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Exploring the Potential of Artificial Intelligence for Diagnosing Oral Cancer: A Review of Imaging and Computational Techniques

Dr. Asifa Munaf [1], Preethi Murali [2], Jayannan J[3], Shanthi V [4], Rajasekhar KK [5], Fabiola M Dhanraj [6], Selvakumar R [7].

Department of Oral Medicine and Radiology, Sree Balaji Dental College and Hospital, Chennai, India. asifamunaf@gmail.com, ORCID ID: 0009- 0008- 0652- 272X

Department of Oral Pathology, Meenakshi Ammal Dental College and Hospital, Meenakshi Academy of Higher Education and Research. pmurali@maher.ac.in, ORCID: 0000-0002-7483-1873

Department of General Medicine, Meenakshi Medical College Hospital & Research Institute, Meenakshi Academy of Higher Education and Research. jayannan@maher.ac.in, ORCID: 0000-0002-0245-7966

Professor, Department of Computer Science, Meenakshi College of Arts and Science, Meenakshi Academy of Higher Education and Research. shanthiv@maher.ac.in, ORCID: 0000-0002-6416-6291

Meenakshi College of Pharmacy, Meenakshi Academy of Higher Education and Research. rajakk@maher.ac.in, ORCID: 0000-0001-5611-1410

Professor, Meenakshi College of Nursing, Meenakshi Academy of Higher Education and Research. fab@maher.ac.in, ORCID: 0000-0001-6948-4398

Assistant Professor, Department of Orthodontics, Meenakshi Ammal Dental College and Hospital, Meenakshi Academy of Higher Education and Research, Chennai, Tamil Nadu, India. 0000-0003-3163-5538 selvar@mahaer.ac.in

ABSTRACT

Oral cancer (OC) is associated with poor survival rates and remains one of the most lethal malignancies worldwide, ranking among the top high-risk tumors. Early and correct diagnosis is critical for improving survival; however, traditional diagnostic techniques like as clinical examination and biopsy are frequently time-consuming and intrusive. Recent breakthroughs in artificial intelligence (AI) provide exciting prospects to address these restrictions by allowing the analysis of large medical datasets such as imaging records, molecular data, and clinical parameters. The incorporation of artificial intelligence into oral cancer diagnostics brings novel approaches to early diagnosis, prognosis prediction, and therapy planning. Machine learning and deep learning algorithms can quickly and reliably evaluate medical imaging data, supporting physicians in detecting cancerous changes that would otherwise go undiscovered. Oral cancer lesions can be automatically detected and classified using AI-driven systems in conjunction with optical imaging methods or intraoral photography data. AI enhances patient outcomes by facilitating prompt clinical interventions and individualized therapeutic decision-making, in addition to increasing diagnostic accuracy. With an emphasis on automated image interpretation, computer-aided diagnostic tools, and machine learning-based models used for oral cancer detection, classification, and clinical management, this study emphasizes the current uses of artificial intelligence in oral cancer diagnosis.

Keywords: *Oral cancer, Artificial intelligence, Early diagnosis, Diagnostic accuracy*

INTRODUCTION

Oral cancer encompasses malignant neoplasms involving the lips, buccal mucosa, gingiva, floor of the mouth, hard palate, and the anterior two-thirds of the tongue [1]. Globally, it ranks as the sixth most prevalent cancer, with oral squamous cell carcinoma (OSCC) accounting for more than 90% of all diagnosed cases [2]. According to World Health Organization reports, over 377,000 new cases and approximately 178,000 deaths were recorded in 2020, reflecting a rising disease burden compared to previous years [3]. Despite advances in therapeutic strategies, the survival rate for oral cancer remains low, primarily due to delayed diagnosis, making it a significant public health challenge.

Dentists play an important role in early detection of oral cancer by identifying documented risk factors such as tobacco use, alcohol intake, genetic vulnerability, immunosuppression, and viral infections. Recently, an

alarming trend has been noted with increasing frequency among younger people, many of whom lack typical risk factors, generating further concerns about disease etiology and early detection [4]. Early detection and appropriate treatments are significant factors in improving survival rates in individuals with oral cancer [5]. This procedure comprises identifying and monitoring oral potentially malignant disorders (OPMDs) over time. OPMDs are mucosal changes that increase the chance of malignant transformation relative to normal oral mucosa; only a small minority develop into cancer [6].

The major screening technique for identifying suspicious lesions is still visual oral examination, although it is subjective and may cause a delayed diagnosis, especially in high-risk individuals (Dholariya et al., 2023). Although histopathological study of biopsy materials is regarded as the gold standard for diagnosis, it is intrusive, necessitates specialized knowledge, and entails complicated laboratory processing [7].

