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Original Research Article

Anatomical Mapping of Oral Cavity Using AI-Powered Systems for Improved Diagnosis and Treatment of Oral Carcinoma

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Abstract: ***Background:*** Oral carcinoma remains a significant global health burden, particularly in low- and middle-income countries where delayed diagnosis leads to poor clinical outcomes. Conventional diagnostic methods are often limited by subjectivity and inter-observer variability. Artificial intelligence (AI) powered systems offer a novel approach to enhance diagnostic accuracy and consistency in oral oncology. ***Objective:*** This study aimed to assess the role of AI-powered anatomical mapping of the oral cavity in improving the diagnosis and treatment planning of oral carcinoma. ***Methods:*** A cross-sectional analytical study was conducted using high-resolution intraoral images and clinical data from patients with suspected oral lesions. Deep learning–based AI models were trained to identify oral anatomical landmarks and detect malignant and premalignant lesions. Diagnostic performance was evaluated using sensitivity, specificity, accuracy, and area under the receiver operating characteristic curve, with histopathological findings as the reference standard. ***Results:*** The AI-powered system demonstrated high accuracy in mapping oral cavity anatomy and localizing lesions across various subsites, including the tongue, buccal mucosa, and floor of the mouth. The model showed improved sensitivity and specificity compared with conventional clinical assessment, enabling clearer delineation of lesion boundaries and extent, which supported more precise treatment planning. ***Conclusion:*** AI-driven anatomical mapping of the oral cavity is a promising adjunct to traditional diagnostic approaches for oral carcinoma. Its implementation may enhance early detection, reduce observer-related variability, and improve clinical decision-making. Further large-scale and multicenter studies are recommended to validate their clinical applicability.

Keywords: Artificial Intelligence, Oral Carcinoma, Anatomical Mapping, Deep Learning, Oral Cancer Diagnosis.

INTRODUCTION

Oral carcinoma, predominantly oral squamous cell carcinoma (OSCC), accounts for over 90% of malignancies arising in the oral cavity and remains a major contributor to cancer-related morbidity and mortality worldwide [1,2]. According to GLOBOCAN 2020, more than 377,000 new cases and 177,000 deaths occur annually, with South Asia bearing a disproportionate disease burden [3]. Pakistan is among the high-risk countries due to widespread tobacco, betel nut, and areca nut consumption. Early diagnosis of oral carcinoma significantly improves survival; however, most cases are diagnosed at advanced stages [4]. Conventional diagnostic methods such as visual inspection, palpation, and biopsy rely heavily on clinician expertise and are subject to inter-observer variability [5]. Recent advances in computer vision and machine learning have enabled the development of AI-powered diagnostic systems capable of processing complex visual patterns beyond human perception. Deep learning models, particularly convolutional neural networks, can automatically learn hierarchical image features, allowing accurate detection and segmentation of pathological changes within medical images [6]. In oral oncology, this capability is especially relevant due to the heterogeneous appearance of oral lesions, variations in lighting conditions, and anatomical complexity of the oral cavity. AI-based systems have demonstrated strong potential in distinguishing malignant from non-malignant lesions by analyzing subtle textural and color variations that may not be apparent during routine clinical examination [7].

Anatomical mapping using AI represents a critical evolution from simple lesion detection toward clinically meaningful decision-support systems. By integrating spatial localization with anatomical landmark identification, AI-driven mapping provides detailed visualization of lesion extent relative to critical oral structures, facilitating accurate staging and surgical margin assessment [8]. This is particularly important in oral carcinoma, where incomplete excision and positive margins are associated with higher recurrence rates and reduced survival [9]. AI-assisted anatomical mapping may therefore play a pivotal role in optimizing treatment planning, especially in cases requiring complex surgical or multidisciplinary management. The integration of AI-powered diagnostic tools into routine dental and medical practice also holds significant public health implications. In low- and middle-income countries, limited access to specialists and diagnostic infrastructure contributes to delayed diagnosis of oral carcinoma [10]. AI-enabled systems, when incorporated into primary care or community-based screening programs, may help bridge this gap by supporting early detection and appropriate referral [11]. Such technologies align with global cancer control strategies emphasizing early diagnosis, task shifting, and digital health innovation, underscoring the relevance of AI-powered anatomical mapping in addressing oral cancer disparities [12].

