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SHORT COMMUNICATIONS

Advancing Oral Cancer Detection and Prevention: Integrating Innovative Screening Tools, Molecular Insights, and Targeted Therapies

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Abstract

This publication aims to explore how current clinical practices can enhance the development and use of oral cancer diagnostic tools and molecular advancements for prevention and detection. A review was conducted to determine the evolving development of diagnostic progress, with several tools that are non-invasive, including salivary biomarkers and imaging techniques that can be a promising discovery to increase detection in clinical practice and progression. Related searches and inclusion criteria were used to identify tools to assess or identify the literature search in databases. The study's essential findings indicate that advanced progress diagnostic approaches and technologies are not yet fully implemented in practice, especially in low-resource countries, where most countries are diagnosed with oral cancer's late-stage occurrence. This diagnostic study can serve as a baseline for future assignments for related studies, significantly improving the application of diagnostic instruments that can help improve progress compared to the disease mortality rate.

Keywords: Biomarkers- Narrow band imaging- Matrix metalloproteinases- Optical coherence tomography- Oral cancer

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Introduction

High mortality and morbidity due to oral cancer is raising concern and demand of improved screening method, especially and mainly in early stages because treatments are more effective at this time. There is significant improvement but still the biggest research gap is that there are no accurate and available diagnostic resources present in all parts of the world. In underdeveloped and low- resource settings this is a huge gap recently. Artificial intelligence development technologies for early diagnosis could be a good research gap for this [1]. Adding non-invasive salivary biomarker detection in clinical routine practice could be an excellent justification for this study because this could change all radiographic and clinical routine practices and screening methods for screening of oral cancer development [2]. Additionally, the relatively high burden of oral cancer, which is also a global health concern, is attributed to its high morbidity and mortality rates due to late diagnosis. Patients are often asymptomatic until the advanced stage, which greatly reduces the effectiveness of existing treatment options [3]. Along with the fact that the possibility of early diagnosis in some region is higher than the other, low-resourced region are more likely to report a late stage diagnosis due to insufficient diagnostic access and healthcare infrastructure [4]. To eliminate this situation, integrating potential yet simple diagnostic practice, such as salivary biomarkers and optical imaging technologies, into routine clinic practice through closing the non-integration gap could lower the oral cancer burden significantly by proving better-access solutions, especially in less resourced

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communities where the urgent need for early diagnostic solution is present. Further, timely and non-invasive diagnosis and prevention of oral cancer poses maximum benefit to patients, as treatment can be started at stages where interventions are most effective.

Non-invasive diagnostic approaches, like salivary biomarkers show great promise in assessment with minimal infrastructure requirements and ease of use [5]. Emerging diagnosis technologies like genomics, proteomics etc can give deeper understanding of the oral cancer landscape on recent developments to help in personalized treatment methods, better prognostic assessments. These technologies not only improved accuracy in diagnosing but also rapid and pre-emptive screening of high-risk populations for targeted preventive measures. But, implementation of these technologies to everyday clinical practice is still a challenge, especially in developing countries and require systemic processes to overcome the barriers of accessibility and affordability [6].

Methods

The systematic review was conducted following utilizing databases such as PubMed, Scopus, and Web of Science, to gather relevant studies. The search encompassed literature published between 2015 and 2023, employing keywords like "oral cancer," "diagnostic tools," "salivary biomarkers," "screening," and "molecular diagnostics." Additionally, the criteria for inclusion of studies for the prepared review corresponded well with the purposes of the current study in terms of promising advancements in the area of oral cancer diagnostics. The reviewed studies had to deal with the non-invasive detection of cancerous changes using cutting-edge technologies, such as salivary biomarkers, optical imaging techniques, or other screening approaches applicable in regions with limited and adequate resources [1]. The exclusion requirements were also applied rigorously, with studies irrelevant to oral cancer early detection or demonstrating no remarkable improvements in diagnostic approaches excluded. Due to these criteria applied, the study was able to select high-quality research which findings might be effective in improving diagnostic outcomes for oral cancer.

