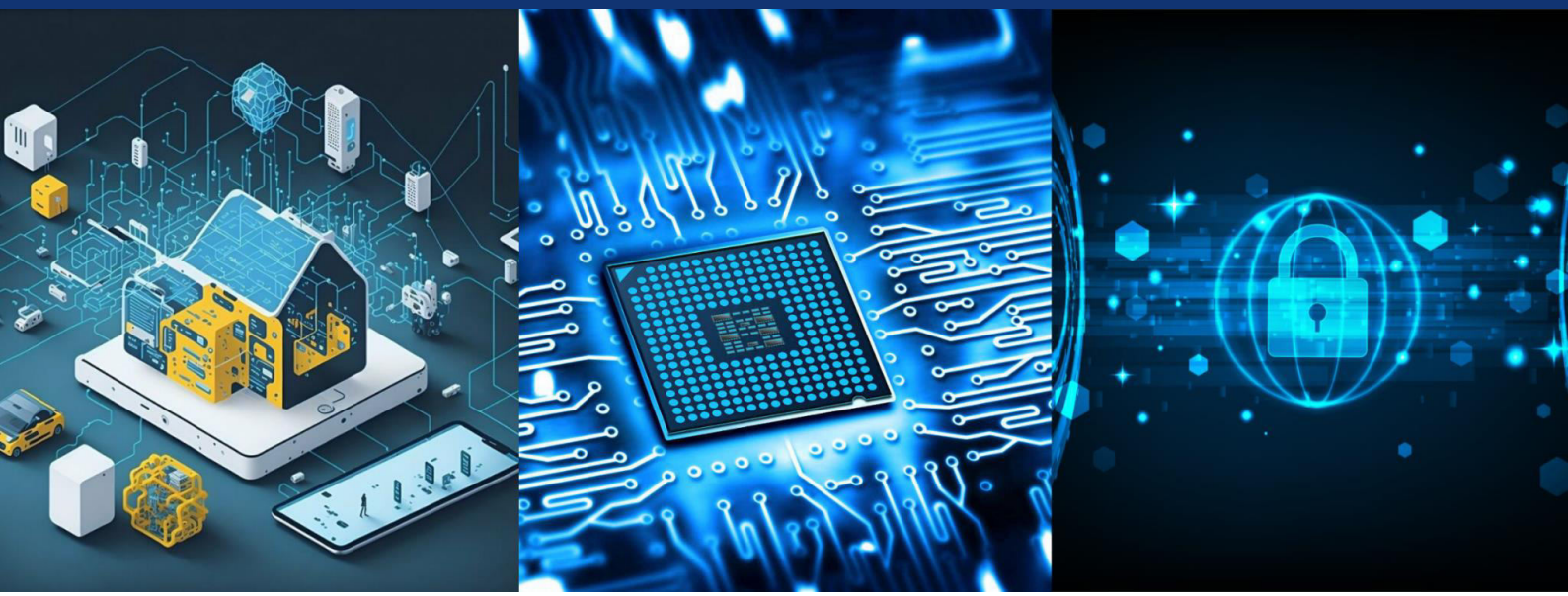
IJIRCCE

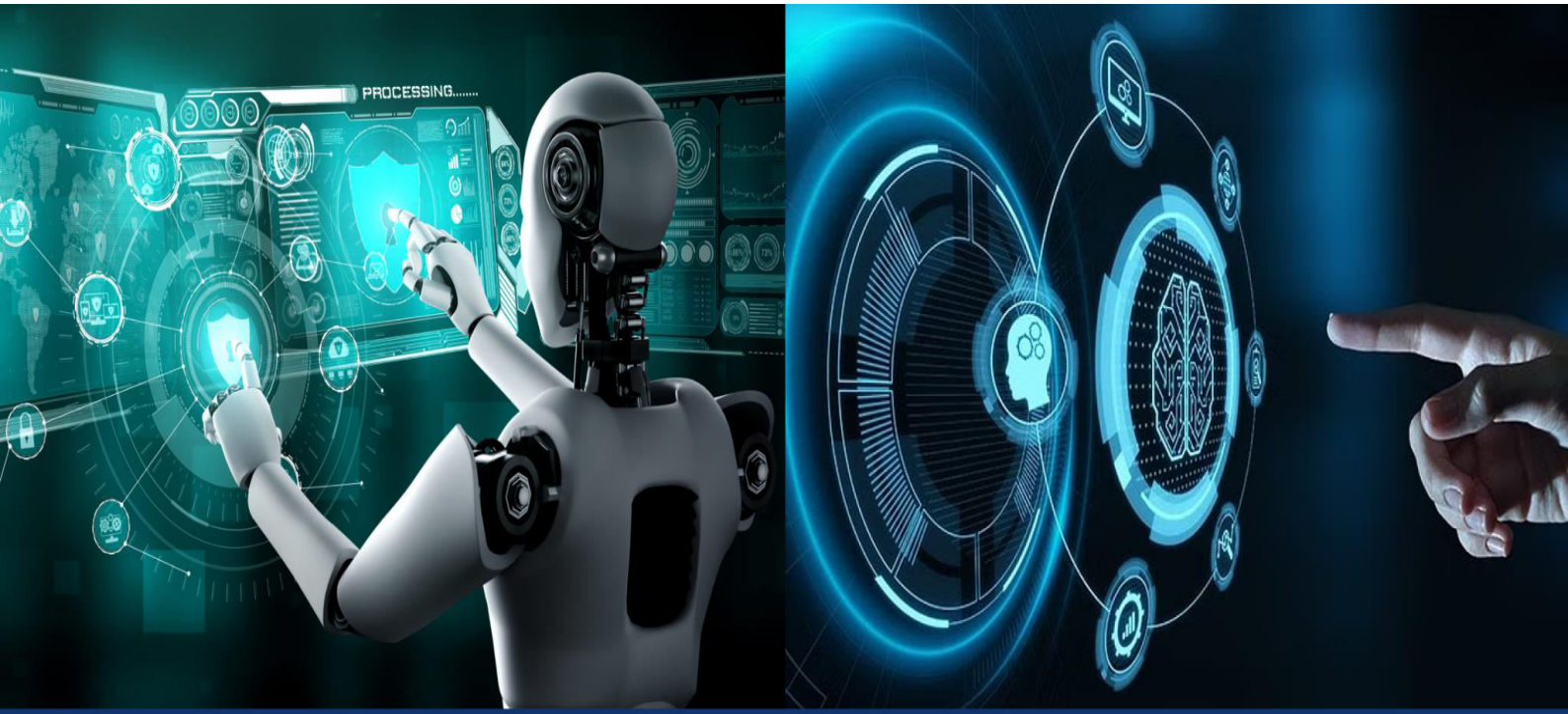
ISSN(O): 2320-9801

ISSN(P): 2320-9798



International Journal of Innovative Research in Computer and Communication Engineering

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 9.927

Volume 14, Issue 6, June 2026

© 2026 IJIRCCE | Volume 14, Issue 6, June 2026 DOI: 10.15680/IJIRCCE.2026.1406017

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 9.927| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Emerging Methodologies for Oral Cancer Detection: Comprehensive Review

Mr. Abhijit G. Kalbande, Dr Ajay P. Thakare, Dr. Vaishali A. Thakare

Research Scholar, Dept. of EXTC, PRMCEAM, Badnera (Amravati), India

Professor, Dept. of EXTC, PRMCEAM, Badnera (Amravati), India

Lecturer, Dept. of General Pathology & Microbiology, Dental College & Hospital, Amravati, India

