

DETECTION OF ORAL CANCER: A REVIEW

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ABSTRACT:

Oral cancer is a significant global health issue, with over 400,000 new cases annually. Despite the accessibility of the oral cavity for examination, late-stage diagnosis remains common, leading to poor survival rates. Early detection is crucial for improving prognosis and reducing morbidity. Major risk factors include tobacco use, alcohol consumption, betel quid chewing, and HPV infection. Targeted screening programs for high-risk populations have proven effective, particularly when coupled with community health worker involvement and public education campaigns. Recent advancements in adjunctive diagnostic tools, such as autofluorescence imaging, toluidine blue staining, and AI technologies, hold promise for enhancing diagnostic accuracy and enabling earlier intervention. AI, in particular, has shown remarkable potential in analyzing clinical images, achieving accuracy rates of up to 99.7%. Despite these advancements, challenges remain, including inconsistent screening protocols and limited access in low-income regions. Continued efforts in screening, education, and research are essential for improving early detection and reducing the global burden of oral cancer.

KEYWORDS: Oral Cancer, Early Detection, Artificial Intelligence (AI)

INTRODUCTION

Oral cancer remains a significant global health burden, accounting for approximately 400,000 new cases annually. Despite the accessibility of the oral cavity for examination, late-stage diagnosis is common, leading to poor survival rates. The early detection of oral cancer is crucial, as it dramatically improves prognosis and reduces treatment-related morbidity[1]. Tobacco use, alcohol consumption, betel quid chewing, and HPV infection are major risk factors contributing to the disease burden. Screening programs targeted at high-risk populations have proven effective in improving early diagnosis rates. Recent advancements in adjunctive diagnostic tools, such as autofluorescence imaging and toluidine blue staining, offer promise for enhancing traditional visual examinations. Moreover, the integration of artificial

intelligence technologies is emerging as a powerful aid to clinicians, improving diagnostic accuracy and enabling earlier intervention[2].

EPIDEMIOLOGY AND RISK FACTORS

Over 90% of oral cancers are squamous cell carcinomas (OSCC), which originate from the epithelial lining of the oral cavity. Major risk factors include tobacco use, alcohol consumption, betel quid chewing—especially prevalent in South and Southeast Asia—chronic sun exposure (particularly for lip cancers), human papillomavirus (HPV) infection, and poor nutrition. Notably, in regions such as Taiwan and India, cultural habits like betel quid chewing significantly elevate oral cancer incidence. Recent studies have highlighted the synergistic effect of tobacco and alcohol, exponentially increasing cancer risk when both are used together[3].

Poor oral hygiene and chronic mucosal irritation from ill-fitting dentures or sharp teeth are additional contributing factors. Immunosuppression, whether due to HIV infection or immunosuppressive therapies, has also been associated with a higher risk of developing oral malignancies. Genetic predisposition and familial syndromes, such as Fanconi anemia, further increase susceptibility. Additionally, dietary deficiencies, particularly in antioxidants like vitamins A, C, and E, may impair mucosal defense mechanisms against carcinogenesis. Emerging evidence suggests that the oral microbiome and chronic inflammation might play roles in tumor initiation and progression. Moreover, occupational exposures, such as to wood dust or certain industrial chemicals, have been linked to an elevated risk of specific oral cancers. Demographic shifts indicate a rising incidence of HPV-related oropharyngeal cancers in younger, non-smoking populations[4].

Given the wide range of risk factors and the often asymptomatic nature of early lesions, the early detection of oral cancer becomes critically important. Comprehensive clinical examinations, especially targeted toward high-risk individuals, along with the use of adjunctive diagnostic tools and screening programs, are essential to improve early diagnosis and ultimately reduce mortality rates associated with oral cancer[4].

IMPORTANCE OF EARLY DETECTION

Survival rates for oral cancer can exceed 80% if detected at an early stage (stage I or II), but fall dramatically to below 50% when the disease is diagnosed at advanced stages (stage III or IV). Despite considerable improvements in surgical techniques, radiation therapy, and chemotherapeutic strategies, the overall five-year survival rate for oral cancer has only marginally improved over the past several decades. This persistent gap highlights the critical role of early diagnosis[5].

