Role of Artificial Intelligence in the Diagnosis and Treatment of Oral Cancer: A Review

Piyush Mishra, Nitya Bhardwaj, Dr. Sumit Bhateja, Dr. Neeraj Bansal
Manav Rachna International Institute of Research and studies

Abstract- Oral cancer remains a major global health concern, especially in developing countries where lifestyle risk factors such as tobacco chewing, betel nut consumption, and alcohol use are prevalent [1]. Despite advancements like Transoral Robotic Surgery (TORS), late diagnosis and inconsistent treatment outcomes contribute to poor prognoses [2]. The integration of Artificial Intelligence (AI) into medical practice offers promising improvements in early detection, diagnosis, and treatment planning for oral cancers [3]. This review explores the current and emerging applications of AI in oral oncology, discusses its synergy with robotic surgery, and highlights the challenges and future directions for implementation in clinical practice.

Keywords: Artificial Intelligence, Oral Cancer, Deep Learning, Early Detection, Transoral Robotic Surgery, Diagnosis, Treatment Planning

1. INTRODUCTION

Oral cancer, particularly prevalent in South and Southeast Asia, is closely linked to specific behavioral and environmental risk factors [1]. It is among the most commonly diagnosed cancers worldwide [1]. Traditional diagnostic methods like biopsies and histopathological assessments, though reliable, are time-consuming and invasive [2]. Moreover, surgical interventions may lead to extended recovery periods and functional impairments [3]. Recent advances in minimally invasive techniques, such as TORS, have shown favorable outcomes in terms of both aesthetics and functionality [3,4].

Artificial Intelligence (AI) is increasingly being recognized as a transformative tool in oncology [5]. Through machine learning and deep learning algorithms, AI can analyze medical imaging, predict therapeutic outcomes, and assist in personalized treatment planning [6]. This review outlines how AI, particularly when combined with robotic surgery, is reshaping oral cancer management [5,7].

2. METHODOLOGY

Relevant studies published between 2005 and 2025 were reviewed using databases including PubMed, Scopus, and Google Scholar. Keywords such as "AI in oral cancer," "deep learning in oncology," and "TORS in head and neck cancer" were used. Articles were selected based on relevance, recency, and clinical applicability.

3. APPLICATIONS OF AI IN ORAL CANCER CARE

3.1 Early Detection and Diagnosis

AI excels in early detection by analyzing radiological, clinical, and histopathological data [6]. Deep learning models such as VGG19 and ResNet50 have demonstrated high accuracy in identifying tongue lesions and distinguishing between benign and malignant tissues [7]. These models can serve as valuable tools in resource-limited settings, enabling early interventions and improved prognoses [8].

3.2 Predictive Analytics and Treatment Planning

AI systems can assess patient-specific risk factors, genetic data, and lifestyle habits to aid in creating personalized treatment plans [6]. Predictive models help estimate the likelihood of treatment success, recurrence risks, and adverse effects [9]. This enables clinicians to tailor interventions more effectively and improve patient outcomes [10].

3.3 AI-Enhanced Robotic Surgery

In procedures such as TORS, AI can support real-time surgical navigation by identifying tumor margins, preserving vital anatomical structures, and enhancing visualization [11]. Although current systems are not fully autonomous, AI integration improves precision and minimizes intraoperative risks [12]. Postoperative

outcomes, including speech and swallowing functions, can be evaluated using AI-driven tools for rehabilitation planning [13].

3.4 Remote Monitoring and Patient Engagement

AI enables continuous remote monitoring by tracking patient symptoms, adherence to therapy, and treatment responses [9]. Real-time analytics provide healthcare professionals with actionable insights, allowing timely interventions [10]. This is particularly beneficial for follow-up care and chronic disease management [14].

3.5 Microrobotics and Targeted Therapy

Innovative research in microrobotics is paving the way for targeted drug delivery systems in oral cancer treatment [10]. These micro-scale devices can navigate complex anatomical regions, deliver localized therapy, and minimize systemic side effects [15].

4. CHALLENGES AND LIMITATIONS

Despite its potential, several barriers hinder the widespread adoption of AI in oral oncology:

- Limited availability of annotated medical datasets [5]
- Lack of standardized protocols and regulatory frameworks [6]
- Concerns regarding data privacy and ethical use [9]
- Need for clinical validation and integration into existing healthcare infrastructure [14]

Additionally, there is a need for more interdisciplinary collaboration among clinicians, data scientists, and regulatory authorities to create scalable and safe AI solutions [16]. Efforts to develop global data-sharing policies and improve the quality of AI training datasets are essential.

