Role of Ultrasonography in Oral and Maxillofacial Surgery: A Review of Literature

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Abstract Maxillofacial surgery, like any other surgical specialty is greatly dependent on the discipline of radiology. This poses a greater challenge because of the complex anatomy of this region. Various investigation modalities have been applied in diagnosing various diseases which are found in the maxillofacial region, including IOPA, PET, USG, CT, MRI and panoramic radiographs. Of these, USG can easily diagnose non invasive and soft tissue diseases. It is very useful in diagnosing the diseases which are not usually evident on a conventional radiograph. However, many of the dentists are not aware of the benefits of USG in diagnosis of oral diseases. In this article, the use of ultrasound in diagnosing the various pathologies of maxillofacial region is elaborated.

Keywords Ultrasonography · Grayscale · Color Doppler's ultrasound · Power Doppler's ultrasound · Maxillofacial diagnosis

Introduction

Although conventional radiology has been the main stay of diagnosis in maxillofacial surgery since a long time, it has been hampered by certain drawbacks, which limited its use and reliability, because of two-dimensional representation for three- dimensional objects. They are of little use in the diagnosis of soft tissue pathologies [1–3]. The early use of

ultrasonic was largely confined to therapy rather than diagnosis. The work of Karl Theodore Dussik (Austria) to locate brain tumors was the first published work on medical ultrasonic. It failed because of technical difficulties in recording the results generated as skull absorbed much of the ultrasound energy used. Subsequently, John Wild and Donald Neal (1949) published their works on unidirectional A-mode ultrasound. Later Wild along with John Reid, built a linear hand held B-mode instrument which helped to visualize tumors by sweeping from side to side through breast lumps. In 1953 real time images of 15 MHz at 4 mm penetration were achieved in cancerous growth of breast.

A recent improvement of B-mode Gray scale, Real time, Computed ultrasonography has now found wide spread application in the field of oral and maxillofacial surgery [2]. Its main advantage is that it is noninvasive, painless, rapid and inexpensive without any known deleterious biological effects and easily reproducible when compared with conventional CT and gives accurate details of soft tissues without much distortion [1, 3, 4].

Ultrasound has been successfully employed as an important diagnostic aid in medical field in detecting pathologies of abdomen, breast, liver, spleen, kidneys and other superficial soft tissue lesions. Studies have shown that ultrasound can be successfully employed in the diagnosis of soft tissue lesions such as salivary gland pathologies, cysts and tumors involving the maxillofacial region [5–8]. It has also been used to assess the extent of superficial facial space infections of maxillofacial region [9, 10]. Recently it was introduced for the osteotomy cuts with minimal/no damage to the adjacent soft tissues in the maxillofacial region [11]. US frequency ranges from 2 to 20 MHz; high-frequency transducers (up to 10–15 MHz range) to image superficial structures and low-frequency

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transducers (typically 2–5 MHz) for imaging the structures that is deep in most of the cases.

Clinical Application

Space Infection

In day to day practice of oral and maxillofacial surgery, infection has the potential to spread through the spaces within the facial planes in head and neck region and affects the vital structures, they often respond to antimicrobial and surgical management if diagnosed and treated relevantly. USG is an effective diagnostic tool to confirm abscess formation in the superficial facial spaces and is highly predictable in detecting the stage of infection (Fig. 1). 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 [12–14] (Fig. 2).

The principle of USG is based on the fact that, there are large differences in the impedance for ultrasound waves between soft tissue and air, and between soft tissue and bone. Bone and air are absolute barriers to an ultrasound

Fig. 1 Cellulites. Ultrasonographic image showing cellulites of buccal and canine spaces

Fig. 2 Abscess. Ultrasonographic image showing abscess with well demarcated margins of hypo echoic

beam, this means that no image within or behind bony or air containing structure can be produced by ultrasound [3, 4]. Therefore some regions of maxillofacial field cannot be evaluated by ultrasound, such as the retropharyngeal region and paranasal sinuses. It can differentiate abscess from cellulites thereby patients can be treated with incision and drainage in the former and medical line of treatment in the latter conditions [9, 15–17].