The development of artificial intelligence (AI) presents new opportunities to enhance the diagnosis and detection of oral cancer [6]. AI is a field of computer science that allows machines to mimic human cognitive processes. It includes a variety of quickly developing technologies that are being used more and more into medical practice [1]. AI is now a potent tool for improving oral cancer detection accuracy because to developments in image processing and computational modeling [1].

For the automatic detection and categorization of oral cancer lesions, AI-based systems are being investigated in conjunction with intraoral photos or optical imaging modalities. To determine cancer risk at the population level, these technologies can be integrated into extensive screening programs [1]. Artificial intelligence (AI) algorithms provide objective, scalable, and effective diagnostic support by identifying tiny trends that would elude human observation.

Additionally, artificial intelligence can help anticipate patient prognosis, tumor activity, and metastatic potential, allowing for more customized treatment plans. AI systems provide early diagnosis and prompt therapeutic decision-making by quickly processing enormous volumes of clinical and imaging data, thereby improving patient outcomes (Hunter et al., 2022).This review discusses the expanding role of artificial intelligence in oral cancer prognosis, including risk stratification and identification of prognostic markers. It also examines current AI-based approaches such as automated image analysis, computer-aided diagnosis, and machine learning integration in oral cancer detection and management [8].

General Concepts of Artificial Intelligence

Artificial intelligence (AI) is a subfield of computer science that focuses on developing algorithms capable of doing tasks that normally require human intelligence [2]. The core goal of AI is to allow computer systems to learn, reason, and make decisions based on available facts. To accomplish this, AI integrates numerous subdomains, such as machine learning (ML), artificial neural networks (ANNs), and deep learning (DL), which enable systems to extract knowledge from input data or previously learned information.

Traditional machine learning uses computational models and statistical algorithms to detect patterns in datasets and produce quantitative results that can aid with diagnostic decision-making. In contrast, deep learning and neural network techniques use numerous layers of nonlinear processing units to understand complicated relationships between input data and associated outputs [6].Deep learning is a more advanced type of AI that goes beyond traditional machine learning by employing artificial neural networks capable of processing massive, complicated information.

In digital pathology, image segmentation is critical for deep learning-based image analysis. This procedure entails breaking a whole slide image (WSI) into smaller, more significant parts in order to extract and classify areas of diagnostic relevance based on optical and structural properties. The availability of WSIs allows for high-resolution imaging of stained tissue sections, accurate diagnostic assessment, and case sharing between oral pathologists for consultation and teaching [2].

Applications of Artificial Intelligence in the Diagnosis of Oral Cancer

Automated Image Analysis

Automated image analysis has emerged as an effective method for early identification and surveillance of oral cancer. This approach uses powerful computer algorithms to precisely identify cancer cells and aberrant tissue patterns, allowing for early diagnosis and tailored therapy planning (Webster and Dunstan, 2014). Integrating

automated image analysis into ordinary clinical workflows has the potential to improve diagnostic accuracy, expedite clinical processes, and, ultimately, patient outcomes [8].
To aid in the diagnosis of oral lesions, multimodal optical imaging techniques are frequently combined with autofluorescence imaging and high-resolution micro-endoscopy. This integrated, non-invasive technique helps clinicians identify high-risk locations with a higher possibility of neoplastic change, providing a more accurate alternative to traditional diagnostic procedures [6].

AI-Based Interpretation of Optical Coherence Tomography Images

In recent years, there has been a lot of research on the use of artificial intelligence in the early detection of oral cancer using photographic imaging and optical coherence tomography (OCT) [9. OCT is a noninvasive optical imaging technique that is commonly used in cancer to detect structural changes associated with malignant transformation.
Many diagnostically important features are not visible to the naked eye, therefore interpreting OCT pictures necessitates specialized knowledge. AI-driven systems can measure these minor differences, allowing for objective and consistent examination [5]. Integrating automated diagnostic algorithms into OCT devices reduces the requirement for substantial user training while increasing usability [10].

In a recent work employing a low-cost OCT prototype, researchers created an automated diagnostic model that linked with an image-processing application and user interface [11].
Following image pre-processing, the system identified OCT pictures as normal, dysplastic, or malignant using a two-stage decision-tree model. Compared to histological findings, our automated screening platform distinguished healthy tissue from dysplastic and malignant lesions with a sensitivity of 87% and a specificity of 83% (Heidari et al., 2019) [10].

