are various modes of USG namely A-mode, B-mode, M-mode and D-mode. A-mode or amplitude mode is not used frequently and rarely used only in ophthalmology. B-mode or brightness mode is basic mode which is important in diagnostic USG. It produces different scales of grey on the basis of different echogenicity of reflected waves. M-mode or motion mode is extremely valuable for accurate valuation of rapid movements. It has excellent temporal resolution. D-mode or Doppler mode is based on the Doppler Effect i.e. change in frequency (Doppler shift) caused by reciprocal movement of sound generator and observer.(1) Power Doppler ultrasonography is the newer technology that displays the strength of Doppler signal in colour rather than the speed & direction information. It is three times more sensitive than Colour Doppler USG for detection of flow particularly useful for small vessels with low velocity flow.

Applications of USG in Maxillofacial region:
In general, USG has role in
1. Salivary Gland Pathology.
2. Internal Derangement of TMJ
3. Soft tissue lesions like Masseteric hyperplasia
4. Cervical lymphadenopathy.
5. Carotid artery calcifications.
6. Infection of maxillofacial region.

7. Oral sub mucous fibrosis.
8. USG in Diagnosis of Oral Vascular Lesions
9. Assessment of Periodontal and Periapical lesions.
10. USG guided Fine needle aspiration.

1. **Salivary gland Pathology**

Salivary gland tumors: The most common benign salivary gland tumours are pleomorphic adenoma, adenolymphoma, basal cell adenoma, myoepithelioma and papillary cystadenoma. The most common malignant salivary gland tumors are mucoepidermoid carcinoma, adenoid cystic carcinoma, acinic cell carcinoma and adenocarcinoma.[2] Intra-glandular mass lesions are hypoechoic when compared with surrounding homogeneous echogenicity of the normal gland parenchyma. Benign lesions tend to be small, well defined, whereas malignant lesions are usually irregular and have heterogeneous internal structure.[3,4] Salivary gland strictures cannot be visualised on routine USG where Sialography is an important diagnostic aid.[5]

Salivary gland calculus: The first use of ultrasound to identify and locate a parotid calculus was reported by Pickrell in 1978. Transcutaneous extra-oral ultrasound was introduced as a simple and safe imaging technique for the detection of calculi in the salivary glands (Fig. 1). It was found to be as effective as sialography in identifying calculi of 2 mm in diameter. Contemporary innovative small high frequency ultrasound probes allow access to the ducts both in the submandibular and parotid glands *via* an intraoral approach.[6]

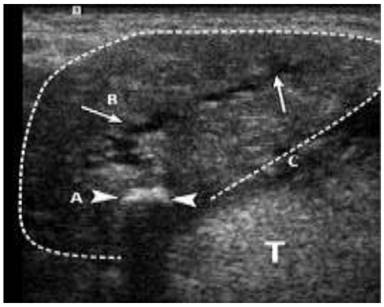

Fig. 1: USG image of a submandibular gland showing the sialolith as hyperechoic (arrows A) above the stone the gland duct is dilated which is hypoechoic (arrows B) in the inflamed parenchyma of submandibular gland which appears hypoechoic and inhomogenous (dotted line C)[7]

2. **Internal Derangement of TMJ:** The TMJ region consists of diverse structures that reflect sound waves differently. Bone tissue, represented by the head of the condyle and the articular eminence, is generally hypoechoic and appears black, however the margin of the bone is hyperechoic and appears white in ultrasonography images. Connective tissue, represented by the joint capsule and the retrodiscal tissue; muscular tissue, represented by the lateral pterygoid and masseter muscles, are isoechoic and appear heterogeneously grey in ultrasonography images as can be seen in (Fig. 2). However the surface of the joint capsule, as well as the surface of the muscles, highly reflects the sound waves generating a hyperechoic (white) line. Empty space and water such as the superior and inferior joint spaces, are hypoechoic and appear black in ultrasonography images, however, these anatomic cavities are virtual because the opposing surfaces are in contact, and usually not detectable, unless effusion is present. Joint effusion can be detected indirectly by measuring the distance between the two articular surfaces/ capsular width.[8,9,10]