Ultrasound Evaluation of Bone Healing

Distraction osteogenesis is a staged technique where the newly formed tissue is generated within the created osteotomy site which was lengthened, molded, and allowed to consolidate. The purpose of the consolidation phase is to retain the improvement in the maxillomandibular relationship while the generated tissue gets ossified.

USG with new high resolution linear scanning probes with varying frequencies of 12–15 MHz, standardized, non-invasive technique to monitor bone-fill and assess the healing of distracted bone. Evidence of bony union on plain radiographs is difficult to evaluate and not reliable during the first 4 weeks of fixation. In addition, anatomical and metal overlap may obscure the distracted wound even in the later stages. Hence, the diagnostic value of plain radiographs is limited and may lead to a delay in the removal of the distraction device which causes more discomfort to the patient. US have the ability to evaluate musculoskeletal system mainly in the examination of distraction wound (Fig. 3). It requires sequential slices from superior to inferior margin with the probe moving along skin on each side of distracter allowing proper visualization of distraction gap, there by detecting fluid within the distraction gap signifies lack of formation of bridging bone indicates infection and non union within the wound [18]. The first clinical observation that US stimulate fracture healing was reported as early as 1953 by Corradi and

Fig. 3 Evaluation of bone healing by ultrasound. Longitudinal ultrasonographic scanning of the same tissues showing complete bridging of the distraction gap with homogeneous echogenic material with well-defined buccal and lingual cortices

Cozzolino [19]. Although some researchers have employed ultrasonography and Power Doppler to assess the appearance and neo-vascularization of the callus tissue during healing, the majority of the studies have utilized quantitative ultrasound techniques [20].

Foreign Body Detection

Foreign bodies embedded in soft tissue can cause inflammation, infection, toxic and allergic reactions with prolonged morbidity, but the severity varies widely. Removal can be difficult and time consuming, and the potential damage to tissues caused by the surgical procedure must be weighed against the risk posed by a particular foreign body. Detection and localization is a difficult task with conventional radiographs. Other modalities such as Ultrasound, CT and MRI can also be used for evaluating the foreign bodies but both CT and MRI are expensive and not easily available.

Ultrasound can demonstrate wood, bamboo, glass or fishbone foreign bodies in soft tissues which may not be apparent radiographically. They are often more clearly demarcated at a later stage when surrounded by hypoechoic reparative granulation tissue, if clinical suspicion remains high or if the infection fails to settle, a repeat ultrasound in about 3 weeks or sooner should be performed. It can demonstrate wooden fragments as small as 2.5 mm with 87 % sensitivity and 90 % specificity (Fig. 4). Ultrasound can also be used to assist percutaneous removal of foreign bodies by forceps [10, 21, 22].

Ultrasound Osteotomy

Most medical devices currently use the piezoelectric effect which was discovered in 1880 by Jacques and Pierre Curie [11]. US possibility of surgical applications was also explored in the 1940s, but in western nations, its use in

Fig. 4 Foreign Body. During cleaning, a wooden probe was accidentally retained inside the abscess cavity. **a** Transverse ultrasound image of the abscess reveals the echogenic wooden probe (indicated by calipers) with acoustic shadowing. Adjacent small echogenic gas locules show no acoustic shadowing

Fig. 5 Various designs of ultrasonic osteotomy tips

dental clinics was limited for long time to supra- and infraggingival dental cleaning, root scaling, retrograde filling, for root canal preparation, and for the removal of posts, cores, and occasionally broken instruments. But in between 1980s and 1990s it saw marked improvement in the clinical introduction of both focused ultrasound and the ultrasonic scalpel. Ultrasonic osteotomy preparation was studied very early, but only in the last few years the ultrasonic devices for osteotomy have become competitive with conventional instruments in certain contexts. In this phenomenon, an electric potential was developed across certain crystalline materials when compressed which become deformed in an electric field.

