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Exploring the Attributes, Medical Scenario, and Treatment Strategies of Oral Cancer

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Abstract: In developing countries like India, where lifestyle choices, delayed diagnosis, and restricted access to healthcare lead to high mortality rates, oral cancer is particularly widespread and continues to be a significant global health concern. The epidemiology, etiological factors, and clinical presentation of oral cancer are among the many characteristics examined in this review. Oral squamous cell carcinoma, the most common type, is closely associated with human papillomavirus infection, alcohol consumption, tobacco use, and chewing betel quid. A majority of cases are still discovered at advanced stages, despite improvements in early detection brought about by advancements in diagnostic modalities ranging from cytological screening to molecular and imaging-based approaches. In order to improve disease control and survival, therapeutic approaches have changed from traditional surgery and radiation to multimodal regimens that include chemotherapy, targeted therapy, and immunotherapy. The review also emphasizes how multidisciplinary management, community awareness campaigns, and preventive measures can improve patient outcomes. Effective control measures require an understanding of how biological mechanisms, behavioral risk factors, and developing therapeutic technologies interact. Together, improving comprehensive care, public health regulations, and early detection can lessen the worldwide impact of oral cancer and improve overall prognosis.

Keywords: *Squamous Cell Carcinoma, Oral Cancer, Risk Factors, Diagnosis, Radiotherapy, Chemotherapy, Prevention, India.*

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I. INTRODUCTION

Oral cancers, primarily oral squamous cell carcinomas (OSCC), account for nearly 90% of all cancers that develop in the oral cavity[1, 3, 4]. It is especially common in South and Southeast Asia and ranks among the top ten cancers worldwide[1, 2, 5]. There is a strong correlation between the disease burden and lifestyle factors, socioeconomic status, and healthcare access[2,6]. Overall survival is still below ideal because of delayed presentation and metastases at diagnosis, even with improvements in diagnostic and treatment modalities [7, 8]. Therefore, it is crucial to comprehend the traits and methods of treatment of oral cancer in order to direct clinical practice and public health programs [6, 12]. Oral squamous cell carcinoma (OSCC) is the most common histological variant of oral cancer, which is a major global public health concern and accounts for a substantial portion of head and neck cancer[1,2]. The overall survival rate has not increased significantly over the past few decades, despite significant advancements in diagnostic and treatment techniques [3, 4]. Due to persistently high behavioral and cultural determinants, such as alcohol consumption, betel quid consumption, and tobacco chewing, the global burden is particularly high in South and Southeast Asia[5-7].Because of the combined effects of biological, behavioral, and environmental factors, the epidemiological distribution of oral cancer varies greatly across populations and geographic regions[1,4,8].

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Human papillomavirus (HPV) infection, especially type 16, has been identified as a significant etiological agent that contributes to the increasing incidence of oropharyngeal squamous cell carcinoma in various parts of the world, in addition to exposures related to lifestyle [9]. With significant regional variations in incidence and outcome, oral and lip cancers continue to rank among the leading causes of cancer-related morbidity and mortality, according to global data from GLOBOCAN 2020[13]. The issue is made worse in developing countries by socioeconomic disparities, ignorance, and restricted access to healthcare[10,12].Leukoplakia and erythroplakia are examples of premalignant oral lesions that frequently act as precursor stages for OSCC, with varying risks of malignant transformation[3,4,17].

Research has shown that compared to nondysplastic lesions, leukoplakic lesions with epithelial dysplasia have a noticeably higher chance of developing into carcinoma [3, 16]. The early detection of potentially malignant disorders and high-risk mucosal changes has been improved by advancements in diagnostic techniques like brush cytology, toluidine blue staining, and molecular biomarker detection [16, 17]. Due to delayed symptom recognition and insufficient screening efforts, many patients still present with advanced disease, despite the fact that early detection and intervention are still crucial for improving prognosis[6,7,12].

According to molecular theory, oral cancer is caused by intricate genetic and epigenetic changes that throw off the equilibrium between cell division and apoptosis[15,19,21].The pathophysiology and progression of OSCC have been linked to mutations in tumor suppressor genes, oncogene activation, and dysregulation of signaling pathways like EGFR, PI3K/AKT, and TP53 [15,19,21]. The development of immunotherapeutic interventions and targeted therapies with the goal of enhancing disease control and survival outcomes has been made possible by these molecular insights [18, 21, 23]. The cornerstone of treatment for oral cancer is still multimodal management, which combines chemotherapy, radiation, and surgery [5, 6, 7]. Combination regimens consisting of cisplatin, fluorouracil, and docetaxel have demonstrated improvements in survival for cases that are advanced or incurable [22]. Treatment approaches for recurrent or metastatic squamous cell carcinoma of the head and neck have changed dramatically in recent years due to the substantial effectiveness of immune checkpoint inhibitors like pembrolizumab and nivolumab [23, 24].