Screening and Diagnostic Tools for Oral Cancer

It is crucial to comprehend how well various screening techniques can detect oral cancer. Due to its high sensitivity and specificity rates, the studies listed above emphasise the significance of visual and tactile assessment as a main screening approach. However, it is equally crucial to understand that due to variances in operator skill and subjective interpretation, visual examination may not always be accurate. Therefore, incorporating cutting-edge diagnostic equipment and technologies can aid in overcoming these constraints and improve the precision of oral cancer detection. Fluorescence visualisation, salivary biomarkers, and digital imaging methods like optical coherence tomography (OCT) and narrow band imaging (NBI) are some of these additional tools. Figure 1 illustrates the conceptual framework for integrating these advanced diagnostic modalities into clinical practice, underscoring their potential to bridge gaps in early detection, particularly in low-resource settings Additionally, the integration of artificial intelligence (AI) algorithms into these technologies has the potential to improve their efficiency by eliminating human error in the interpretation of results. Visual examination remains the primary screening tool for oral cancer and its limitations should be recognized. Combining it with other diagnostic tools and technologies could significantly improve the accuracy of oral cancer detection. Early diagnosis through effective screening methods is essential to increase survival and reduce mortality from this devastating disease.

Warnakulasuriya performed a systematic review and meta-analysis to assess the effectiveness of visual examination in detecting oral cancer and found that the combined sensitivity was 84% and specificity was 94%. That is why early diagnosis by sight and palpation is so important. All studies by Warnakulasuriya and Mehrotra showed the importance of using these methods in the early detection of oral cancer. This suggests that VIA may be a quick and affordable technique to identify oral cancer early on before it has spread too far. Furthermore, the value of routine dental exams to identify pathological changes in the oral cavity is highlighted by the effectiveness of visual examination alone. Finally, Warnakulasuriya findings on the combined sensitivity and specificity suggest the use of visual examination as a useful technique for early identification of oral cancer. This study emphasises the importance of complete visual and tactile inspections as part of routine exams by healthcare providers in addition to listening to patients concerns. They have a chance to identify oral cancer early and perhaps save lives. People should prioritise their health by scheduling regular consultations with a dentist or other healthcare provider and talking about any strange symptoms. It has been demonstrated that toluidine blue has a moderate sensitivity and a high specificity for the detection of oral dysplasia and cancer. As a result, questionable spots that might need more testing or biopsies can be appropriately identified. According to research studies, Toluidine blue may also be particularly helpful in identifying regions that have a high risk of developing oral cancer.

Another instrument used frequently for oral examinations is the VELscope. It makes it simpler for clinicians to detect oral cancer symptoms since it employs fluorescent light to identify abnormal tissue in the mouth. VELscope can enhance visualisation and offer more information for diagnosis, even if it cannot replace visual and tactile inspection. The detection and management of oral cancer can be considerably improved by using toluidine blue and VELscope as an assistance in oral inspection. These tools help ensure prompt and effective patient care by giving healthcare providers useful information. When used in conjunction with conventional research techniques, these technologies provide a potent strategy for combating this illness. A 2009 study by Poh et al. [7] found that the VELscope can help detect oral cancer with a sensitivity of 97%

and a specificity of 100%. It might aid in reducing the frequency of false positive biopsies for those who are worried about needless procedures. Fakhry investigated the efficiency of VELscope in identifying oral cancer. They noted a sensitivity rate of 100% and a specificity rate of 57%, indicating that this technique may be useful in identifying high-risk lesions. Early oral squamous cell carcinoma (OSCC) detection is made possible by imaging techniques. With the aid of these procedures, clinicians can see the tissues in the mouth in great detail, making it simpler to detect malignant lesions and assess treatment outcomes. Optical coherence tomography (OCT) and fluorescence imaging are two imaging modalities that have proven extremely useful in OSCC (Figure 2).