US guided osteotomies called peizosurgeries assist the surgeons in reducing operating time, less thermal damage, minimal post operative swelling and minimal risk to critical anatomical structures. This is a new surgical technique used in dentistry to section hard tissues without damaging adjacent soft tissues such as inferior alveolar nerve, palatal mucosa and brain [11, 23] (Fig. 5).

Ultrasonic osteotomy was first used to reposition the Inferior Alveolar Nerve in 2005, by Bovi. Geha et al. reported that integrity of Inferior Alveolar Nerve in 20 bilateral mandibular sagittal split operations, with maximum recovery of neurosensory function within 2 months.

Osteomyelitis

Osteomyelitis is usually caused by *S. aureus* in young patients, and by Gram-negative bacteria in the elderly individuals. Radiographically apparent osteolysis or periosteal new bone formation may not become apparent for up to 2 weeks after the onset of infection. Ultrasound detects certain features of osteomyelitis several days ahead of conventional radiographs. Juxtacortical soft-tissue swelling together with early periosteal thickening is the earliest sign of acute osteomyelitis on ultrasound. This is followed by increased periosteal thickening accompanied by a layer of subperiosteal exudates, and rarely abscess formation.

Fig. 6 Osteomyelitis. Transverse ultrasound reveals isoechoic juxtacortical soft-tissue thickening (arrows)

Fig. 7 Vascular disorders. Grey-scale ultrasound image of a well-delimited (arrows), oval, mixed echogenicity lesion, consistent with an hypo echoic soft-tissue mass with anechoic internal areas which corresponded to vascular spaces on subsequent Doppler studies. The lesion was a hemangioma of lower lip

Finally, cortical erosion can become apparent. Sympathetic joint effusions or co-existent inflammation of juxtacortical tissues can occur (Fig. 6). Ultrasound examination is likely to be most sensitive in children with suspected acute osteomyelitis of the tubular bones where the propensity of developing a periosteal reaction is maximum. Ultrasound-guided aspiration is helpful in confirming an infective etiology. Reactivation of chronic osteomyelitis may be associated with soft-tissue abscess, fistula or sinus tract formation, all of which may be apparent on ultrasound. [21].

Vascular Malformations

Congenital vascular anomalies are poorly understood. This is because of unclear understanding of the natural history of these lesions. In addition, clinicians from various specialties are involved in the management of these patients and have checked for solutions within their specialty and applied them to all lesions. In order to treat the lesion with minimal morbidity and mortality rate a proper diagnosis has to be done.

Doppler US is essential in differentiating venous malformations from other vascular anomalies. It should be performed with a high-frequency linear array transducer (5–10 MHz) [12, 24] and exploration begins with a gray-scale examination to delineate the margins of the malformation. The target of color 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 color flow signal [25, 26]. Blood flowing towards the USG transducer is displayed as red and that moving away

Fig. 8 Color Doppler mode. Two examples of highly vascular lesions. **a** Numerous vessels are visible within a hemangioma of the tongue in Color Doppler mode. **b** Low flow Power Doppler

visualization of a high-density vascular lesion in the supraciliary region, which was a hemangioma in proliferative phase

from transducer as blue. In contrast the retained pus which does not contain flowing blood cells is delineated as no color flow signal. This property of Doppler ultrasonography allows it to differentiate blood vessels from static regions of images [25, 27]. Venous malformations appear as hypo echoic or heterogeneous lesions in 80 % of cases. Anechoic channels can be visualized in less than 50 % of cases. Sometimes, isoechoic thickening of the subcutaneous tissues without a solid mass or discernible channel is the only feature. Hyper echoic foci with posterior acoustic shadowing are seen in less than 20 % of cases [25] (Fig. 7).

Non enhanced MRI with ultrasound/color Doppler can be substituted for enhanced MRI to provide the best diagnostic information and at reduced cost. Ultrasound/color Doppler is an important adjuvant to CT and MRI in the diagnosis of vascular or suspected vascular anomalies [27] (Fig. 8).

