Research Article

Role Of Ultrasound in Oral Cancer Management – A Systematic Review

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Abstract

Background : In Southern Asia, oral cancer is widespread and a major burden. Depending on the disease's stage, surgery with or without adjuvant radiation therapy (RT) or chemoradiation therapy is the preferred course of treatment. Cervical lymph node (LN) metastases and a close or positive resection margin are significant prognostic variables. A diagnostic imaging method based on the application of ultrasonic (US) waves with a frequency greater than 20,000 Hz, which corresponds to the upper limit of audible human sound, is called ultrasonography (USG), sometimes referred to as real-time ultrasound imaging or sonography. The reciprocal piezoelectric effect is a method used by electromechanical transducers to create ultrasonic waves by converting electrical impulses into high-frequency sound waves using a piezoelectric crystal. The tissues under examination receive these waves. Internal body structures such as tendons, muscles, joints, arteries, and organs are observed in the majority of medical applications. A straightforward, non-invasive, quick, and affordable diagnostic technique is ultrasound (US). It can accurately display soft tissues without exposing users to radiation. During the test, the image is also shown continuously and in real time. Additionally, the physician can simultaneously perform core needle biopsy (CNB) or US-guided fine needle aspiration (FNA). The need for FNA/CNB and elective neck dissection in clinical early-stage oral cancer can be guided by the US-based prediction model's prediction of a malignant cervical LN (nodal metastasis). During the post-treatment surveillance period, US with or without US-guided FNA or CNB can evaluate the likelihood and severity of carotid artery stenosis following radiation therapy and be useful in identifying nodal persistence or LN recurrence. The management of oral cancer may benefit from both US swallowing evaluation and US elastography. Material and Methods: Major databases such as Medline were explored detailed literature search in resulting in a systematic review pertaining to the applications and potential developments of ultrasound in oral cancer management. Results: Five original research scientific articles dated between 2020 – 2024 pertaining to mentioned topic were highlighted. Conclusions: The various stages and possible uses of US clinical applications in the treatment of oral cancer are as follows. US can be utilized to assess tumor depth and surgical margins of oral cancer. The management of oral cancer may benefit from both US swallowing evaluation and US elastography. It is important to support the clinical use of US for oral cancer. Detailed information regarding the applications and potential developments of ultrasound in oral cancer management is discussed in this systematic review.

Keywords: Ultrasound, oral cancer, Intra-oral ultrasound; Diagnostic imaging, intraoperative ultrasound; margins.

1. Introduction

One-third of all cancer cases in India are oral squamous cell carcinoma (OSCC), which also has a high cancer-specific death rate. This high incidence is caused by the extensive use of areca nut and tobacco. Although alcohol and tobacco are powerful etiological agents regardless of geographic location, oropharyngeal malignancies caused by the human papillomavirus have recently increased dramatically in wealthy countries. Even though OSCC treatment in India is similar to that in high-income countries, the severe disease burden, delayed presentation, and associated advanced stage of the disease provide particular difficulties in a setting with limited resources. Even with optimal and sufficient treatment, advanced OSCC is associated with a dismal prognosis, with a 5-year overall survival rate of 20% to 40%. Survival chances are low even with a multimodal therapy strategy.

Delays in diagnosis, improper investigation and referral, and inadequate or ineffective treatment are frequently the reasons for late presentation, resulting in subpar patient outcomes and increased costs for the healthcare provider. Appropriate diagnosis and imaging, along with appropriate investigations and referral, are essential to overcome this

critical factor. This can lower the expenses for the healthcare provider while also improving patient outcomes. Before beginning the therapeutic procedures, it would be helpful to find a non-invasive and precise way to measure the thickness of the tumor and identify the lesion. Computed tomography (CT), magnetic resonance imaging (MRI), and intraoral ultrasonography are among techniques for determining the extent of oral cancer. In the oral and maxillofacial regions, ultrasound (US) is a simple method for detecting soft tissue-related and non-invasive disorders. The B-mode, which displays the anatomical surface features of soft tissues in ultrasound pictures, is frequently used to identify a variety of disorders in the oral and maxillofacial regions. The surface features of computed tomography (CT) and magnetic resonance (MR) pictures are shown by the ultrasound image.