OCT is a non-invasive method that makes cross-sectional pictures of oral tissue using light waves. This enables medical professionals to check for any unusual growths or tissue alterations that might point to OSCC. A fluorescent dye is injected into the bloodstream during fluorescence imaging, and the mouth's cells then take it up. Special cameras are able to detect a fluorescence signal that cells release when exposed to light of a specific wavelength. This method draws attention to potential cancer cell locations. Numerous lives have been saved due to the enormous advantages that OCT and fluorescence imaging have in the early diagnosis of oral cancer. OCT was used by Colstone to examine oral tissue, and they discovered good sensitivity and specificity in separating mucosa from dysplastic and malignant tumours. In their investigation on the use of OCT for the early diagnosis of OSCC, WilderSmith discovered good sensitivity (92.3%) and specificity (92.3%). A fluorescent substance is used in fluorescence imaging technique to enhance OSCC visualisation. These substances can be kept in the malignant tissue specifically, improving the contrast for tumour detection. Numerous studies demonstrate how well fluorescence imaging works to find OSCC.

Autofluorescent imaging was used in a study by de Veld et al. [8] to find oral tumours. They are said to have good dysplasia and cancer detection sensitivity (95%) and specificity (83%) rates. Tsai investigated the use of 5-aminolevulinic acid-induced fluorescence imaging for the detection of OSCC and reported sensitivity and specificity values of 96.9% and 89.4%, respectively. These studies highlight the potential of OCT and fluorescent imaging as important imaging techniques in the diagnosis and management of OSCC. Saliva has become a useful diagnostic tool for many non-malignant diseases, including oral squamous cell carcinoma. Analysis of salivary biomarkers has advantages such as easy sample collection, cost-effectiveness, and patient compliance. Various biomarkers have been identified and studied because of their potential use in OSCC detection, diagnosis, and clinical monitoring. Many studies have investigated the use of salivary biomarkers for early detection of OSCC. Saliva levels of matrix metalloproteinases (MMPs) are associated with OSCC. Expression of MMP-2 and MMP-9 is increased in OSCC patients compared to healthy controls. Elevation of salivary cyfra 21-1, a fragment of cytokeratin, has been observed in OSCC patients and may serve as a diagnostic marker [9]. Certain salivary biomarkers are associated with prognosis and treatment response in OSCC patients. Salivary interleukin 6 (IL-6) levels are associated with tumor stage and lymph node metastasis, demonstrating its potential as a prognostic marker [10]. Due to its correlation with tumour size and metastasis, salivary squamous cell carcinoma antigen (SCCA) has been shown to be useful in predicting treatment response and recurrence .

Numerous molecular and genetic markers that are essential for the growth and development of OSCC grown in OSCC have been discovered because of advances in molecular and genetic research. These indicators can be employed as diagnostic or diagnostic instruments and give information about the underlying biological pathways. According to research on OSCC, oncogenes such TP53, EGFR, and cyclin D1 can develop mutations or modifications that lead to tumour growth and development [11]. Tumour suppressor genes, such as p16INK4a and p53, have been found to be deficient or downregulated in OSCC, which implies their role in the disease's aetiology . OSCC is related to miRNA dysregulation. MiR-21, miR-31, and miR-375, for instance, have different expression levels in OSCC and are linked to the development and spread of tumours [12, 13]. In OSCC, lncRNAs such as HOTAIR and MALAT1 exhibit abnormal expression that has been linked to tumour growth, invasion, and prognosis .Artificial Intelligence (AI) and machine learning (ML) techniques have shown great potential in diagnosing oral cancer. These advanced computational techniques have the potential to improve the accuracy, efficiency, and effectiveness of oral cancer screening. Here are some examples of applications of Ai and ML in the evaluation of oral and oral interpretations to monitor for malignant or premalignant symptoms. These algorithms are good at identifying patterns and features that indicate oral cancer. Studies proposed a deep learning model to detect oral cancer from images [14]. The model achieved 91.8% accuracy in mask classification. Zelenik [15] used convolutional neural networks (CNNs) to identify masks from images showing height and specificity.