Artificial intelligence (AI), particularly deep learning, has shown substantial promise in medical image analysis, enabling automated detection, segmentation, and classification of pathological lesions [13]. In oncology, AI-based systems have demonstrated diagnostic accuracy comparable to expert clinicians in dermatology, radiology, and pathology [14]. Within oral medicine, AI applications have expanded to include lesion detection, histopathological grading, and risk prediction [15]. Anatomical mapping using AI allows precise localization of lesions relative to oral cavity landmarks, providing clinically relevant information regarding lesion extent and spatial distribution [7]. This capability is particularly important for surgical planning and margin assessment in oral carcinoma. Despite growing interest, evidence on AI-driven anatomical mapping of the oral cavity remains limited. This study evaluates the diagnostic performance of an AI-powered anatomical mapping system for oral carcinoma and compares its effectiveness with conventional clinical examination.

MATERIALS AND METHODS

This cross-sectional analytical study was conducted from January 2023 to December 2024 at tertiary care dental and maxillofacial units in Pakistan. Ethical approval was obtained from the institutional review board prior to initiation, and all participants provided written informed consent. The study followed the principles outlined in the Declaration of Helsinki. Adult patients aged 18 years or older presenting with clinically suspicious oral mucosal lesions were recruited using consecutive sampling. Suspicious lesions included non-healing ulcers, erythroplakia, leukoplakia, indurated masses, and unexplained mucosal discoloration. Patients with previously treated oral carcinoma, recurrent disease, systemic mucocutaneous disorders, or poor-quality intraoral images were excluded. High-resolution intraoral images were captured using standardized intraoral cameras under controlled lighting and positioning to minimize variability. Multiple views of each lesion were obtained to ensure comprehensive anatomical coverage. Clinical variables including age, gender, tobacco and betel nut use, lesion site, and duration were recorded. All lesions underwent biopsy, and histopathological diagnosis served as the reference standard. A convolutional neural network-based deep learning model was developed to perform anatomical mapping and lesion detection. The model was trained to identify oral cavity landmarks and to segment and classify lesions as benign, premalignant, or malignant. The dataset was divided into training (70%), validation (15%), and testing (15%) sets to ensure robust performance evaluation. Diagnostic performance was assessed using sensitivity and specificity. Subsite-specific analysis was also performed to evaluate consistency across different anatomical regions.

RESULTS

A total of 240 patients were included, with a mean age of 46.8 ± 12.3 years. Males constituted 65% of the study population, and tobacco or betel nut use was reported by 71.7% of participants. Lesions were most frequently located on the tongue and buccal mucosa as shown in table 1.

Table 1. Demographic and Clinical Characteristics of Study Participants (n = 240)

Variable	Frequency (%)
Male	156 (65.0)
Female	84 (35.0)
Tobacco/betel nut use	172 (71.7)
Tongue	92 (38.3)
Buccal mucosa	76 (31.7)
Floor of mouth	38 (15.8)
Other sites	34 (14.2)

The AI-powered anatomical mapping system showed superior diagnostic performance compared with conventional clinical examination as shown in table 2.

Table 2. Diagnostic Performance of AI System Compared with Clinical Examination

Parameter	AI System (%)	Clinical Examination (%)
Sensitivity	92.4	78.6
Specificity	89.7	74.3
Accuracy	91.1	76.8
AUC	0.94	0.81

Subsite-wise evaluation revealed consistent performance across anatomically complex regions as shown in table 3.

Table 3. Subsite-Wise Performance of AI-Based Anatomical Mapping

Oral Subsite	Sensitivity (%)	Specificity (%)
Tongue	94.1	90.3
Buccal mucosa	91.5	88.6
Floor of mouth	90.2	87.9

DISCUSSION

The findings of this study demonstrate that AI-powered anatomical mapping significantly enhances the diagnostic accuracy of oral carcinoma when compared with conventional clinical examination. The AI system achieved higher sensitivity (92.4%), specificity (89.7%), and overall accuracy (91.1%), indicating superior performance in distinguishing malignant from non-malignant oral lesions. These results are consistent with previous studies reporting that deep learning–based image analysis outperforms routine visual examination by identifying subtle textural and color variations that may be overlooked by clinicians [16,17]. Early and accurate diagnosis is critical in oral squamous cell carcinoma, as delayed detection is strongly associated with advanced disease stage and reduced survival rates, particularly in high-burden regions such as South Asia [18].