The Doppler effect of blood vessel flow has recently been used in Doppler ultrasound imaging to assess whether vascular flow is present or absent in normal tissues as well as in disorders of the oral and maxillofacial regions. As a result, Doppler pictures linked to the B-mode can offer vascular details related to soft tissue architecture. As a result, US is crucial for examining both normal and aberrant anatomical structures. US may be used clinically to assess illnesses related to the tongue, lymph nodes, salivary glands, and subcutaneous tissues in the oral and maxillofacial areas. Because intraoral ultrasonographic examination is non-invasive, quick, and simple to repeat, its potential uses have expanded. Ultrasonography has been used in head and neck surgery to diagnose tongue carcinoma, salivary gland tumors, neck masses, and other oral abnormalities. Ultrasonography was used to examine oral lesions by inserting a transducer on an extraoral location, but obtaining detailed data was challenging. It has been suggested that intraoral ultrasonography is a helpful diagnostic method for paratonsillar abscesses. In addition to helping with diagnosis, USG speeds up the healing process for a variety of injuries.

Over time, USG has also seen numerous advancements, including surface renderings, color Doppler sonography for the assessment of blood flow, and three-dimensional imaging to enable multiplanar reformatting. The precision of USG has increased with the use of transducers. The majority of recent studies on USG demonstrate its diagnostic potential, including the identification of inflammatory swellings in the maxillofacial and periapical regions. USG has a promising future in the dental industry, but radiologists and students need to be properly trained in the assessment of different pathologies. To determine the effectiveness of USG in the craniofacial region, a number of clinical studies with a sufficient sample size are needed.

Material And Methods:

“Oral cancer” AND “diagnostic” AND “ultrasound’’ were the words used in MEDLINE database using advance search strategy targeting different article categories between 2020 to 2024. The result was 68 articles, out of which we selected 5 articles based in the inclusion criteria. Inclusion criteria was of case studies and scientific literature between 2020-2024. Exclusion criteria was of scientific literature irrelevant to the specific search. This systematic review was conducted to determine importance of the applications and potential developments of ultrasound in oral cancer management following the guidelines of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). PubMed, Lilacs, Embase, Scopus, and Web of Science were the source of electronic databases. The search strategy used Boolean operators (AND and OR): [ALL (“Oral”) AND (cancer OR diagnostic OR imaging OR non-invasive OR pathology) AND (tumor depth)]. The following data were collected: first author, year, country of study, type of study and outcome. The quality of studies was assessed using the STROBE (Strengthening the Reporting of Observational Studies) checklist.

RESULTS: Five articles were included in this systematic review based on the selection criteria. We analyzed and mentioned in the five articles reviewed. This included only relevant research articles and excluded articles pertaining to nonspecific search terms.

Table 1 – An overview

Author	Title	Journal	Outcome
Fariba Esperouz, Vito Carlo Alberto Caponio, Andrea Santarelli, Andrea Ballini, Lorenzo Lo Muzio, Domenico	Are we ready to use ultrasounds in the clinical assessment of depth of invasion and tumor thickness in oral squamous cell carcinoma? Results	Esperouz F, Caponio VC, Santarelli A, Ballini A, Muzio LL, Ciavarella D, Russo LL. Are we ready to use ultrasounds in the clinical assessment of depth of invasion and tumor	The results of ultrasound and histological examination, the clinical use of this device cannot yet be confirmed.