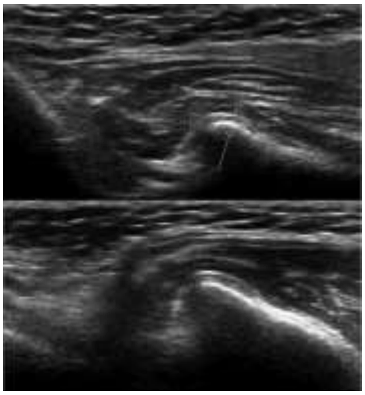

Fig. 2: USG image showing

A. Closed Mouth: The mandibular condylar head and glenoid fossa are hyperechoic curved lines and the articular disc (arrows) is present between both with displacement of disc anteriorly over madibular condyle.

B. Open mouth: The articular disc (arrows) is displaced anteriorly is seen as hypoechoic band over head of mandibular condyle[11]

3. **Soft Tissue Lesions like Masseteric Hypertrophy:** Masseteric hypertrophy usually presents as a relatively firm, painless, pre-auricular swelling, but may cause considerable diagnostic difficulty. On Ultrasonography examination thickness of the masseter muscle at rest and at maximum clenching position can be recorded.[12]
4. **Cervical lymphadenopathy:** The lymph node staging plays an important role in head and neck cancer patients. The N-staging and the localization of metastatic lymph nodes are mandatory for the choice of therapy. However, clinical examinations are unspecific and do not yield to satisfactory results. Therefore, radiology plays an important role in staging the lymph nodes in patients with oral cancer.

In USG examination, a linear transducer with a high frequency around 10 MHz or more should be used. B-mode is used for the delineation of the shape and internal structure of the lymph nodes. Transverse and longitudinal planes are obtained in standard investigation. On USG, lymph nodes are in general depicted as low echogenic oval or round structures. An echogenic hilum, containing vessels and fat, is seen as a central area of higher echogenicity (Fig. 3). Doppler sonography is performed for investigation of vessel structures and vascularity. The value of Doppler USG criteria (avascular pattern, scattered pattern, peripheral vascularity) as an adjunct to differentiate between benign and metastatic lymph nodes has been reported.(13)

Fig. 3: USG image showing typical malignant node enlarged, roughly rounded, hypoechoic and inhomogeneous, with no visible hilum

In oval-shaped lymph nodes, a hyperechoic linear structure is seen going into the lymph node. This is the fatty hilum which contains the vessels supporting the lymph nodes.(11) In benign lymph nodes on a longitudinal section, these vessels are seen as a linear structure which is dividing regularly.(14)

The characteristics of metastatic lymph nodes that can be depicted are increased size, a round shape, and heterogeneity caused by tumor necrosis, keratinization, or cystic degeneration inside the tumor. The shape of the node is used by several authors. In general, a round shape is considered more suspicious than an oval or flat shape. Grouping of lymph nodes is used as a criterion by several authors. Whereas necrosis or cystic degenerations are very reliable criteria for lymph node metastases, those which are unfortunately not visible in every metastatic lymph node.

USG criteria used in differentiating benign vs. malignant lymph nodes:(15)

Criterion	Benign	Malignant
B scan criteria		
Size	Small	Large
Shape	Oval	Rounded
Hilum	Present	Absent
Echogenicity	Moderate or low	Marked hypoechoic
Margins	Sharp	Irregular, blurred, angular & invasive
Structural changes • Focal cortical nodules • Intranodal necrosis • Reticulation • Calcification • Matting	Absent	Present
Soft tissue edema	May be present	Absent
Doppler Criteria		
Flow	Absent	Present
Vessel location	Central	Peripheral
Vascular pedicles	Single	Multiple
Vascular pattern	Regular	Chaotic
Impedance values	Low	High

5. **Carotid artery calcifications:** Cerebrovascular accidents (CVA) are the third most leading cause of death globally. One-half of all strokes are believed to be the result of atherosclerotic disease at the carotid bifurcation. USG can diagnose carotid calcifications in which location, number, size, shape, borders of calcifications along with condition of artery, thickness of intima media complex hemodynamic alterations, flow velocity & spectral patterns can be assessed(19) (Fig. 4).