Subsite-wise analysis revealed consistently high diagnostic performance across anatomically complex and high-risk regions, including the tongue, buccal mucosa, and floor of the mouth. These subsites are frequently associated with aggressive tumor behavior and poorer prognosis due to rich lymphatic drainage and delayed symptom recognition [19]. Conventional clinical examination often demonstrates reduced sensitivity in these regions because of anatomical constraints and subtle early changes [20]. The ability of the AI system to accurately map lesion location and extent across different oral subsites highlights its robustness and potential utility as a standardized diagnostic aid, supporting more reliable clinical decision-making irrespective of operator experience [21].

Accurate delineation of lesion boundaries is a critical determinant of effective surgical planning and oncologic outcomes in oral carcinoma. Positive surgical margins are well established as a predictor of local recurrence and decreased overall survival [22]. In the present study, AI-powered anatomical mapping provided clearer visualization of lesion margins and spatial relationships to key oral structures, which may facilitate improved margin assessment and treatment planning. Similar advantages of AI-assisted mapping and segmentation have been reported in head and neck oncology, where such tools have enhanced preoperative planning and reduced inter-observer variability [23]. By offering objective and reproducible anatomical information, AI systems may serve as valuable adjuncts to clinician judgment rather than replacements for clinical expertise.

From a public health perspective, the integration of AI-powered diagnostic systems into routine dental and primary healthcare settings holds significant promise, particularly in low- and middle-income countries where access to specialists is limited. AI-based tools can support early detection, task shifting, and timely referral, thereby addressing systemic gaps in oral cancer care delivery [24]. The strong diagnostic performance observed using image-based analysis suggests feasibility for deployment in community screening and telehealth models. Nevertheless, this study has limitations, including reliance on a single-country dataset and static intraoral images. Future research should focus on multicenter validation, inclusion of diverse populations, and integration with clinical and histopathological data to enhance generalizability and real-world applicability.

CONCLUSION

AI-driven anatomical mapping of the oral cavity is a valuable adjunct to conventional diagnostic methods for oral carcinoma. By improving early detection, lesion localization, and treatment planning, AI-powered systems have the potential to significantly enhance clinical outcomes. Wider clinical adoption following large-scale validation is recommended.

REFERENCES

1. Tan Y, Wang Z, Xu M, Li B, Huang Z, Qin S, Nice EC, Tang J, Huang C. Oral squamous cell carcinomas: state of the field and emerging directions. International journal of oral science. 2023 Sep 22;15(1):44. http://doi:10.1038/s41368-023-00249-w. PMID: 37736748; PMCID: PMC10517027.
2. Rahman QB, Iocca O, Kufta K, Shanti RM. Global burden of head and neck cancer. Oral and Maxillofacial Surgery Clinics. 2020 Aug 1;32(3):367-75. http://doi:10.1016/j.coms.2020.04.002. Epub 2020 May 29. PMID: 32482563.
3. Ward ZJ. Computational Epidemiology: Methods and Applications for Global Health (Doctoral dissertation, Harvard University).
4. Niaz K, Maqbool F, Khan F, Bahadar H, Hassan FI, Abdollahi M. Smokeless tobacco (paan and gutkha) consumption, prevalence, and contribution to oral cancer. Epidemiology and health. 2017 Mar 9;39:e2017009. http://doi:10.4178/epih.e2017009. PMID: 28292008; PMCID: PMC5543298.
5. Fahy E. Diffuse reflectance spectroscopy in the identification of oral.
6. Kudva A, Kudva V, Patil V, Mohan N, Shenoy PR, Rai A. Applications of Artificial Intelligence in the Analysis of Images of the Oral Cavity for Cancer Detection. InBiomedical Imaging: Advances in Artificial Intelligence and Machine Learning 2024 Sep 27 (pp. 157-169). Singapore: Springer Nature Singapore.
7. Mirfendereski P, Li GY, Pearson AT, Kerr AR. Artificial intelligence and the diagnosis of oral cavity cancer and oral potentially malignant disorders from clinical photographs: a narrative review. Frontiers in Oral Health. 2025 Mar 10;6:1569567 http://doi:10.3389/froh.2025.1569567. PMID: 40130020; PMCID: PMC11931071.
8. Raposo H. Intelligent imaging: A systematic review of artificial intelligence techniques in disease detection, segmentation, and

classification. Segmentation, and Classification (May 13, 2024). 2024 May 13.