Early detection primarily relies on careful visual inspection and tactile palpation of the oral cavity during routine clinical examinations. However, studies have shown that early lesions are frequently missed by both patients and healthcare providers due to their asymptomatic nature and subtle clinical

presentation. Standardized oral cancer screening protocols are underutilized, with many general dentists and primary care physicians failing to perform comprehensive mucosal examinations[5].

Early detection of oral cancer plays a crucial role not only in improving survival rates but also in enhancing patients' post-treatment quality of life. Diagnosing the disease at an early stage significantly reduces the extent of surgical intervention needed, thereby preserving critical oral functions such as speech, swallowing, and aesthetics. Patients identified early often experience fewer complications and lower rates of disfigurement compared to those treated at advanced stages. Moreover, treatment costs are substantially lower for early-stage cancers, alleviating the financial burden on healthcare systems and patients alike. Early diagnosis also minimizes the need for multimodal therapies, such as combined surgery, chemotherapy, and radiotherapy, which are typically associated with increased morbidity. Furthermore, patients detected early have a lower risk of cancer recurrence and better long-term outcomes. High-risk populations, particularly tobacco users, betel quid chewers, and heavy alcohol consumers, benefit greatly from routine oral cancer screening programs that focus on early identification. The integration of adjunctive diagnostic aids—such as toluidine blue staining, brush biopsies, and autofluorescence imaging—can further enhance the sensitivity and accuracy of traditional examinations. Recently, artificial intelligence (AI) technologies have shown promising potential in supporting clinicians to detect malignant and premalignant lesions at earlier stages, especially in resource-limited settings. Public education initiatives, coupled with the implementation of opportunistic screening during routine medical or dental visits, are critical strategies that can significantly increase early diagnosis rates. Together, these measures underscore the profound impact that early detection can have in reducing mortality, minimizing treatment complexity, and ultimately improving the overall prognosis for patients with oral cancer[6].

METHODS OF DETECTION

• CONVENTIONAL EXAMINATION

Routine visual inspection and palpation of the oral mucosa remain the cornerstone of conventional oral cancer detection. Dentists and primary care providers play a pivotal role, as they often encounter asymptomatic or subtle lesions during regular dental check-ups, long before the patient reports any discomfort. A systematic approach—carefully examining all areas of the oral cavity, including the buccal mucosa, tongue (especially the lateral borders and ventral surface), floor of the mouth, palate, gingiva, and oropharynx—is essential for a thorough evaluation. Suspicious lesions that persist beyond two weeks, despite the removal of local irritants, must be biopsied promptly to confirm or exclude malignancy. Importantly, early-stage oral cancers can mimic benign lesions such as aphthous ulcers, traumatic ulcers, or fungal infections, which underscores the need for clinicians to maintain a high index of suspicion, especially in high-risk individuals. Visual examination alone, however, has limitations due to the potential for human error, lesion variability, and subjective interpretation[6].

• **ADJUNCTIVE DIAGNOSTIC TOOLS**

In addition to conventional visual and tactile examination, several adjunctive diagnostic tools have been developed to enhance the early detection of oral cancer. These tools assist clinicians in identifying lesions that might otherwise go unnoticed under standard examination techniques, providing critical support in differentiating benign from potentially malignant disorders. While none of these tools replace histological confirmation through biopsy, they serve as valuable aids in clinical decision-making, particularly in borderline or ambiguous cases. Among the most widely used adjunctive techniques are toluidine blue staining, autofluorescence imaging, brush biopsies, and the analysis of salivary biomarkers[7].

➤ **TOLUIDINE BLUE STAINING**

Toluidine blue is a vital dye that selectively stains nucleic acids, binding preferentially to tissues with high DNA and RNA content such as dysplastic or malignant cells. In clinical practice, the application of toluidine blue to suspicious lesions can help highlight areas with a greater likelihood of undergoing malignant transformation. A positive staining reaction often indicates the presence of abnormal tissue, warranting further investigation through biopsy. The use of toluidine blue is simple, cost-effective, and minimally invasive, making it a valuable tool, especially in settings with limited access to advanced diagnostic technologies. However, clinicians must interpret results cautiously, as false positives can occur in areas of inflammation or ulceration[6,7].