Fig. 4: Color Doppler USG of right carotid region showing internal carotid artery with an Echolucent atherosclerotic plaque (arrow) causing stenosis of internal carotid artery[20]

6. **Infections of maxilla facial region:** USG is a valuable diagnostic as well as therapeutic help in the management of superficial fascial space infections. Sometimes clinical diagnosis alone is difficult to differentiate between cellulitis and abscess; in such cases USG provides accurate imaging of the superficial structures of head and neck region, delimited medially by a bony skeleton. Compared to clinical examination, ultrasound imaging is much superior in defining the exact location of abscess because of its real-time processing.

With proper case selection, traditional open surgical incision and drainage can be avoided. B-scan sonography is non-invasive diagnostic technique that should be used to supplement clinical examination in patients with inflammatory soft tissue swellings of many regions in head and neck. It can be used to help locate abscess cavities and thereby give hints for the surgical approach. It can be used to follow the course of the disease and its response to the nonsurgical treatment. Though USG cannot differentiate an abscess from surrounding blood vessels, but combination of colour Doppler ultrasonography with grey scale has solved this problem. The target of colour Doppler imaging is the moving blood cells within the blood vessel. The vessels of the inflammatory tissue which has a higher blood volume due to increased permeability of the vessel wall are depicted as a colour flow signal. Blood flowing towards the US transducer is displayed as red and that moving away from transducer as blue. In contrast the retained pus which does not contain flowing blood cells is delineated as no colour flow signal.

This property of Doppler ultrasonography allows it to differentiate blood vessels from static regions of images. CT and MRI are effective in diagnosing inflammatory conditions and choice between these two techniques usually depends on the area involved. However, both techniques are expensive. CT exposes the patient to large doses of radiation especially if repeated follow-up examinations are to be performed. Artefact produced by bone and metal degrade images around the face, poor contrast between the various soft tissues.

The major disadvantage of MRI is the prolonged time for image acquisition, and also the image may suffer from the effects of the patient motion. The high static magnetic field also poses a danger to those individuals with cardiac pacemakers, neurostimulator units and intraocular therapeutic devices.[21]

7. **USG in Oral Submucous Fibrosis (OSMF):** Oral Submucous Fibrosis (OSMF) is a precancerous condition and predominantly seen amongst betel quid chewers in south Asian countries. It demonstrates the number, length, thickness of the fibrotic bands and pattern of overall vascularity in the affected area. OSMF showing increased hyperechoic areas (Fig. 5) representing fibrous bands or diffuse fibrosis with normal/decreased vascularity and peak systolic velocity. USG is a valuable modality for evaluating fibrosis and vascularity status during & post treatment period thereby helps to monitor the efficacy of the treatment instituted. USG monitoring during treatment helps to alter and assess the efficacy of treatment schedule instituted. In some OSMF cases, it evaluates feeble fibrotic bands in clinically appearing normal buccal mucosa. USG helps monitoring the progress or otherwise of the lesion.[23]

Fig. 5: USG Image of the right buccal mucosa, showing the hyper echoic oral mucosal lining (white arrow), the hypoechoic fibrous bands above which is the buccinators muscle

8. **USG in Diagnosis of Oral Vascular Lesions:** High resolution and high frequency Color Doppler USG is a reliable non-invasive imaging tool that helps to identify the presence, quantity and type of Doppler flow, and to identify feeding and draining vessels. In addition, Color-Doppler spectral curve analysis of a blood vessel determines the arterial or venous nature of the flow, as well as its velocity. On USG, mixed AV malformation may reveal multiple cystic spaces within the lesion and hypo to anechoic serpengenous structures suggestive of multiple vascular channels within. On color flow imaging lesion may show intense vascularity and the presence of both arterial and venous flow[24] (Fig. 6).