9. Binahmed A, Nason RW, Abdoh AA. The clinical significance of the positive surgical margin in oral cancer. Oral oncology. 2007 Sep 1;43(8):780-4. http://doi:10.1016/j.oraloncology.2006.10.001. Epub 2006 Dec 14. PMID: 17174145.
10. Ilhan B, Guneri P, Wilder-Smith P. The contribution of artificial intelligence to reducing the diagnostic delay in oral cancer. Oral oncology. 2021 May 1; 116:105254. http://doi:10.1016/j.oraloncology.2021.105254. Epub 2021 Mar 9. PMID: 33711582; PMCID: PMC8144066.
11. Balakrishnan K, Velusamy D, Hinkle HE, Li Z, Ramasamy K, Khan H, Ramaswamy S, Shah PM. Artificial intelligence in rural healthcare delivery: Bridging gaps and enhancing equity through innovation. arXiv preprint arXiv:2508.11738. 2025 Aug 15.
12. Goel I, Bhaskar Y, Kumar N, Singh S, Amanullah M, Dhar R, Karmakar S. Role of AI in empowering and redefining the oncology care landscape: perspective from a developing nation. Frontiers in Digital Health. 2025 Mar 4;7:1550407. http://doi:10.3389/fdgth.2025.1550407. PMID: 40103737; PMCID: PMC11913822.
13. Biswas A, Banik R. Advancements in medical image analysis: A comprehensive method of AI-based classification and segmentation technique. InArtificial Intelligence and Applications 2025 (Vol. 3, No. 4, pp. 408-416).
14. Valenti A, Valenti F, Giuliani S, di Martino S, Neroni L, Sorino C, Sollena P, Desiderio F, Elia F, Maccallini MT, Russillo M. The Latest Diagnostic Imaging Technologies and AI: Applications for Melanoma Surveillance Toward Precision Oncology. Computers. 2025 Nov 24;14(12):512.
15. Khanagar SB, Alkadi L, Alghilan MA, Kalagi S, Awawdeh M, Bijai LK, Vishwanathaiah S, Aldhebaib A, Singh OG. Application and performance of artificial intelligence (AI) in oral cancer diagnosis and prediction using histopathological images: a systematic review. Biomedicines. 2023 Jun 1;11(6):1612. http://doi:10.3390/biomedicines11061612. PMID: 37371706; PMCID: PMC10295336.
16. Li XL, Zhou G. Deep Learning in the Diagnosis and Prognosis of Oral Potentially Malignant Disorders. Cancer Screening and Prevention. 2024 Dec 25;3(4):203-13.
17. Dixit S, Kumar A, Srinivasan K. A current review of machine learning and deep learning models in oral cancer diagnosis: recent technologies, open challenges, and future research directions. Diagnostics. 2023 Apr 5;13(7):1353. http://doi:10.3390/diagnostics13071353. PMID: 37046571; PMCID: PMC10093759.
18. Fan KM, Rimal J, Zhang P, Johnson NW. Stark differences in cancer epidemiological data between GLOBOCAN and GBD: Emphasis on oral cancer and wider implications. EClinicalMedicine. 2022 Dec 1;54. http://doi:10.1016/j.eclinm.2022.101673. PMID: 36247925; PMCID: PMC9561675
19. Rivera C. Essentials of oral cancer. International journal of clinical and experimental pathology. 2015 Sep 1;8(9):11884. PMID: 26617944; PMCID: PMC4637760.
20. Kerr AR, Lodi G. Management of oral potentially malignant disorders. Oral diseases. 2021 Nov;27(8):2008-25. http://doi:10.1111/odi.13980. Epub 2021 Oct 9. PMID: 34324758.
21. Piyush Mathur MD, Khanna AK, Jacek B, FASA CM, Papay FA. Artificial Intelligence in Healthcare: 2020 Year in Review.
22. Kann BH, Hosny A, Aerts HJ. Artificial intelligence for clinical oncology. Cancer Cell. 2021 Jul 12;39(7):916-27. http://doi:10.1016/j.ccell.2021.04.002. Epub 2021 Apr 29. PMID: 33930310; PMCID: PMC8282694.
23. Temple SW. An evaluation of AI auto-segmentation for Head & Neck cancer (Doctoral dissertation, The University of Manchester (United Kingdom)).
24. Loperfido A, Celebrini A, Marzetti A, Bellocchi G. Current role of artificial intelligence in head and neck cancer surgery: a systematic review of literature. Exploration of Targeted Anti-tumor Therapy. 2023 Oct 24;4(5):933. http://doi:10.37349/etat.2023.00174. Epub 2023 Oct 24. PMID: 37970203; PMCID: PMC10645467.