Ciavarella, Lucio Lo Russo	from a systematic review, meta-analysis and trial sequential analysis	thickness in oral squamous cell carcinoma? Results from a systematic review, meta-analysis and trial sequential analysis. Oral oncology. 2024 Dec;159:107104. doi: 10.1016/j.oraloncology.2024.107104.	
Ryland N Spence, Vivienne H Au, Yan Zhao, Allen L Feng, Amy F Juliano, Deborah Goss, Mark A Varvares	Intraoperative Ultrasound for the Management of Oral Tongue Cancer: a Systematic Review and Meta-Analysis	Spence RN, Au VH, Zhao Y, Feng AL, Juliano AF, Goss D, Varvares MA. Intraoperative Ultrasound for the Management of Oral Tongue Cancer: a Systematic Review and Meta-Analysis. OTO open. 2024 Jun 6;8(2):e147. doi: 10.1002/oto2.147.	IOUS-assisted resection may represent a more reliable approach to achieving clear margins than conventional resection
Deepa Sharma, Kai XuanLeong, Gregory J Czarnota	Application of Ultrasound Combined with Microbubbles for Cancer Therapy	Sharma D, Leong KX, Czarnota GJ. Application of Ultrasound Combined with Microbubbles for Cancer Therapy. International journal of molecular sciences. 2022 Apr 15;23(8):4393. https://doi.org/10.3390/ijms23084393	The tumour vascular effects mediated by USMB and cancer therapies
Antonio Romano, Dario Di Stasio, Massimo Petruzzi, Fausto Fiori, Carlo Lajolo, Andrea Santarelli, Alberta Lucchese, Rosario Serpico, Maria Contaldo	Noninvasive Imaging Methods to Improve the Diagnosis of Oral Carcinoma and Its Precursors: State of the Art and Proposal of a Three-Step Diagnostic Process	Romano A, Di Stasio D, Petruzzi M, Fiori F, Lajolo C, Santarelli A, Lucchese A, Serpico R, Contaldo M. Noninvasive Imaging Methods to Improve the Diagnosis of Oral Carcinoma and Its Precursors: State of the Art and Proposal of a Three-Step Diagnostic Process. Cancers. 2021 Jun 8;13(12):2864. doi: 10.3390/cancers13122864.	The contribution to OSCC diagnosis, with ideal three-step diagnostic procedure, is to make the diagnostic path faster, better, and more accurate
Vismaya S Bachu, Jayanidhi Kedda, Ian Suk, Jordan J Green, Betty Tyler	High-Intensity Focused Ultrasound: A Review of Mechanisms and Clinical Applications	Bachu VS, Kedda J, Suk I, Green JJ, Tyler B. High-Intensity Focused Ultrasound: A Review of Mechanisms and Clinical Applications. Annals of biomedical engineering. 2021 Sep;49(9):1975-91. doi:10.1007/s10439-021-02833-9.	The growing importance of this biomedical technology and for the development of possible pathways for the future use commonplace treatment modality

Discussion

The presentation of oral and maxillofacial lesions encompasses a wide spectrum of clinical, radiological, and histological features.[1]