In order to promote both functional and aesthetic recovery, supportive care, rehabilitation, and reconstructive surgery are also essential elements of comprehensive management [10, 20, 25].

Prevention and early detection continue to be the most economical and effective approaches from the perspective of public health. The World Health Organization (WHO) promotes the inclusion of oral cancer prevention strategies in national health frameworks, with a focus on community-based screening programs, public education campaigns, and tobacco cessation programs [12, 25]. Global disease incidence and mortality could be decreased by implementing these preventive measures in conjunction with enhanced diagnostic and treatment approaches [6, 10, 25].

All things considered, a complex interaction of biological, behavioral, and environmental factors leads to oral cancer. Designing successful interventions requires a thorough understanding of all of its characteristics, from molecular mechanisms to clinical management.

In order to improve survival and quality of life globally, prevention, early detection, and multidisciplinary care are crucial. This review attempts to examine the epidemiological features, pathogenesis, diagnostic developments, and changing treatment approaches of oral cancer [1-25].

II. RISK FACTORS, EPIDEMIOLOGY, AND THE GLOBAL SCENARIO

With an estimated 377,000 new cases and roughly 177,000 deaths reported each year worldwide, oral cancer remains a major global health concern [13]. Geographically, the disease varies greatly, and it is most common in developing nations like India, where it makes up almost one-third of all cases worldwide [2, 13]. Chewing betel quid, drinking alcohol, and using tobacco products in smokeless and smoked forms are all known risk factors for oral squamous cell carcinoma, and they have all been linked to the high incidence in India [2, 5, 13]. Due to the high cultural prevalence of these behaviors, regional data show that southern Indian states, such as Kerala, Tamil Nadu, and Andhra Pradesh, have some of the highest incidence rates of oral cancer [2, 6].

According to epidemiology, oral cancer usually appears after the age of 40 and is more common in men than in women. This is primarily because men are more likely than women to be exposed to risk factors like alcohol and tobacco [1, 5, 13]. Depending on the stage at diagnosis, socioeconomic status, and availability of comprehensive treatment facilities, the five-year survival rate for oral cancer varies between 50% and 60% worldwide[5,8,10,13]. While advanced disease at presentation is linked to a worse prognosis and higher mortality, early-stage cancers typically have favorable outcomes [5, 10].

Oral cancer development is closely associated with a number of risk factors. Human papillomavirus (HPV) infection, especially high-risk types 16 and 18, is a major contributing factor to the development of or pharyngeal squamous cell carcinoma [9, 21]. Furthermore, a higher risk of malignant transformation and weakened mucosal immunity have been linked to nutritional deficiencies, particularly in antioxidant vitamins A, C, and E[4,15]. There is also evidence of a genetic predisposition, with variations in detoxification and metabolic

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enzymes affecting vulnerability to alcohol and tobacco-derived carcinogens [15, 21]. Additionally, poor oral hygiene, sharp tooth margins, and poorly fitting dentures can cause chronic mechanical irritation that leads to mucosal trauma and inflammation, which can lead to dysplasia and neoplastic change [3, 6, 17]. In addition to biological factors, socioeconomic inequalities, low health literacy, and a lack of knowledge about early disease symptoms all play a role in delayed diagnosis and treatment, especially in settings with limited resources [2, 6, 12].

Table 1 Risk Factors, Epidemiology and the Global Scenario

Category	Details
Global Burden	• ~377,000 new cases annually • ~177,000 deaths worldwide • Significant global health burden
Geographical Distribution	• Highest burden in developing countries • India accounts for nearly one-third of global cases • High incidence in Southern states: Kerala, Tamil Nadu, Andhra Pradesh
Gender Prevalence	• More common in men than women • Higher male prevalence due to increased exposure to tobacco and alcohol • Male-to-female ratio remains high in India and other high-risk regions
Age Distribution	• Typically occurs after age 40 • Risk increases progressively with age
Major Lifestyle Risk Factors	• Chewing betel quid • Use of smokeless and smoked tobacco • Excessive alcohol consumption • Cultural habits contribute to high Indian incidence
HPV-Related Risks	• High-risk HPV types 16 and 18 strongly associated with oropharyngeal SCC
Nutritional Deficiencies	• Deficiency of antioxidant vitamins A, C, E weakens mucosal immunity and increases malignant transformation risk
Genetic Predisposition	• Polymorphisms in detoxification/metabolic enzymes increase susceptibility to carcinogens from tobacco and alcohol
Local Mechanical Factors	• Chronic irritation from poor oral hygiene, sharp teeth, and ill-fitting dentures → inflammation → dysplasia and neoplastic change
Socioeconomic & Awareness Factors	• Poverty, low health literacy, limited access to early screening • Contributes to late-stage presentation • Higher mortality in resource-limited settings
Survival & Prognosis	• Global 5-year survival: 50–60% • Early-stage disease → better outcome • Late-stage presentation → poor prognosis, high mortality