➤ **AUTOFLUORESCENCE DEVICES**

Autofluorescence imaging is another adjunctive tool that aids in the detection of early malignant changes within the oral mucosa. Under specific light wavelengths, normal oral tissues emit a characteristic fluorescence pattern, while dysplastic or cancerous tissues often show a loss of fluorescence or altered fluorescence patterns. Devices such as VELscope make use of this principle, providing a real-time, non-invasive method for identifying areas of concern. Autofluorescence can reveal subclinical lesions that are not easily visible under normal lighting conditions, thereby improving early detection rates. Nevertheless, this technique also has limitations, including a degree of subjectivity in interpretation and potential interference from inflammatory or pigmented lesions[7].

➤ **BRUSH BIOPSIES AND SALIVARY BIOMARKERS**

Brush biopsy is a minimally invasive technique that involves collecting epithelial cells from oral lesions using a special brush designed to reach the basal cell layer. The collected sample is then analyzed cytologically for cellular abnormalities indicative of dysplasia or malignancy. Brush biopsies offer the advantage of being painless and easy to perform in a primary care or dental office setting, potentially increasing patient compliance with early diagnostic procedures. In parallel, the

emerging field of salivary diagnostics is offering new, non-invasive methods to detect biomarkers associated with oral cancer. Saliva contains a wide array of biological molecules, including DNA, RNA, proteins, and metabolites, which can reflect pathological changes. Researchers are actively investigating salivary biomarkers for their potential to aid in the early detection, prognosis, and monitoring of oral cancer, potentially offering a future where a simple saliva sample could serve as a reliable diagnostic tool[8].

• **ARTIFICIAL INTELLIGENCE (AI)**

AI technologies, particularly deep learning models, have demonstrated remarkable potential in enhancing the detection of oral cancer through clinical images. Recent studies highlight that these models can achieve accuracy rates of up to 99.7%, showcasing their ability to identify oral cancer with exceptional precision. This high accuracy is complemented by strong sensitivity and specificity, meaning the models can effectively detect true positive cases while minimizing false positives. The application of deep learning in oral cancer detection is a game-changer, as it enables earlier and more accurate diagnoses, which is critical for improving patient outcomes. By analyzing large datasets of clinical images, AI can identify subtle patterns that may not be easily visible to the human eye, aiding clinicians in making more informed decisions[9]. Furthermore, the integration of AI into clinical practice can alleviate the burden on healthcare professionals, streamlining workflows and reducing diagnostic errors. As AI continues to evolve, its ability to assist in routine screening and early detection holds promise for revolutionizing the way oral cancer is diagnosed and treated, potentially leading to better survival rates and quality of life for patients[9].

• **SCREENING PROGRAMS**

Targeted screening for high-risk populations, such as smokers, alcohol consumers, and betel quid chewers, has proven to be an effective strategy for identifying oral cancer at its earliest and most treatable stages. These high-risk groups are more susceptible to developing oral cancer, making targeted screening programs essential for early intervention and improving survival rates. In addition to clinical screenings, community health worker involvement and public awareness campaigns have played a pivotal role in enhancing early detection. By educating the public about the risks and symptoms of oral cancer, these programs have empowered individuals to seek timely medical advice, leading to earlier diagnoses. Countries that have implemented these integrated programs have seen significant improvements in detection rates, particularly in underserved areas where access to healthcare might be limited. The combination of community outreach, targeted screening, and public education creates a holistic approach to combating oral cancer, ultimately reducing the burden of this disease and ensuring that more people receive the care they need before the cancer progresses to later, more challenging stages. These efforts, when coupled with advanced diagnostic technologies like AI, further strengthen the overall impact of early detection initiatives[10].

CHALLENGES AND FUTURE DIRECTIONS

Despite ongoing advances in oral cancer detection, several significant challenges remain. One major limitation is the lack of widespread, standardized screening protocols, which leads to inconsistencies in clinical practice and delays in diagnosis. Furthermore, there is considerable variability in clinicians' ability to recognize early, subtle lesions, often resulting in missed opportunities for early intervention. This diagnostic gap is compounded by socioeconomic barriers, particularly in low- and middle-income regions, where access to regular dental care and preventive screening is limited. In many cases, patients may not seek care until symptoms become severe, by which point the disease has often progressed to a late stage. Additionally, public awareness about the early signs of oral cancer and the importance of regular oral health checks remains insufficient. Misconceptions about risk factors, fear of diagnosis, and lack of knowledge about the significance of persistent oral lesions contribute to delays in seeking professional evaluation[11].