Computer-Aided Detection and Diagnosis

In 2019, a novel computer-aided diagnostic framework was presented to help detect oral cancer using hyperspectral imaging of oral tissues [8]. This innovative system analyzes spectral data to give automated and dependable diagnostic support.
The study suggested a partitioned convolutional neural network (CNN) architecture that is optimal for medical picture classification. The segmented deep CNN's performance was tested in terms of classification accuracy. Using a 500-image training dataset, the system obtained 95.6% classification accuracy in distinguishing between normal oral tissue and malignant tumors, suggesting its potential as a diagnostic aid [8].

Artificial Intelligence for Omics-Based Oral Cancer Research

The advancement of high-throughput omics technologies, such as genomics and proteomics, has permitted the creation of massive databases related to cancer biology. Artificial intelligence (AI) has been widely used in oral cancer omics research to construct prognostic prediction models, assess lymph node involvement, find HPV-associated biomarkers, and analyze transcriptome and metabolomic patterns [1].

Integration of Machine Learning Algorithms

Machine learning algorithms are increasingly being employed in oral oncology to increase diagnostic accuracy, solve complicated classification problems, and improve clinical outcomes [8]. ML systems make predictions based on previous training, allowing computers to identify significant relationships in data (Tobias et al., 2022). Warin and colleagues investigated the use of convolutional neural network models to detect and classify oral potentially malignant disorders (OPMDs) using intraoral pictures. DenseNet-121 and ResNet-50 outperformed the other architectures examined in recognizing OPMDs, demonstrating the efficacy of deep learning models in oral lesion screening [8].

Screening for Oral Squamous Cell Carcinoma Using Color Intensity–Based Textural Features

In the diagnosis of oral squamous cell carcinoma (OSCC), texture analysis based on color intensity features derived from gray-level co-occurrence matrices (GLCM) is important in distinguishing normal cells from dysplastic and malignant cells [4]. When compared to normal epithelial cells, Papanicolaou (PAP)-stained OSCC cells had higher entropy and contrast values, but lower energy, correlation, and homogeneity. Pathologists can use the created algorithm in conjunction with microscope systems to evaluate manually selected picture sections and acquire quantitative measurements to help them make diagnostic judgments. Computer-assisted texture analysis has the potential to enhance therapeutic outcomes by allowing for earlier diagnosis of oral cancer. However, additional research and clinical validation are required to validate the reliability and practicality of these approaches in routine diagnostic settings [4].

Risk Stratification

Risk stratification is the process of categorizing people based on their chance of acquiring oral cancer or having severe disease outcomes [8]. Recent advances in machine learning have made the k-nearest neighbor (KNN) algorithm more useful for predicting survival length and identifying illness stages. Evidence suggests that senior people with a larger load of genetic mutations are more likely to develop advanced-stage disease, whereas older individuals with extensive mutational profiles have a higher risk of short-term mortality (Siddalingappa and Kanagaraj, 2022).

Tumor-associated autoantibodies have also emerged as possible biomarkers for detecting various cancers. Machine learning algorithms with salivary biomarkers are being investigated to aid in the early risk assessment of oral squamous cell cancer (OSCC) (Wang et al., 2021) [8]. Furthermore, evaluating past patient data improves the accuracy of AI-based diagnostics. AI-powered systems can classify patients into high- and low-risk groups more effectively than traditional approaches, supporting physicians with treatment planning and clinical decision-making. This strategy encourages healthcare providers to make educated decisions and enhances patient counseling (Khanagar et al., 2021; Tiwari et al., 2023) [8].

Role of Artificial Intelligence in Oral Cancer Management

Artificial intelligence is increasingly applied to address issues connected with oral cancer treatment planning and administration. Its uses include automated treatment planning, clinical decision support systems, dosage computation for intensity-modulated radiotherapy (IMRT), outcome prediction, and automated patient segmentation. Alabi et al. conducted a systematic analysis and found that deep learning-based models considerably help doctors pick appropriate treatment regimens, optimize care pathways, and improve overall management of oral cancer patients [6].