➢ *Presentation in Clinical Settings*

Oral cancer frequently presents subtly in its early stages, which delays diagnosis and leads to worse outcomes for many patients. Mucosal ulceration and local tissue infiltration cause the typical initial symptoms, which include dysphagia, difficulty masticating, and persistent pain [5, 7]. Patients may develop a palpable lump in the oral cavity, localized swelling, or bleeding as the disease worsens; these symptoms are all signs of tumor invasion into nearby soft tissues [14]. Muscular involvement and metastatic spread, respectively, often result in additional symptoms like limited tongue movement and cervical lymph node enlargement [5, 7].

The first obvious sign of malignant transformation is frequently a non-healing ulcer or the development of red or white mucosal patches known as erythroplakia and leukoplakia [3, 16, 17]. In order to stop the development of invasive carcinoma, these lesions should be evaluated right away because they are regarded as potentially malignant disorders [3, 16]. The gingiva, floor of the mouth, buccal mucosa, and lateral borders of the tongue are among the anatomical sites of involvement that are frequently affected. These areas are especially vulnerable to long-term irritation from alcohol, tobacco, or mechanical trauma [4, 7]. For prompt diagnosis, efficient treatment, and a better prognosis, early identification of these warning indicators is essential.

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III. IDENTIFICATION AND STAGING

➢ *Diagnosis and Evaluation*

Because early detection enables prompt intervention and slows the progression of the disease, early diagnosis is essential for improving prognosis and overall survival among patients with oral cancer [7, 8, 12]. A thorough clinical examination and medical history are the first steps in the diagnostic process. Risk factors like alcohol, tobacco, and betel quid use are examined, and any visible or palpable lesions in the oral cavity are assessed [5]. The gold standard for diagnosis is still a brush biopsy or an incisional/excisional biopsy to obtain tissue samples for histopathological confirmation when suspicious lesions are found [14, 20]. Imaging modalities like computed tomography (CT), magnetic resonance imaging (MRI), and positron emission tomography (PET) scans are frequently used to assess the degree of local invasion and identify potential metastases[18,20]. These imaging methods offer vital data for prognostication and treatment planning. Standardization in reporting and management is ensured by using the American Joint Committee on Cancer (AJCC) TNM system for tumor staging and the World Health Organization (WHO) classification for histopathological grading of oral squamous cell carcinoma [20].

New diagnostic tools have been developed recently with the goal of improving the accuracy of early detection. Methods like autofluorescence imaging, toluidine blue staining, and salivary biomarker analysis have shown promise in detecting premalignant and early malignant lesions prior to the onset of clinical symptoms [16, 17, 19]. In addition to complementing conventional techniques, these supplemental diagnostic modalities have the potential to increase early detection rates, which will ultimately improve treatment outcomes and patient survival.

➢ *Methods of Treatment*

In order to achieve the best results, managing oral cancer requires a multidisciplinary approach that integrates surgical, radiotherapeutic, chemotherapeutic, immunotherapeutic, and targeted strategies [5, 10, 18, 25]. Surgery is still the mainstay of care, especially for early-stage lesions where the best chance of recovery is achieved by complete excision with sufficient margins [5, 10]. In order to treat regional lymph node involvement in more advanced stages, surgical resection is frequently coupled with neck dissection [10, 18]. In situations where surgery is not practical or appropriate, radiotherapy can be used as a final treatment option as well as an adjuvant [10, 18]. Particularly for patients with positive margins or nodal metastases, postoperative radiotherapy dramatically lowers the risk of local recurrence [18].

In order to improve locoregional control and lessen distant metastases, chemotherapy which frequently uses drugs like cisplatin, 5-fluorouracil, and paclitaxel is used either in conjunction with radiotherapy [chemoradiation] or in a neoadjuvant/adjuvant setting [18,25].