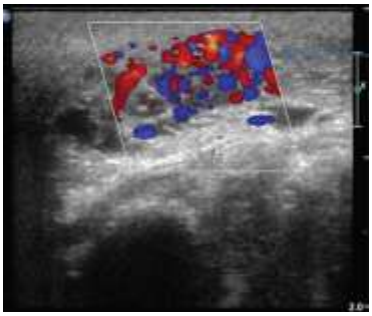

Fig. 6: Color Doppler USG showing intense vascularity and presence of both arterial and venous flow[(24)]

9. **Assessment of Periodontal and Periapical lesions:**

Periodontal assessment: USG has emerged as a non-invasive periodontal assessment tool that yields real time information regarding clinical features such as pocket depth, attachment level, tissue thickness, calculus and bone morphology as well as tooth structure for fracture cracks. Authors designed a specific intraoral probe for dental use. Because of the small size of the probe and its special design, patients felt that the oral USG was a stress free, painless and fast examination tool. The periodontal width was directly accessible and measurable. Besides, it offered new prospects for gum thickness evaluation, earlier detection of a small anatomic change, and diagnosis of oral mucosa lesions. Furthermore studies are required before intra-oral USG is accepted for routine dental use.[(25)]

Periapical assessment: The use of USG in the differential diagnosis of periapical lesions was introduced by Cotti et al. in 2002[(26)] and 2003.[(27)] They defined cystic lesion as a hypoechoic well-contoured cavity filled with fluids with no evidence of internal vascularity on power Doppler imaging, and granuloma as a hyperechoic or mixed hyper- and hypoechoic areas with a rich vascular supply on power Doppler imaging. Gundappa et al reported that USG demonstrated a high diagnostic accuracy in the differentiation of periapical granulomas and radicular cysts with a side-by-side comparison between USG and hisopathology.[(28)]

10. **USG-Guided Fine Needle Aspiration:** For Guided-FNAB various imaging modalities such as USG, CT, MRI may be used to complete the procedure without disturbing important blood vessels and other structures. Of these modalities USG is least invasive, relatively inexpensive and easy to use technique. In addition, accuracy of USG-guided FNAB has been relatively high. USG guided needle aspiration is a safe and effective procedure & can be used as reliable alternative to surgical incision and drainage of fascial space infection cases.[(9)]

Advantages:

1. Absence of ionizing radiation
2. Portability
3. Possibility of dynamic and repeated examinations.
4. Fast & comfortable.
5. Economic.

Disadvantages:

1. USG waves can damage tissues at high exposure levels.
2. Teratogenic effects, due to heat, and acoustic cavitation. However, within the diagnostic range at low intensities and pressure levels, occurrence of heating beyond the normal physiological range has very low probability.
3. Metallic implants, dental fillings and restorations may cause blurring of the image due to artefacts generated by the metal.
4. Poor hard tissue details.

Conclusion

Ultrasonography is an innovative and evolving imaging technology in medical & dental field. Ultrasonography imaging as a diagnostic tool stands as a non-invasive, cost effective, readily available and repeatable technique. It is relatively easy to use. And also the use of Colour and power Doppler ultrasound imaging allows detecting blood flow within or around the lesion.

References

1. WJ Meredith, JB Massey. 1977, Fundamental Physics of Radiology, Year Book Medical Publishers, Pg- 380.
2. Liu Y, Li J, Tan YR, Xiong P, Zhong LP. Accuracy of diagnosis of salivary gland tumors with the use of ultrasonography, computed tomography, and magnetic resonance imaging: a meta-analysis. *Oral Surg Oral Med Oral Pathol Oral Radiol* 2015;119:238-245.
3. Bradley MJ. Ultrasonography in the investigation of salivary gland disease. *Dentomaxillofac Radiol* 1993;22:115-119.
4. Lee YY, Wong KT, King AD, Ahuja AT. Imaging of salivary gland tumours. *Eur J Radiol* 2008;66:419-436.
5. Metha SS, Mhapuskar AA, Hiremutt D, Kamble VD, Nisa SU. Chronic parotid sialadenitis with sialectasis: diagnosis of case through CT sialography. J Pharm Biomed Sci 2016;06(03):234–237.
6. Brown JE, Escudier MP, Whaites EJ, Drage NA, Ng SY. Intra-oral ultrasound imaging of a submandibular duct calculus. *Dentomaxillofac Radiol* 1997;26:252-255.
7. *Ewa J. Bialek, MD, PhD, et al* US of the Major Salivary Glands: Anatomy and Spatial Relationships, Pathologic Conditions, and Pitfalls.
8. Manfredini D, Guarda-Nardini L. Ultrasonography of the temporomandibular joint: a literature review. *Int J Oral Maxillofac Surg*. 2009;38(12):1229-236.
9. Em Shoff, Jank S, Rudisch A, Bodner G. Disc displacement of temporomandibular joint: Sonography versus MR imaging 2002. Am J Roentgenol;178(6):1557-568.
10. Byahatti SM, Ramamurthy BR, Mubeen M, Agnihothri PG. Assessment of diagnostic accuracy of high-resolution ultrasonography in determination of temporomandibular joint. Int J Oral Maxillofac Surgery 2009:1016;1-8.
11. Habashi H, Eran A, Blumenfeld I, Gaitini D. Dynamic high-resolution sonography compared to magnetic