This diversity necessitates a comprehensive diagnosis approach that integrates clinical examination, imaging, and histopathology examination to ensure proper diagnosis and treatment planning.[2] General dentists have wide range of dental imaging modalities to enhance their diagnosis. Conventional radiographs are often used as the initial imaging tool to gain information about a lesion's key features and location.[3] A more comprehensive form of assessment with advanced imaging modalities is often needed to provide more diagnostic information to clinicians.[4] Ultrasound (US) is a non-invasive imaging modality, with low cost, portability, and realtime imaging without ionizing radiation.[5] Ultrasound uses electrical energy to create real-time tissue images (B-mode) and evaluate blood flow (Doppler) in lesions like hemangiomas and tumors.[6] It was discovered in 1880 by the Curie brothers; ultrasound evolved from wartime and industrial applications into a vital medical tool.[7] The medical ultrasound uses varying energy intensities, typically delivering 0.1 W/cm² for diagnostic purposes alongside low, medium, and high-intensity categories.[8] Ultrasound (US) as imaging and diagnostic purposes is well known in both medical and dental fields. It is considered as “real time” imaging. It is an oscillating sound with a greater frequency.[9] Therapeutic US has been widely used in medical field for surgical intervention, in healing of fractures, urological application, osteointegration and cancer therapy. The utility of therapeutic US in dentistry is still in its initial phase.[10] In dentistry, therapeutic ultrasound treats various jaw, tooth, and tissue conditions while accelerating healing, relieving pain, and improving tissue flexibility.[11] Ultrasound imaging in dentistry is based on the propagation of high frequency mechanical sound waves through oral tissues and their reflection at interfaces of differing acoustic impedance.[12] As these waves travel through structures, they undergo reflection, refraction, scattering, or absorption depending on the density and stiffness of each tissue.[13] The portion of the wave that is reflected back to the transducer is converted into electrical energy that the imaging system processes to generate a grayscale image.[14] Brightness on the display corresponds to the amplitude of the returning echo: highly mineralized tissues such as enamel produce strong reflections appearing as bright hyperechoic lines, whereas soft tissues generate lower-intensity echoes.[15] The ability to generate real-time, radiation-free images of both soft and mineralized tissues underscores the growing importance of ultrasound as an adjunct— and future alternative—to conventional dental radiography.[16] Compared with established imaging modalities, MRI provides excellent soft tissue and TMJ visualization but is limited by high costs, low availability, motion sensitivity, and metallic implant contraindications.[17] Computed tomography (CT) and CBCT provide precise bone imaging but involve ionizing radiation and are unsuitable for pregnant women or patients requiring frequent follow-ups.[18] Ultrasound allows safe, real-time soft tissue and vascular assessment without radiation, whereas X-rays have poor soft tissue resolution and struggle to differentiate cysts from granulomas.[19] Advancing ultrasound technology—through higher frequency probes, faster processing, and Doppler imaging—increasingly complements traditional imaging by offering a safer, radiation-free diagnostic alternative.[20] Among oral cancer, Oral squamous cell carcinoma accounts for 90–95% of malignant tumors of this anatomic region, while the remaining 5–10% is made up by rarer malignancies. OSCC is the 11th most common malignancies in males, and the 16th in females.[21] Delays in the diagnosis of OSCC are responsible for high mortality and morbidity, frequently in late-stage, which reduce overall survival and poor quality of life.[22] The diagnostic procedure for diagnosing OSCC is time-consuming and invasive, since it must consider the multistep processes, always culminating in biopsy and histopathological assessment as gold standards.[23] Advanced or clear-cut oral cancers are easily spotted, but early or uncertain lesions require precise presurgical mapping or multiple biopsies because clinical inspection and palpation alone cannot accurately diagnose them.[24] To overcome these diagnostic challenges, oral pathologists and oncologists use novel, non-invasive imaging techniques during clinical exams to quickly identify highly suspicious sites and guide precise, targeted biopsies.[25] Intraoral ultrasound examination has direct contact with the region, maintaining also non-invasiveness and has considered particularly useful in determining the interface between tumor tissue and the surrounding myo-architecture.[26] Early intraoral ultrasound studies demonstrated that it measures oral squamous cell carcinoma thickness with high histological accuracy, proving comparable to CT and MRI scans.[27] Studies confirmed the capabilities of the US imaging technique in detecting lesions smaller than 1 mm thick were detectable in the intraoral ultrasound image in the context of the tongue parenchyma.[28]Tumor thickness measurements can misrepresent true invasiveness by underestimating ulcerated cancers and overestimating superficial, exophytic tumors because it measures from the outer surface to the deepest point.[29] Unlike tumor thickness, depth of invasion (DOI) measures from the basement membrane to the deepest tumor point, making it a more reliable prognostic factor for predicting lymph node metastasis and patient survival.[30] High-frequency ultrasound can accurately evaluate tumor depth of invasion preoperatively, showing 91–93.1% sensitivity and 100% specificity in detecting submucosal infiltration compared to postoperative histology.[31] Several studies and authors proposed the intraoperative use of the ultrasound probe, to guide the resection of the deep margins with the use of eco-reflective instruments.[32] In oral cancer, the primary treatment is surgical resection with adequate margins. The surgeon defines the tumour’s dimensions by vision and manual palpation, and plans for resections. This technique is often successful.[33]