Immunotherapy, which enhances the host immune response against tumor cells by targeting immune checkpoints like PD-1/PD-L1, is one of the emerging treatment paradigms [25]. Furthermore, targeted treatments, particularly cetuximab and other epidermal growth factor receptor (EGFR) inhibitors, have demonstrated encouraging outcomes in enhancing overall survival, especially in cases of recurrent or metastatic disease[18,25]. The transition to personalized and precision-based oncology is highlighted by this integrative, multimodal treatment framework, which prioritizes not only tumor eradication but also maintaining oral function and enhancing quality of life [5, 10, 18, 25].

➢ *Management by Surgery*

The mainstay of treatment for localized oral cancer is still surgery, which has the best chance of curing the disease when done early [6, 7, 10]. In order to reduce the chance of a local recurrence, the main goal of surgery is to completely remove the primary lesion with histologically clear margins [10, 14]. To guarantee sufficient removal of cancerous tissue, intraoperative margin evaluation and frozen section analysis are frequently used [14]. After tumor excision, reconstructive procedures such as local, regional, or free flap reconstruction are often necessary to restore speech, oral function, and facial appearance [7, 10]. In order to improve postoperative quality of life and facilitate early rehabilitation, such reconstructive efforts are essential [10].

When there is a high risk of occult metastasis or clinical or radiological evidence of cervical lymph node metastasis, neck dissection is recommended [20, 22]. The stage and location of the primary tumor dictate the extent of neck dissection, whether it is radical, modified, or selective [20, 22]. Overall, the cornerstones of successful surgical management for oral cancer are careful surgical planning, oncological accuracy, and functional reconstruction [6, 7, 10, 14, 20, 22].

➢ *Radiation Therapy*

Depending on patient characteristics and disease stage, radiation therapy is used in a variety of clinical settings and is essential to the overall management of oral cancer [6, 10]. In order to eliminate any remaining microscopic disease and lower the likelihood of local recurrence, it is commonly used as adjuvant therapy after surgical resection [6, 10]. Radiotherapy can also be used as the main treatment option for patients with early-stage lesions, maintaining anatomical structures and function while achieving local control rates that are comparable to those of surgery [7, 10].

Radiotherapy is frequently used for palliative purposes in cases of advanced, recurrent, or incurable disease in order to improve quality of life by reducing pain, bleeding, dysphagia, and other distressing symptoms [5, 6, 25].

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The safety and accuracy of radiotherapy have been greatly improved by technological developments. Conformal dose delivery is made possible by contemporary modalities like Image-Guided Radiation Therapy (IGRT) and Intensity-Modulated Radiation Therapy (IMRT), which better spare nearby healthy tissues and important structures [10, 18, 19]. These developments have improved functional outcomes, decreased radiation-related toxicity, and enhanced tumor control[10,18,19].All things considered, radiotherapy continues to be a crucial part of multimodal oral cancer treatment, striking a balance between oncologic effectiveness and patient welfare [5-7,10,18,19,25].

➢ *Chemotherapy*

In order to enhance locoregional control and survival outcomes, chemotherapy is a vital adjunct to surgical and radiotherapeutic approaches in the multimodal management of oral cancer [5, 22, 25]. Cisplatin, 5-fluorouracil (5-FU), paclitaxel, and docetaxel are frequently used cytotoxic agents that have shown effectiveness in both induction and concurrent treatment protocols [22].

Concurrent chemoradiation improves local disease control by increasing the therapeutic effect of radiotherapy by making tumor cells more radiosensitive [5, 22]. Chemotherapy is given prior to surgery in neoadjuvant settings in order to manage possible micrometastases, lessen tumor burden, and enable surgical resection [22, 25]. In order to increase survival and reduce symptoms, it is also frequently used in palliative settings for patients with advanced or metastatic disease [5, 25].Because of their demonstrated cytotoxic efficacy and radiosensitizing qualities, platinum-based regimens especially those that include cisplatin remain the gold standard of care for advanced and recurrent oral squamous cell carcinoma [22]. In certain patient populations, combination protocols involving 5-FU or taxanes have further enhanced results[22, 25].All things considered, incorporating chemotherapy into interdisciplinary treatment plans is still essential for maximizing patient quality of life and disease control [5,22,25].

➢ *Immunotherapy and Targeted Therapy*

The development of immunotherapy and targeted therapy as a result of recent developments in molecular oncology has opened up new treatment options for advanced and recurrent oral squamous cell carcinoma (OSCC) [21–24]. One targeted agent that has shown notable clinical benefit is cetuximab, a monoclonal antibody against the epidermal growth factor receptor (EGFR), especially when used in conjunction with platinum-based chemotherapy or radiation therapy. In addition to improving locoregional control and radiosensitivity, cetuximab provides a good substitute for patients who are not suitable for traditional chemoradiation [21, 22].