resonance imaging for diagnosis of temporomandibular joint disk displacement. J Ultrasound Med. 2015 Jan;34(1):75-82.
12. Hayashi T. Application of Ultrasonography in dentistry. Jpn Dent Sci Rev 2012;48(1):5-13.
13. Castelijns JA, van den Brekel MW. Imaging of lymphadenopathy in the neck. Eur Radiol 2002;12:727—38.
14. van den Brekel MW, Castelijns JA, Snow GB. Detection of lymph node metastases in the neck: radiologic criteria. Radiology 1994;192:617—8.
15. Krestan C, Herneth AM, Formanek M, Czerny C. Modern imaging lymph node staging of the head and neck region. Eur J Radiol 2006;58:360—6.
16. Sorin M. Dudea, Manuela Lenghel, Carolina Botar-Jid, Dan Vasilescu, Magdalena Duma Ultrasonography of superficial lymph nodes: benign vs. malignant. Med Ultrason 2012;14(4):294-306.
17. King AD, Tse GM, Ahuja AT, Yuen EH, Vlantis AC, To EW, et al. Necrosis in metastatic neck nodes: diagnostic accuracy of CT, MR imaging, and US. Radiology 2004;230:720—6.
18. Szmeja Z, Wierzbicka M, Kordylewska M. The value of ultrasound imaging examination in preoperative neck assessment and in early diagnosis of nodal recurrences in the follow-up of patients operated for laryngeal cancer. *Eur Arch Otorhinolaryngol* 1999;256:415-7.
19. Rachael A Wyman. Ultrasound-detected carotid plaque as a predictor of cardiovascular events Vascular Medicine 2006;11:123–130.
20. Kakkos SK, Geroulakos G (2005) A 75-year-old woman with a hemispheric stroke. PLoS Med 2(4): e79.
21. Nao WS, Kodama M, Matsuo K, Yamamoto N, Oda M, Ishikawa A et al. Advanced clinical usefulness of ultrasonography for diseases in oral and maxillofacial regions. Int J dent. 2010;2010:639382.
22. Sharma M, Patil K, Guledgud MV. Ultrasonic evaluation of fascial space infections of odontogenic origin. J Oral Maxillofac Radiol 2014;2:8-14.
23. Manjunath K, Rajaram PC, Saraswathi TR, Sivapathasundharam B, Sabarinath B, Koteeswaran D, Krithika C. Evaluation of oral submucous fibrosis using ultrasonographic technique: A new diagnostic tool. Indian J Dent Res 2011;22:530-6.
24. Rakhee Modak, Amit Mhapuskar, Darshan Hiremutt, Manjula Hebbale, Shubhangi Gaikwad. Arteriovenous Malformation of the Oral Cavity: A Case Report and Review of Literature. J Pharm Biomed Sci Vol. 06 No. 09 514–517.
25. Bains VK, Mohan R, Gundappa M, Bains R. Properties, effects and clinical applications of ultrasound in periodontics: an overview. *Periodontal Practice Today* 2008; 5: 291-302.
26. Cotti E, Campisi G, Garau V, Puddu G. A new technique for the study of periapical bone lesions: ultrasound real time imaging. Int Endod J 2002;35:148—52.
27. Cotti E, Campisi G, Ambu R, Dettori C. Ultrasound real-time imaging in the differential diagnosis of periapical lesions. Int Endod J 2003;36:556—63.
28. Gundappa M, Ng SY, Whaites EJ. Comparison of ultrasound, digital and conventional radiography in differentiating periapical lesions. Dentomaxillofac Radiol 2006;35:326-33.