Surgeons can use real-time intraoperative and immediate *ex vivo* ultrasound to assess deep margins, potentially replacing frozen section analysis and guiding immediate re-resection to prevent local adjuvant treatment.[34] While accurate imaging can reduce unnecessary elective neck dissections, while studies advocate for sentinel lymph node biopsy to detect the remaining occult metastases in early oral cancer.[35] Early detection of regional recurrences is crucial during the follow-up programs for oral cancer patients. Neck US is reported to be effective in the posttreatment surveillance.[36] The recurrent cervical LNs in treated oral cancer patients with previous neck irradiation are smaller in size and have more signs of irregular margin and calcification under US than those without previous neck irradiation.[37] In the treated neck of head and neck cancer patients, ultrasound-guided core needle biopsy demonstrates higher sensitivity and comparable specificity relative to ultrasound-guided fine-needle aspiration.[38] Although CNB has been considered to have a higher diagnostic rate in detecting true malignancy, the sensitivity and specificity do not differ significantly between both methods.[39] Head and neck cancer patients treated with radiotherapy face at least a twofold higher risk of cerebrovascular disease, with high-resolution and Doppler ultrasound serving as the primary tools for diagnosing and screening carotid artery stenosis.[40] The carotid intimal–medial thickness (CIMT), which is the predictor for cardiovascular and stroke events, measuring CIMT using US is useful for assessing CVD risk in oral cancer survivors.[41] Lifestyle intervention and medical management, including antiplatelet, statins, and angiotensin-converting enzyme inhibitors, are indicated for patients who have atheromatous lesions.[42] Ultrasound (US) has wide and varied range of applications in the diagnostic field of medicine. The therapeutic effects of US are derived from both its thermal and non-thermal properties.[43] This is the US mode traditionally used for therapy in musculoskeletal conditions such as spasm. Thermal effects usually last for 5-10 minutes and non-thermal effects are achieved at intensities of <0.3-1Watts/ cm^2.[44] US therapies can broadly be divided into '-high-' power and '-low-' power therapies. High power applications include high intensity focused US (HIFU) and lithotripsy. Low power US encompasses sonophoresis, gene therapy and bone healing.[45] Used for over half a century in bone healing, ultrasound causes thermal damage at high intensities but stimulates new periosteal bone formation at lower intensities.[46] Its therapeutic effects rely on multiple physical mechanisms, where sonic vibrations mechanically stimulate cells and tissues by creating a micro-massage effect in cellular fluids and membranes.[47] Thus, ultrasonication as a method of diagnosis and treatment has found its application in medicine and, in particular, in dentistry. US is easy to use for the detection of soft tissue-related diseases in oral and maxillofacial regions.[48] US technology is uniquely positioned to move from a supplementary tool to a primary, non-invasive in oral cancer management and treatment.[49] Ultrasound has evolved into an intraoperative tool for cancer margin assessment and accurate, image-guided biopsies and mapping tumor thickness also depth of invasion (DOI) with near-histological accuracy.[50]

Conclusion

These days, a variety of non-communicable diseases—also referred to as modern epidemics—affect the entire world. One of them is cancer. Among all cancers, head and neck cancer (HNC) has a significant mortality rate and is the sixth most prevalent cancer recorded globally. One-third of the global burden is on the Indian subcontinent. One of the most physically and psychologically traumatic tumors, head and neck cancer frequently leaves its victims crippled and deformed. A collection of physiologically related tumors that start in the upper aerodigestive tract is referred to as head and neck cancers. Squamous cell carcinoma accounts for about 90% of head and neck cancer cases. Although the majority of patients present with advanced disease, early-stage head and neck malignancies have a good cure rate. Advanced cases have lower cure rates; the likelihood of a cure is inversely correlated with the size of the tumor and even more so with the degree of regional node involvement.

Although the histopathological microscopic examination is the gold standard for diagnosing the majority of oral disorders, imaging techniques appear to be a potential diagnostic tool for the physician. In actuality, these methods enable the doctor to assist in both operational and diagnostic aspects. All of these methods have been used to treat inflammatory and autoimmune conditions of the oral mucosa as well as to prevent and treat oral squamous cell carcinoma (OSCC). For the noninvasive identification of soft tissue-related disorders in the oral and maxillofacial areas, US is a simple method. Therefore, for the differential diagnosis of soft tissue surfaces, particularly disorders related to salivary glands and lymph nodes. One promising non-invasive diagnostic method for the early identification of oral malignancies is ultrasound elastography. Clinical decision-making can be improved by its capacity to distinguish benign from malignant tumors based on tissue stiffness. To confirm these results and create standardized procedures for their clinical use, more extensive research is necessary.

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