TMJ Problems

The term temporomandibular disorders (TMDs) are defined as a “collective term embracing a number of clinical problems that involve the masticatory musculature, the temporomandibular joint (TMJ) and associated structures, or both”. They are considered to be musculoskeletal disorders and are a major source of orofacial pain of non-

dental origin. Plain-film radiographs and tomography are basic hard tissue imaging techniques for proper assessment of the TMJ; but, evaluation of the adjacent soft tissues is always necessary as these techniques are rarely definitive. Other modalities such as arthrography, CT, MRI and, more recently, ultrasound have been improved in understanding the anatomy and the diagnoses of internal derangement of the TMJ. It has been recognized for some time with several important advantages as it does not require special facilities which have the potential of becoming available in a dental office, and can be used to view the joint in a continuum without invasion, discomfort, alteration of the patient's normal head posture, or interference with condylar motion. Its use for the diagnosis of temporomandibular joint (TMJ) disorders is uncommon, although several reports have been found in the literature, suggesting evident advantages of the utilization of such procedure which is inexpensive and noninvasive compared to the other imaging tools habitually used, such as MRI, arthrography and CT scan [28–30].

The difficulty of picturing the TMJ using ultrasounds depends on the limited accessibility of the deep structures, especially the disc, due to absorption of the sound waves by the lateral portion of the head of the condyle and the zygomatic process of the temporal bone. In fact, the transducer that emits and receives the sound waves is usually located over these structures i.e. on the skin in front of the tragus

Fig. 9 Method of using ultrasound in TMJ. Positioning of the transducer and consequent visualization of the temporomandibular joint (TMJ). **a** Horizontal positioning, transverse image of the TMJ. **b** Vertical positioning, coronal/sagittal image of the TMJ (depending on the angulations of the transducer)

Fig. 10 Schematic figure of the anatomic structures seen on the display of the sonographic equipment. Ultrasound temporomandibular joint image seen on the display. Measurement of the distance between the articular capsule and the lateral condyle surface is seen

Fig. 11 TMJ view. Longitudinal ultrasound scans of left temporomandibular joints with a capsular width of 4.8 mm. The joint was painful to palpation and MRI depicted effusion

[31–33]. It is a diagnostic procedure that has been shown to be accurate for the diagnosis of articular disc dislocation and joint effusion [34, 35] (Figs. 9, 10, 11).

Fractures

The zygomatic arch plays an important role in the facial contour and its malposition affects the normal unhindered excursion of the coronoid process of the mandible. Therefore, for both cosmetic and functional reasons, it is imperative that zygomatic arch injuries be properly diagnosed and adequately treated. Plain films and CT have their place in determining the type, location, magnitude, direction and displacement of zygomatic arch fractures. The main disadvantages of CT are the patient's exposure to a high dose of radiation and the potential risk of development of cataract. It is contraindicated in pregnant women and in patients with cervical spine injuries. It has traditionally been used in the diagnosis of orbital and ocular lesions, but its role in maxillofacial trauma was not well recognized till the 20th century [36–39]. McCann et al. used ultrasound with 85 %

accuracy in diagnosing fractures of the zygomatico-orbital complex (ZMC). According to Friedrich et al. application of ultrasound is most useful for visualization of the fractures of zygomatic arch (Fig. 12) and the anterior wall of the frontal sinus [36]. It can be an alternative primary technique in the diagnosis of nasal bone fractures, especially in pregnant women and children along with intraoperative evaluation of repositioning of the nasal bone [37]. The discontinuity is seen on the outer table of the bone if examined under it.

Salivary Gland Pathology

Various types of salivary gland infections are more common in the head and neck region. Parotid is most frequently involved followed by submandibular gland. Diagnosis of the pathology in this region plays a major role in the treatment plan. Ultrasonography for salivary gland examination is best performed using linear-array broadband transducers with a frequency of 7–12 MHz. Selection of the transducer frequency depends on the depth of the lesion to be examined and on the attenuation of

Fig. 12 Zygomatic arch fracture

Fig. 13 The ultrasound examination shows an enlarged parotid gland, with multiple poorly defined hypo echoic areas. No calculi were seen. Assessment of the ductal system was not possible with ultrasound alone