While visual examination remains the primary tool, advanced imaging techniques such as OCT show promise. However, limitations include the high cost and lack of availability in low-resource settings, resulting in inequitable access to these technologies. Recent studies indicate the potential of salivary biomarkers in accurately diagnosing OSCC, though they also face challenges related to standardization and implementation in clinical practice. Genetic research highlights novel targets for early detection, yet issues with validation in diverse populations limit their immediate application.

Risk assessment and prediction models

AI and ML techniques were used to develop risk assessment and prediction models for oral cancer. This model incorporates a variety of medical and demographic factors to predict an individual's cancer risk. Development of a machine learning model combining clinical data, genetics and lifestyle factors to predict oral squamous cell

carcinoma risk. The model achieves a prediction accuracy of 80 % .Using machine learning tools to develop risk models for oral violence. The model shows distinction and efficiency.

Data Mining and Feature Selection

AI and ML algorithms can analyse large datasets and extract relevant features for oral health diagnosis. These techniques help identify important biomarkers and are associated with oral cancer. Patil used Machine Learning Algorithms to analyse Genomic Data and Identify Key Genes Associated with Oral Squamous Cell Carcinoma. A study by Chattopadhyay [16] studied Identification of Potential Biomarkers of Oral Cancer Based on Gene Expression Profiles Using Data Mining Techniques.

Prevention Strategies

Smoking and Alcohol Prevention Programs

Giving up alcohol and smoking is a crucial OSCC preventative approach. To help people stop smoking and drinking, these programmes offer counselling, behavioural therapy, and medication [17]. It gives a general review of the prevalence of oral and oropharyngeal cancers worldwide, including OSCC, and emphasises the role that smoking and alcohol use have in OSCC prevention by lowering the likelihood of these harmful side effects. While alcohol programmes concentrate on lowering or eliminating alcohol intake, smoking cessation programmes are designed to assist people in quitting cigarettes and other tobacco products. These programmes frequently employ a combination of techniques, including counselling, behavioural interventions, pharmaceuticals, and support groups, to assist individuals in overcoming drug addiction and refraining from protracted alcohol and smoking use.

Human papillomavirus (HPV) vaccination

A key factor in preventing HPV-related OSCC is HPV immunisation. The incidence of HPV-associated OSCC is decreased by vaccination against high-risk HPV strains such HPV-16 and HPV-18 [18]. Researchers tested the efficacy of the bivalent HPV16/18 vaccination in less than three doses as a proof-of-concept. The study emphasises how HPV vaccination may lower the risk of malignancies linked to HPV, including OSCC. The OSCC and other high-risk HPV strains that are known to cause cancer are protected against by the HPV vaccine. Teenagers and young adults frequently receive the HPV vaccine because it is typically advised before introduction to the virus. By immunising people against high-risk HPV strains including HPV-16 and HPV-18, the chance of developing HPV-related OSCC can be decreased. The HPV vaccine has the potential to have a significant impact on the prevention of OSCC and other HPV-related cancers.

Dietary modification and micronutrient supplementation

Altering one's diet and taking extra micronutrients can help avoid dental illness. Adequate nutrition and a balanced diet high in fruits and vegetables can help lower the risk of developing cancer (World Cancer Research Fund/American Cancer Research Institute, 2018) [19]. Information on the links between nutrition, food, activity, and cancer prevention is available in the Cumulative Update (CUP) from the World Cancer Research Fund and the American Cancer Research Institute. The study emphasises the value of a balanced diet, which includes consuming lots of fruits and vegetables, in order to lower the incidence of oral cancer.

Key Lifestyle Factors

Healthy practises include frequent dental check-ups, brushing and flossing, and keeping good oral hygiene. For the purpose of preventing oral disease, routine cleaning is essential. By aiding in the early detection of any anomaly, these lifestyles assist lower the risk of cancer [17]. The study emphasises the value of maintaining a healthy lifestyle, including frequent dental check-ups and proper oral hygiene, to prevent oral disorders.