5. FUTURE PROSPECTS

AI is anticipated to evolve from supportive tools to integral components of clinical workflows [5]. Future developments should focus on:

- Integrating AI with radiomics, genomics, and patient records [8]
- Enhancing real-time decision-making during surgeries [11]
- Developing user-friendly interfaces for clinical use [9]
- Conducting large-scale clinical trials to validate effectiveness [14]

Further research should also explore the role of AI in palliative care, psychological support for cancer patients, and cost-effectiveness analysis in treatment pathways [13,16]. This could bridge the gap between cutting-edge technology and holistic patient care.

6. CONCLUSION

AI and robotic technologies are revolutionizing oral cancer diagnosis and treatment [5]. TORS has emerged as a precise, minimally invasive surgical option with promising outcomes [4]. When augmented with AI, the potential for improving early detection, surgical precision, and personalized care becomes significantly greater [7,11]. Continued research, ethical deployment, and interdisciplinary collaboration will be key to fully realizing AI's role in enhancing oral cancer care [16].

Summary Table: AI Applications in Oral Cancer

Application Area	AI Tool/Technology	Impact/Benefits
Early Detection	Deep Learning (e.g., VGG19, ResNet50)	High accuracy in lesion identification, early diagnosis
Treatment Planning	Predictive Analytics	Customized interventions, improved outcomes
Robotic Surgery	AI-assisted Navigation (TORS)	Enhanced precision, preserved function
Remote Monitoring	AI-based symptom tracking	Improved follow-up and adherence
Targeted Therapy	Microrobotics	Localized drug delivery, minimal side effects

REFERENCE

[1] Warnakulasuriya S. Global epidemiology of oral and oropharyngeal cancer. Oral Oncol. 2009;45(4-5):309-316.

[2] Fedele S. Diagnostic aids in the screening of oral cancer. Head Neck Oncol. 2009;1:5.

[3] Esteva A, Kuprel B, Novoa RA, et al. Dermatologist-level classification of skin cancer

with deep neural networks. Nature. 2017;542(7639):115-118.

[4] Moore EJ, Hinni ML. Robotic surgery in otolaryngology and head and neck surgery: review of indications and techniques. Head Neck. 2012;34(6):762-768.

[5] Chiesa-Estomba CM, Lechien JR, Calvo-Henríquez C, et al. Artificial intelligence in head and neck cancer diagnosis. Curr Opin Otolaryngol Head Neck Surg. 2021;29(2):85-91.

[6] Cruz JA, Wishart DS. Applications of machine learning in cancer prediction and prognosis. Cancer Inform. 2006;2:59-77.

[7] Shamim M, Singh A, Gupta R, Sharma A. Automated detection of oral pre-cancerous tongue lesions using deep learning. Oral Oncol. 2019;96:58-63.

[8] LeCun Y, Bengio Y, Hinton G. Deep learning. Nature. 2015;521(7553):436-444.

[9] Jiang F, Jiang Y, Zhi H, et al. Artificial intelligence in healthcare: past, present and future. Stroke Vasc Neurol. 2017;2(4):230-243.

[10] Chandrashekar G, Patel M, Srinivasan A. Microbots: Transforming the treatment of oral cancer. Nano TransMed. 2024;3:100043.

[11] Lin TS, Luo CW, Hsieh TL, et al. Transoral robotic surgery for oral cancer: evaluating surgical outcomes. Cancers. 2024;16(6):1111.

[12] Calabria CM, Ward PA. Anaesthesia for transoral robotic surgery in oral cancer: a review. J Oral Maxillofac Anesth. 2023;2(6).

[13] Al-Raeei M. The future of oral oncology: how artificial intelligence is redefining surgical procedures and patient management. Int Dent J. 2024;75:109-116.

[14] Shah S, Goldenberg D. Robotic surgery for oropharyngeal cancer. Rambam Maimonides Med J. 2014;5(2):e0014.

[15] Chang CC, Chen CH, Hsieh TL, et al. Clinical characteristics and treatment outcomes of oral cancers using transoral robotic surgery in an endemic region. Cancers. 2023;15:4896.

[16] Alsayeg A, Alshammari MN, Alajmi AM, et al. Evaluating the efficacy of TORS versus radiotherapy, chemotherapy, and open surgery in treating oropharyngeal squamous cell carcinoma: a systematic review. J Med Law Public Health. 2024;5(1):546-564.