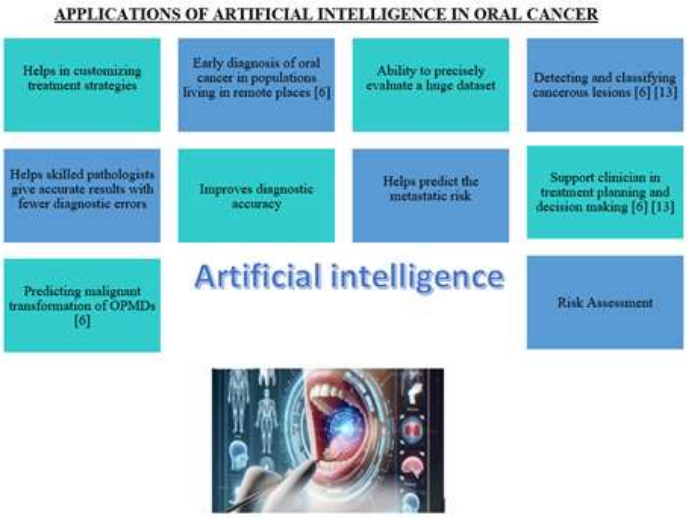

Fig. 1. Applications of artificial intelligence in oral cancer

Future Perspectives and Translational Potential

Future research should prioritize the creation of data integration frameworks that can combine several modalities, including as clinical observations, histology, radiological imaging, and genomic data, to aid in early diagnosis and prognosis [6]. Studies have shown that artificial intelligence improves pathologists' capacity to do correct multiclass cancer classification, lowering effort and enhancing diagnostic efficiency.

Deep learning-based risk prediction models can also divide patients into high- and low-risk groups, assisting oncologists in deciding whether aggressive or cautious treatment options are preferable. Such categorization may help to protect low-risk patients from the negative effects of aggressive therapy. Although these advances

encourage the translation of AI research into everyday oncology practice, significant difficulties remain to be overcome before widespread clinical implementation[12].

LIMITATIONS

Ethical Considerations

Ethical concerns remain a key impediment to the clinical application of artificial intelligence in oncology. Concerns about patient privacy, data confidentiality, and accountability in the event of diagnostic errors, whether by clinicians or AI systems, remain unaddressed. Furthermore, AI integration in cancer care may have an impact on patient autonomy as well as the traditional clinician-patient relationship [12,13]. The use of AI in healthcare involves substantial legal and ethical considerations, demanding stringent regulatory monitoring and strong data protection measures to prevent misuse or illegal access to patient information (Redrup Hill et al., 2023) [8]. In the absence of well-defined legal frameworks, AI deployment raises concerns about diagnostic mistakes (Amann et al., 2020), data breaches, and potential patient harm (Zhang and Zhang, 2023).The lack of comprehensive regulation controlling AI application in healthcare is still a serious concern (Esmaeilzadeh, 2020) [8].

Without strict monitoring, the unchecked development and implementation of AI systems may lead to errors, wrong interpretation of AI-generated suggestions, and negative therapeutic consequences. Although AI algorithms can handle massive datasets and discover patterns beyond human perception (Liu et al., 2022; Cheng et al., 2021), errors in diagnosis or treatment planning can have a negative impact on patients, emphasizing the importance of validation, accuracy, and dependability [8].

Interpretability and Trustworthiness

Despite its transformative potential, maintaining the transparency and dependability of AI systems is still one of the most significant difficulties in healthcare [8]. Many machine learning and deep learning models are sophisticated "black boxes," which limit interpretability and clinician trust (Papadimitroulas et al., 2021). Furthermore, the lack of transparency in AI decision-making processes makes it difficult to detect and mitigate bias or discriminatory consequences (Nazer et al., 2023; Tsamados et al., 2022) [8]. Ongoing research on explainable AI and transparent model design is expected to resolve these concerns and permit the safe integration of AI into oral cancer diagnosis and management [6].

CONCLUSION

Artificial intelligence has demonstrated remarkable potential in the early detection of oral cancer lesions and oral potentially malignant disorders (OPMDs) using oral imaging data [14]. AI-based diagnostic tools provide access to specialist care, especially for patients who live in distant places or are unable to travel to cutting-edge medical facilities because of logistical or budgetary limitations. Furthermore, the accuracy of surgical planning in the treatment of oral cancer can be improved by openly accessible AI-driven software systems. The COVID-19 pandemic highlighted the significance of technology that lessen the need for physical presence in the provision of healthcare. Research on AI-driven medical imaging and diagnostic technologies has significantly increased in recent years.

The fundamental goal of incorporating AI into oncology is to improve the accuracy, efficiency, and scope of cancer screening systems. Rapid technology breakthroughs are altering the healthcare scene, and artificial intelligence now offers strong tools for evaluating and interpreting large datasets in seconds, thereby assisting clinical decision-making [10]. One of AI's most valuable features is its ability to quantify tiny differences that conventional analysis may not detect. Furthermore, AI systems may combine several data sources, like as imaging, clinical, pathological, geographic, electronic health record, and risk factor information, to provide a more thorough and data-driven diagnostic assessment.