Chemopreventive agents

Some anti-inflammatory medications, including retinoids and nonsteroidal anti-inflammatory medications (NSAIDs), have reportedly demonstrated the capacity to lower the incidence of mouth cancer. Sankaranarayanan [20] showed that the EIA study is particularly promising as it shows high sensitivity and specificity. Vitamin A derivatives known as retinoids have been investigated for their potential to slow the growth of oral precancerous lesions and stop them from developing into mouth cancer [20]. Oral cancer has been demonstrated to be successfully treated with NSAIDs, which are well-known for their anti-inflammatory characteristics [21]. This study has also covered the potential of retinoids and NSAIDs as oral anti-inflammatory drugs. These studies examine their effectiveness in avoiding the growth of precancerous lesions in the mouth and lowering the risk of oral cancer.

The role of public health policy and public awareness

In order to avoid oral diseases, public health knowledge and policy are essential. These efforts emphasise informing the public about risk factors, encouraging healthy practises, and highlighting the value of routine cancer screening and early cancer diagnosis [22].

Early Detection Programs

Community-Based Screening Program

In order to avoid oral diseases, public health knowledge and policy are essential. These efforts emphasise informing the public about risk factors, encouraging healthy practises, and highlighting the value of routine cancer screening and early cancer diagnosis [22].

The Role of the Dentist in Early Diagnosis

Dentists play a key role in the early detection of OSCC. Regular dental check-ups provide the dentist a chance to inspect the mouth and look for any anomalies or anomalies that could be signs of oral cancer [23]. Sciubba [23] talks about the value of a dentist in detecting oral illnesses at

an early stage. It emphasises the value of routine mouth examinations by dentists to spot any anomalies and send patients for additional testing and diagnosis.

Self-Assessment and Patient Education

The OSCC Early Detection Programme includes patient education and self-assessment heavily. Promote self-diagnostic methods that enable people to spot anomalies and seek treatment over time by educating people on the warning signs and symptoms of oral cancer. For the early identification of several cancers, including oral cancer, it emphasises the value of patient education and self-examination.

Integrating oral cancer screening into routine health care visits

Incorporating oral cancer screening in regular doctor appointments, regular health examinations, like the initial visit, can aid in the early detection of OSCC. Clinicians can conduct a quick screening, assess risk factors, and, if more information is required, refer patients for additional testing [24]. In the early diagnosis and treatment of many cancers, including oral cancer, primary healthcare services play a crucial role. The inclusion of oral cancer screening into routine medical examinations based on the detection of anomalies and the referral of patients for necessary therapy.

Early detection using Telemedicine and Health applications

Telemedicine and health applications have the potential to help with OSCC early detection. Doctors are now able to direct patients and measure masks because of technology that enables remote communication, image sharing, and real-time communication. Oral cancer was one of several types of cancer that Rathore evaluated for the possibility of telemedicine and health applications to help with early identification and offer remote counselling.

Novel Approaches and Future Directions

Advances in Molecular and Genetic Research

The biology of OSCC and its development plans are now well understood because of developments in molecular and genetic research. It may be possible to identify new therapeutic targets and biomarkers for early diagnosis and personalised therapy by identifying genetic changes, gene expression patterns, and molecular pathways linked to OSCC (The Cancer Genome Atlas Network, 2015) [25]. The Cancer Genome Atlas Network's genome search is available in the reference database. The genetic makeup of head and neck squamous cell carcinomas, including OSCC, is thoroughly investigated. This study emphasises how molecular and genetic research might help us better understand OSCC and identify new treatment targets. The Polymerase Chain Reaction (PCR) is a molecular biology technique that can be used to identify infectious diseases and investigate tumors caused by microbes. PCR can help with cancer research by shedding light on the complex pathophysiology of neoplasia. It is a valuable detection method because it can identify both oncogenes associated with cancer, such as K-ras and Nras, and tumor suppressor genes, such as p53 and p16. However, PCR technology is not without its challenges. Contamination and amplification artifacts can make it difficult to interpret results. Despite its potential to improve diagnostic accuracy, PCR is not yet widely used due to its high cost. Some studies have shown that these issues need to be addressed before PCR can become a more widely used diagnostic tool.