ABSTRACT: Oral cancer remains a major global health burden, accounting for significant morbidity and mortality worldwide. Despite considerable advances in treatment strategies, survival rates remain relatively low due to delayed diagnosis and limited access to early detection facilities. Conventional diagnostic approaches, including visual examination and biopsy, continue to serve as the standard methods for diagnosis. These traditional invasive methods are time taking and painful and often identify lesions only after substantial disease progression. Consequently, there is a growing need for innovative, non-invasive, accurate, and cost-effective diagnostic technologies capable of identifying oral cancer at its earliest stages. Recent advancements in biomedical engineering, molecular biology, artificial intelligence (AI), and imaging technologies have significantly transformed the landscape of oral cancer detection. Advanced optical imaging techniques, including fluorescence imaging, narrow-band imaging, and con-focal microscopy, have enhanced the visualization of precancerous and malignant lesions. Simultaneously, molecular diagnostic approaches utilizing salivary biomarkers, circulating tumor DNA (ctDNA), proteomics, and metabolomics have emerged as promising tools for non-invasive cancer screening. Artificial intelligence-based diagnostic systems, portable point-of-care devices, and telemedicine platforms further support early diagnosis and improved accessibility to healthcare services. This review discusses recent advancements in oral cancer detection technologies, their clinical applications, advantages, limitations, and future prospects.

KEYWORDS: Oral Cancer, Early Detection, Optical Imaging, Artificial Intelligence, Salivary Biomarkers, Liquid Biopsy, Molecular Diagnostics, Point-of-Care Testing, Telemedicine, Oral Oncology.

I. INTRODUCTION

Oral cancer is among the most prevalent malignancies affecting the head and neck region and represents a significant public health concern worldwide. According to global cancer statistics, oral cancer contributes substantially to cancer-related morbidity and mortality, particularly in developing countries where tobacco consumption, alcohol use, poor oral hygiene, and human papillomavirus (HPV) infections remain major risk factors [1].

Although advancements in surgical techniques, chemotherapy, and radiotherapy have improved treatment outcomes, the overall survival rate remains unsatisfactory because many patients are diagnosed at advanced stages of disease progression [1].

Early detection is universally recognized as one of the most effective strategies for reducing mortality associated with oral cancer. Patients diagnosed during the early stages generally exhibit significantly higher survival rates and better quality of life compared with those diagnosed at advanced stages. Traditional diagnostic approaches primarily rely on clinical examination, visual inspection, palpation, and histopathological confirmation through biopsy. While biopsy remains the gold standard for diagnosis, it is invasive, time-consuming, and often associated with patient discomfort. Recent developments in optical imaging, molecular diagnostics, biosensor technologies, artificial intelligence, and telemedicine have opened new avenues for screening, diagnosis, and disease monitoring [2–5]. This review examines the latest innovations in oral cancer detection and discusses their potential impact on clinical practice, public health, and future research.

© 2026 IJIRCCE | Volume 14, Issue 6, June 2026 DOI: 10.15680/IJIRCCE.2026.1406017

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 9.927| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

II. LITERATURE REVIEW

Several studies have explored emerging technologies for early oral cancer detection. Macey et al. [2] reported that advanced optical imaging techniques significantly improve the visualization of oral lesions and facilitate earlier diagnosis. Esteva et al. [3] demonstrated the effectiveness of deep learning algorithms in medical image analysis, highlighting their potential role in oral cancer screening. Park et al. [4] showed that PET and MRI innovations improve tumor localization and staging accuracy.

Similarly, Zhang et al. [5] emphasized the role of salivary biomarkers as promising non-invasive diagnostic tools. Crowley et al. [6] highlighted the clinical significance of circulating tumor DNA (ctDNA) and liquid biopsy technologies for cancer monitoring. Gupta et al. [7] identified several protein and metabolic biomarkers associated with oral carcinogenesis using proteomic and metabolomic approaches.

Liu et al. [8] demonstrated the utility of portable diagnostic devices for rapid screening, while Smith et al. [9] reported improved accessibility to oral oncology services through telemedicine. Topol [10] further emphasized the transformative role of artificial intelligence in predictive healthcare and personalized medicine. Despite these advancements, large-scale validation studies and standardized implementation strategies remain limited, creating barriers to widespread clinical adoption.