REFERENCES

[1] Ilhan B, Guneri P, Wilder-Smith P. The contribution of artificial intelligence to reducing the diagnostic delay in oral cancer. Oral Oncol. 2021;116:105254. doi:10.1016/j.oraloncology.2021.105254

[2] Pereira-Prado V, Martins-Silveira F, Sicco E, et al. Artificial Intelligence for Image Analysis in Oral Squamous Cell Carcinoma: A Review. Diagnostics (Basel). 2023;13(14):2416. Published 2023 Jul 20. doi:10.3390/diagnostics13142416 Artificial intelligence in early diagnosis and prevention of oral cancer Shruthi Hegde a , Vidya Ajila a , Wei Zhu b,* , Canhui Zeng

[3] Hsu Y, Chou CY, Huang YC, et al. Oral mucosal lesions triage via YOLOv7 models. J Formos Med Assoc. Published online July 12, 2024. doi:10.1016/j.jfma.2024.07.010

[4] Sharma PN, Chaudhary M, Patel SA, Zade PR. Screening of Oral Squamous Cell Carcinoma Through Color Intensity-Based Textural Features. Cureus. 2024;16(3):e56682. Published 2024 Mar 22. doi:10.7759/cureus.56682

[5] Ramezani K, Tofangchiha M. Oral Cancer Screening by Artificial Intelligence-Oriented Interpretation of Optical Coherence Tomography Images. Radiol Res Pract. 2022;2022:1614838. Published 2022 Apr 23. doi:10.1155/2022/1614838

[6] Hegde S, Ajila V, Zhu W, Zeng C. Artificial intelligence in early diagnosis and prevention of oral cancer. Asia Pac J Oncol Nurs. 2022;9(12):100133. Published 2022 Aug 24. doi:10.1016/j.apjon.2022.100133

[7] Beristain-Colorado MDP, Castro-Gutiérrez MEM, Torres-Rosas R, et al. Application of neural networks for the detection of oral cancer: A systematic review. Dent Med Probl. 2024;61(1):121-128. doi:10.17219/dmp/159871

[8] Kapoor DU, Saini PK, Sharma N, et al. AI illuminates paths in oral cancer: transformative insights, diagnostic precision, and personalized strategies. EXCLI J. 2024;23:1091-1116. Published 2024 Sep 3. doi:10.17179/excli2024-7253

[9] Kim JS, Kim BG, Hwang SH. Efficacy of Artificial Intelligence-Assisted Discrimination of Oral Cancerous Lesions from Normal Mucosa Based on the Oral Mucosal Image: A Systematic Review and Meta-Analysis. Cancers (Basel). 2022;14(14):3499. Published 2022 Jul 19. doi:10.3390/cancers14143499

[10] Ilhan B, Lin K, Guneri P, Wilder-Smith P. Improving Oral Cancer Outcomes with Imaging and Artificial Intelligence. J Dent Res. 2020;99(3):241-248. doi:10.1177/0022034520902128

[11] Al-Rawi N, Sultan A, Rajai B, et al. The Effectiveness of Artificial Intelligence in Detection of Oral Cancer. Int Dent J. 2022;72(4):436-447. doi:10.1016/j.identj.2022.03.001

[12] García-Pola M, Pons-Fuster E, Suárez-Fernández C, Seoane-Romero J, Romero-Méndez A, López-Jornet P. Role of Artificial Intelligence in the Early Diagnosis of Oral Cancer. A Scoping Review. Cancers (Basel). 2021;13(18):4600. Published 2021 Sep 14. doi:10.3390/cancers13184600

[13] Mali, Shrikant & Dahivelkar, Sachinkumar & Pradeep, G.L. (2023). Artificial intelligence in head neck cancer full of potential BUT filled with landmines. Oral Oncology Reports. 6. 100035. 10.1016/j.oor.2023.100035.

[14] Wuttisarnwattana P, Wongsapai M, Theppitak S, et al. Precise Identification of Oral Cancer Lesions Using Artificial Intelligence. Stud Health Technol Inform. 2024;316:1096-1097. doi:10.3233/SHTI240601.

[15] M. Babylatha. (2026). Optimizing Greenhouse Thermal Regulation Using AI-Controlled Phase Change Material (PCM) Systems. Journal of Environmental Sustainability, Climate Resilience, and Agro-Ecosystems, 32–37.

[16] K. Geetha, & M. Babylatha. (2025). Behavioral Neuroscience of Stress Resilience: Insights from Animal Models. Frontiers in Life Sciences Research, 23–29.

[17] B.M.Brinda. (2025). Carbon Footprint Reduction through Intelligent Energy Distribution in Smart Cities. Journal of Smart Infrastructure and Environmental Sustainability, 2(3), 25-31.