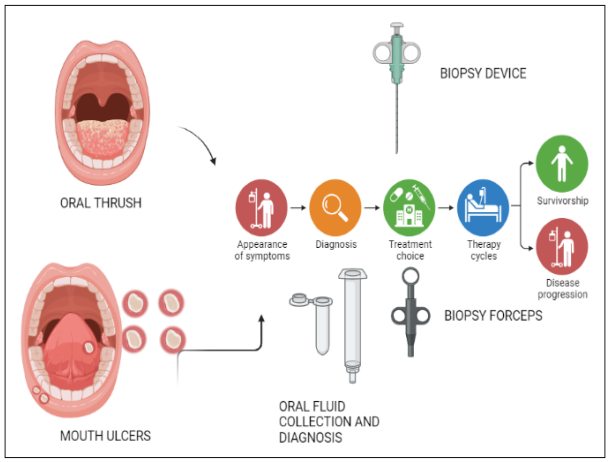

Figure 1. Schematic Representation for Diagnosis and Treatment of OSCC

Development of New Screening Methods

The creation of novel screening techniques may help in OSCC diagnosis and early detection. To raise the sensitivity and specificity of oral cancer diagnosis, enable early intervention, and enhance patient outcomes, new techniques such optical imaging, fluorescence-based approaches, and saliva biomarker analysis are being researched. The function of new generation technologies in the detection and interpretation of head and neck cancer treatment is explained by Hashibe . The article emphasises how novel screening techniques, such as molecular profiling and biomarker analysis, may help in OSCC early identification and diagnosis. Saliva testing is a new and promising approach for detecting oral squamous cell carcinoma (OSCC). Saliva is easily accessible, minimally invasive, and highly effective as a diagnostic medium. In the future, saliva-based diagnostics may be used to diagnose oral cancer by analyzing the patient's saliva transcriptome.Studies have shown that certain viruses and tumor suppressor genes are abnormally elevated in saliva of patients with head and neck conditions [26]. However, more research is needed to confirm the effectiveness of this approach. Although there is growing interest in using saliva to identify genes associated with oral cancer, this technology has not yet been commercialized. The researchers hope that it will soon be widely available. Early detection of oral cancer is essential to improve survival, and using saliva as a diagnostic tool can help achieve this goal.

Targeted Therapy and Personalized Medicine

The landscape of OSCC is evolving as a result of

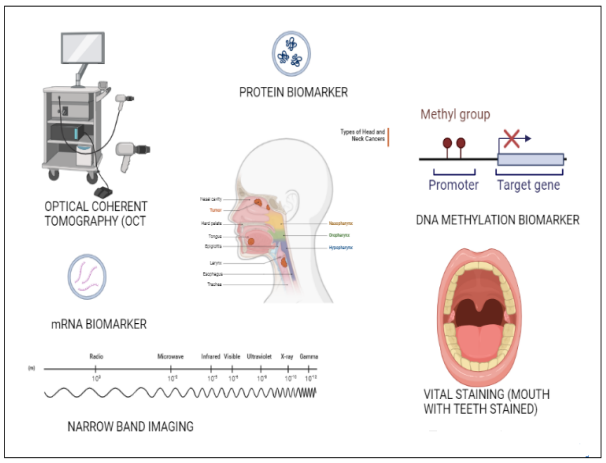

Figure 2. Schematic Representation of Diagnostic Tools Used for the Detection of OSCC