The treatment of recurrent or metastatic head and neck squamous cell carcinoma (HNSCC) has been completely transformed by immunotherapy. Pembrolizumab and nivolumab are two examples of programmed death-1 (PD-1) inhibitors that have demonstrated notable effectiveness by blocking immune checkpoint pathways and reviving antitumor immune responses. In patients who have not responded to conventional cytotoxic treatments, these agents have greatly increased overall survival and disease control rates [23, 24].

A paradigm shift has occurred with the introduction of immune checkpoint inhibitors into routine care, which emphasizes individualized, biomarker-driven treatment targeted at improving patients' quality of life and long-term survival in cases of advanced oral cancers [21-24].

➢ *Preventive Measures and Early Detection*

Comprehensive preventive measures and early detection initiatives that address the clinical and behavioral factors that contribute to the onset of the disease are essential for the effective management of oral cancer [6, 8, 12, 17, 25].

The mainstay of controlling oral cancer is still primary prevention, which focuses on removing modifiable risk factors like alcohol consumption, tobacco use, and chewing betel quid, which together account for the majority of cases worldwide[6,12,25]. When properly executed, extensive public health programs that prioritize quitting alcohol and tobacco, improving nutrition, and educating people about oral hygiene have demonstrated quantifiable drops in incidence rates [6, 12]. Through screening, public education, and routine oral examinations conducted by qualified medical professionals, secondary prevention seeks to achieve early diagnosis [6, 12, 17]. Identification of lesions at a treatable stage is made possible by targeted screening programs for high-risk groups, such as those with poor oral hygiene, precancerous lesions, or alcohol or tobacco use [17].

Community-based outreach and screening programs have proven to be very successful in lowering diagnostic delays and enhancing survival rates, particularly in underserved and rural areas [6, 12, 17]. In the end, oral cancer morbidity and mortality are greatly reduced by early detection and prompt intervention, highlighting the necessity of ongoing preventive and educational initiatives [6, 8, 12].

➢ *Difficulties and Prospects*

Effective prevention, early detection, and treatment of oral cancer are hampered by a number of enduring issues. The biggest obstacles still include socioeconomic inequality, restricted access to organized screening programs, and a lack of specialized oncology centers, especially in low- and middle-income nations. Despite improvements in diagnostic and treatment modalities, these disparities frequently result in late-stage diagnoses, higher treatment costs, and worse survival outcomes [2, 6, 12].

Looking ahead, there are a number of cutting-edge opportunities that could enhance the treatment of oral cancer.

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Among these is the creation of affordable immunotherapies, which may increase access to state-of-the-art care in a variety of medical contexts [23–25]. By customizing treatment plans based on each patient's unique genetic and molecular tumor profile, precision oncology and personalized medicine techniques seek to maximize effectiveness and reduce toxicity [21, 25]. Furthermore, it is anticipated that the development of new biomarkers and molecular diagnostic instruments will transform early detection by empowering medical professionals to detect cancers at preclinical stages [16, 19, 21]. The combination of digital health platforms and telemedicine is another exciting development that holds promise for enabling multidisciplinary consultations, patient education, and remote follow-up, particularly in areas with limited resources [25].

Public health officials, physicians, researchers, and legislators must work together in concert to address these issues in order to improve healthcare infrastructure, encourage fair resource distribution, and put sustainable cancer control measures into place [6, 12, 25].

IV. CONCLUSION

Oral cancer is still a major global health concern, contributing significantly to cancer-related morbidity and mortality, especially in low- and middle-income countries where access to healthcare is limited and diagnosis is often delayed[1, 2, 13]. The overall prognosis still largely depends on the stage at presentation and the accessibility of specialized care, even with notable improvements in diagnostic and treatment modalities [1, 2, 13].

Implementing thorough, multidisciplinary strategies that incorporate robust preventive measures, multimodal treatment, and early detection is necessary to improve outcomes [6, 8, 12, 25]. In order to lower disease incidence and enable prompt intervention, public awareness campaigns targeting the reduction of alcohol and tobacco use are crucial, as is routine screening of high-risk groups [6, 8, 12]. In order to guarantee fair access to care, maximize treatment delivery, and improve long-term survival and quality of life, health systems, public health organizations, and clinical teams must work together to effectively control oral cancer [6, 12, 25]. Addressing the persistent issues and enhancing global results in the treatment of oral cancer will require sustained investment in research, education, and community-based health programs [1, 6, 12, 25].

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