Fig. 14 Sialolithiasis and sialadenitis, as seen on color Doppler ultrasound of the submandibular gland. Two small calculi, 2 and 3 mm in size, respectively (*arrows*), are seen as hyper echoic structures with posterior shadowing. The increased vascularization of the slightly enlarged gland should be noted

the interposed tissues [12, 40]. To examine very superficial lesions with ulcerations a standoff pad made of silicone elastomer can be used. In large lesions, additional transducers with a lower frequency are advisable to delineate the lesion completely. Although color Doppler and power Doppler imaging are often very useful for salivary gland examinations, most diagnoses are made using the standard gray-scale technique. Bilateral investigation of the salivary glands is extremely important, as many diseases occur bilaterally.

Ultrasound can be used as a first-line of examination to detect sialolithiasis. The reported sensitivity of ultrasound for detecting salivary gland calculi varies between 71 and 94 %, and the specificity may vary between 80 and 97 % [41–44]. It is also useful in diagnosing the malignancy in the salivary glands [45–47] (Figs. 13, 14).

Cervical Lymphnodes Metastasis

The staging of cervical lymphadenopathy is an important consideration in the management of oral cancer since it

Fig. 15 Schematic diagram showing US findings in various studies

determines the patient's prognosis. Ultrasound is useful in the diagnosis of cervical lymph nodes metastasis [48–53]. The staging is an important consideration in the management of oral cancer as it determines the patient's prognosis and the management. B-mode Ultrasound with a high-resolution real time linear scanner with 7.5 MHz transducer is used to detect the nodes [6, 54–57]. Scans were evaluated for the presence of definite internal echoes, homogeneous hilar echoes and the ratio of the short and long axis (L/S ratio).

Schematic diagram (Fig. 15) showing the US findings evaluated in various studies. The longest length of each lymph node was defined as the 'long axis' and the longest distance perpendicular to 'long axis' was defined as the 'short axis'. The homogeneous echogenic structure is the so-called 'hilar echo' and corresponds to the fatty tissue around the hilar of the lymph node. The echoes of the parenchyma were defined as internal echoes [58] (Fig. 16). It is also helpful in guiding needle for FNAC which is one of the most useful diagnostic examinations of the lymph nodes [58, 59] (Fig. 17).

Criteria for US

1. A lymph node with definite internal echoes is defined as malignant.
2. A lymph node with hilar but no definite internal echoes is defined as benign.
3. A lymph node measuring 10 mm or more in the short axis is defined as malignant.
4. A lymph node with an L/S ratio of 3.5 or more is considered benign.
5. A lymph node which cannot be associated to categories 1–4 is considered to be questionable.

Conclusion

USG is an inexpensive, quick and non invasive excellent investigation method for a wide range of clinical problems

Fig. 16 Typical US appearance: **a** a lymph node showing definite internal echoes. **b** A lymph node showing hilar echoes

Fig. 17 View of ultrasonography-guided fine-needle aspiration biopsy. An ultrasound image showing successful centesis (arrowhead) of the needle into the mass suspected to be a neurilemoma

in the oral and maxillofacial region. Power Doppler USG is used to measure the blood flow, diagnose soft tissue lesions, hemangiomas and vascular malformations. It aids in prenatal evaluation of craniofacial anomalies of head and neck region (cleft lip and palate). It is used to differentiate calculi from the inflammatory diseases of salivary glands. It also differentiates solid from cystic lesions. In combination with FNAC it diagnoses the tumors and pathologies of lymph nodes. The clinician should be aware of using various modalities of USG in diagnosing bony lesions because USG can detect only superficial bony lesions. It differentiates superficial and deep space infection from cellulites. Its use in osteotomy cuts with piezoelectric effect has a greater advantage by minimizing soft tissue injuries in orthognathic surgeries.

This article deals with the uses of USG in diagnosing various pathologies of soft tissues, glands, lymph node metastasis and to some extent of hard tissues (fractures, bone healing), etc. It also focuses the use of USG as an important diagnostic aid for maxillofacial surgeons to diagnose the pathologies related to this region and in pediatrics and pregnant women where X-rays are contraindicated.

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