improvements in focused therapy and personalised medicine. In order to specifically inhibit the detrimental molecular targets and pathways involved in OSCC, targeted therapeutics including antiviral medicines and molecularly targeted medications are being developed [27]. Brockstein analyses the current state and potential developments in head and neck cancer prevention, particularly OSCC, in this article. The outcomes of targeted therapy, including anti-inflammatory medications and personalised medicine, may act as a potentially effective treatment for OSCC. Molecularly targeted therapies are essential to improve drug efficacy and reduce the toxicity of conventional chemotherapeutic agents. Smart manipulation of drug release behavior can be achieved through controlled nanodelivery systems, which deliver drugs when there is a small change in the microenvironment and this can be used for targeted therapy. Drug delivery systems based on nanotechnology allow selective strategies in the treatment of OSCC, with advantages such as improved therapeutic effect and reduced side effects They include various nanoparticles, liposomes, cyclodextrins, nanolipids, and hydrogels are discussed in terms of their properties. Biomimetic nanoparticles such as exosomes, peptides/proteins, and virus-like particles have also been used as potential carriers for chemotherapeutic agents for oral cancer therapy [28]. Liposomes are small molecules composed of membrane lipids, phospholipids, and cholesterol. They are not toxic to normal tissues or cells and are widely used as drug delivery systems to enhance drug accumulation at target sites [28]. This has generated considerable interest in them used to provide drug release and drug delivery for greater therapeutic efficacy. For example, researchers have prepared liposomes that can modify the release of aluminum phthalocyanine chloride for photodynamic therapy, showing effective treatment of oral cancer. In another study, mixed lipids based on phosphocholine binary motifs were proposed for targeted drug delivery. These vesicles were stable in solutions for over 50 days and bonded with AlClPc molecules that could distribute in cellular organelles and undergo a disaggregation process after uptake by OSCC. This could guide future research on the intracellular mechanism of PDT for oral cancer therapy [28].

Action Research and strategies to improve interventions

For the purpose of addressing OSCC in the general population, research and methods to enhance interventions are crucial. Healthcare professionals can maximise the use of preventative measures, early intervention programmes, and treatments to lessen the burden of OSCC and enhance patient outcomes by undertaking practise studies and establishing evidence-based policies [29]. 6% of normal tissue may be distinguished from cancerous tissue using it. OCT pictures showed good correlation with histological findings when Sivak assessed its use in the diagnosis of oral dysplasia and OSCC, suggesting that it may be able to make a non-diagnostic diagnosis.

Discussion and Conclusion

It can be concluded that a lot of the new diagnostic techniques or proposed biomarkers have the ability to find oral cancer. Evaluations can evaluate the efficiency of various measures, such as regional screening programmes, educational initiatives, or therapies, in reducing oral cancer discomfort or enhancing outcomes. This review emphasises the significance of altering risky lifestyle behaviours including smoking and drinking alcohol, as well as the effects of dietary modifications and micronutrient supplementation on immunity. The methods and instruments revealed will highlight the necessity of changing the therapeutic procedure to take into account these recent developments in immunity. Oral cancer early detection and diagnosis. These discoveries could aid in the development of tailored therapies based on unique risk factors, genetics, or particular biomarkers to improve the efficacy of prevention. In summary, the identification of biomarkers or diagnostic tools will require further study and modelling in different populations to ensure their reliability and clinical usefulness. Long-term studies will be needed to assess the effectiveness and duration of the intervention and its contribution to reducing oral cancer incidence and mortality. Policy development will focus on integrating new ideas into daily practice, improving access and opportunities, and fostering collaboration between health professionals, researchers and policymakers. In critically discussing the advantages and limitations of the reviewed approaches, salivary biomarkers exhibit a non-invasive potential for early detection but require more extensive validation and standardization. Advanced imaging techniques provide detailed insights into lesion characterization, yet their accessibility poses significant challenges in low-resource environments.

Recommendations for clinical integration of these tools include developing training programs for healthcare providers in under-resourced areas and creating awareness campaigns about the importance of early detection. Policymakers should prioritize funding for training and technology access to improve early diagnosis rates.This study contributes to the existing literature by emphasizing the need for innovative diagnostic tools that are feasible in diverse healthcare settings. Future research should focus

on collaborative efforts to standardize diagnostic protocols and enhance the applicability of findings across various ethnic and socio-economic groups, ultimately improving oral cancer outcomes globally.

Declarations

Ethical Statements

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Competing Interests

Authors declares no competing interests

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Not Applicable

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