To overcome these challenges, future strategies must focus on several key areas. First, integrating artificial intelligence (AI) into diagnostic workflows could enhance clinicians' ability to detect early malignant changes with greater accuracy and consistency. AI technologies, such as deep learning models, have shown great promise in analyzing clinical images and identifying precancerous and cancerous lesions at an early stage. Second, comprehensive training programs should be implemented to better equip primary care providers, dentists, and allied health professionals with the skills necessary for early recognition and management of suspicious oral lesions. Public health initiatives must also be expanded, emphasizing the importance of regular oral examinations through targeted awareness campaigns, especially in high-risk populations. By combining technological innovation, enhanced clinical training, and robust public education efforts, the goal of improving early detection rates and reducing the global burden of oral cancer can be more effectively achieved[12].

EVALUATION OF CURRENT AND EMERGING ADJUNCTIVE TECHNIQUES

It would appear reasonable to employ adjunctive approaches that are commercially accessible, such as assistance to increase or improve the accuracy of the VOE. It is possible that the VOE will eventually be superseded in this era of advanced technology. These screening adjuncts use light-based technologies or oral rinses (or maybe both), evaluate the oral cavity in a "wide-field" manner beyond what is visible to the human eye, and are intended to precisely identify and define aberrant mucosal "fields" that correspond to oral carcinogenesis[13].

This study examines the diagnostic accuracy of commercially available adjunctive techniques (such as optical-based adjuncts, vital staining, and cytopathologic platforms) for the detection of oral cancer or OPMDs in comparison to gold-standard histopathology after OPMDs are detected by VOE [13]. Although critical rinsing with toluidine blue and tissue autofluorescence devices have been investigated in a screening context, no platform has yet to provide compelling data to support their usefulness [14,15].

Saliva, due to its ease of collection and proximity to oral cancers, is a promising biofluid for detecting biomarkers related to oral cavity and oropharyngeal cancers—a field known as "salivaomics." This includes genomics, proteomics, transcriptomics, metabolomics, and microbiomics. While numerous case-control studies have explored salivary biomarkers and shown some promise, issues like methodological variability and cancer heterogeneity limit their utility. Multiplex biomarker panels may address these challenges and even allow for home-based screening. Compared to saliva, blood-based biomarkers for oral cancer have been less studied and seem less practical given the direct contact of saliva with the tumor site. However, developing diagnostic panels that work across saliva and blood to detect multiple cancer types remains a long-term goal[16].

Two commercial point-of-care salivary diagnostic tests for oral cancer are available: one detects soluble CD44 and protein levels, and the other uses six mRNA markers. Although they show promising sensitivity, neither is FDA-approved for general screening and both require further validation. Currently, no adjunctive screening tools have been prospectively tested in primary care. While novel salivary and blood-based tests are in development, their adoption is limited by costs, equipment needs, and shortages of trained personnel, especially in low-resource settings[17].

CONCLUSION

Early detection of oral cancer dramatically improves outcomes. Dentists and primary healthcare providers play a key role in recognizing early lesions. While traditional methods remain essential, adjunctive tools, including AI, promise to enhance detection accuracy. Efforts must continue to promote regular screening, education, and research into novel diagnostic technologies.

Oral cancer screening models vary, and selecting the appropriate one depends on factors such as disease incidence, available resources, and the healthcare system of the country. While existing screening studies have shown both strengths and weaknesses, they provide useful frameworks for clinicians and policymakers to guide screening recommendations. Challenges include the need for cost-effective approaches and greater efficiency, with potential solutions like targeting high-risk populations, incorporating telemedicine, and combining adjunctive aids for visual examination. Additionally, salivary or blood-based biomarker testing, though not yet explored in primary care, could be valuable in future oral cancer screening research[17].

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