Sr. No.	Author(s)	Year	Technology Used	Objective	Major Findings	Limitations
1	Macey et al.	2022	Optical Imaging	Early lesion detection	Improved visualization of suspicious lesions	High equipment cost
2	Park et al.	2022	PET/MRI Imaging	Tumor localization	Better staging and diagnosis	Expensive and less accessible
3	Smith et al.	2022	Telemedicine	Remote diagnosis	Improved healthcare accessibility	Internet dependency
4	Narayanan et al.	2022	Emerging Diagnostic Technologies	Early detection	Improved detection accuracy	Need for large-scale implementation
5	Esteva et al.	2021	Artificial Intelligence	Image-based diagnosis	High diagnostic accuracy using deep learning	Requires large datasets
6	Zhang et al.	2021	Salivary Biomarkers	Non-invasive diagnosis	Effective biomarker identification	Biomarker variability
7	Gupta et al.	2021	Proteomics & Metabolomics	Molecular diagnosis	Identification of novel biomarkers	Complex analysis process
8	Crowley et al.	2020	Liquid Biopsy (ctDNA)	Early cancer detection	Real-time monitoring possible	High testing cost

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 9.927| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

9	Liu et al.	2020	Portable Diagnostic Devices	Point-of-care screening	Rapid diagnosis	Limited clinical validation
10	Topol	2019	Predictive AI	Risk prediction	Personalized screening possible	Data quality dependency

Table 1. Literature Review Matrix

III. CURRENT CHALLENGES IN EARLY DETECTION OF ORAL CANCER

Despite significant advancements in oral healthcare, early detection of oral cancer remains a major clinical challenge. One of the primary limitations is the dependence on conventional diagnostic methods such as visual examination and histopathological biopsy. Although biopsy remains the gold standard for definitive diagnosis, it is invasive, time-consuming, and generally performed only after suspicious lesions become clinically evident. Furthermore, many oral cancers remain asymptomatic during their early stages, resulting in delayed patient presentation and diagnosis. Consequently, a substantial proportion of cases are identified at advanced stages, when treatment becomes more complex and prognosis less favorable. Geographical and socioeconomic disparities further exacerbate this problem, particularly in rural and resource-limited settings where access to specialized diagnostic equipment and trained healthcare professionals is often inadequate. These challenges highlight the urgent need for innovative, non-invasive, cost-effective, and accessible diagnostic technologies capable of facilitating early detection and timely intervention.

3.1 Advancements in Imaging Technologies:- Recent advances in imaging technologies have significantly improved the early detection and diagnosis of oral cancer. Among these, advanced optical imaging techniques have emerged as valuable tools for identifying precancerous and malignant lesions at an early stage. Fluorescence imaging utilizes tissue autofluorescence properties to detect biochemical and structural alterations associated with malignant transformation, thereby enhancing lesion visualization beyond conventional clinical examination [2]. Similarly, Narrow-Band Imaging (NBI) improves the visualization of vascular architecture and angiogenic changes that commonly occur during cancer progression, allowing clinicians to identify suspicious lesions more accurately [2]. Confocal microscopy further enhances diagnostic capability by providing high-resolution, real-time microscopic images of tissue architecture without the immediate need for biopsy [2]. In addition to optical imaging, digital imaging systems integrated with artificial intelligence have transformed diagnostic workflows by enabling automated lesion detection and classification. Machine learning algorithms can analyse large image datasets, reduce observer variability, and improve diagnostic accuracy [3]. Furthermore, advancements in Positron Emission Tomography (PET) and Magnetic Resonance Imaging (MRI) have enhanced tumor localization, staging, and treatment planning through improved image resolution and functional assessment capabilities [4].

3.2 Biomarkers and Molecular Diagnostics: - Molecular diagnostic approaches have gained considerable attention as promising tools for the non-invasive detection of oral cancer. Salivary biomarkers, including DNA, RNA, proteins, cytokines, enzymes, and metabolites, have demonstrated significant potential for identifying early molecular changes associated with oral carcinogenesis [5]. Saliva-based diagnostics offer several advantages, including ease of collection, patient comfort, cost-effectiveness, and suitability for repeated monitoring. In parallel, liquid biopsy technologies have enabled the detection of circulating tumor DNA (ctDNA) in blood samples, providing valuable information regarding tumor-specific genetic alterations, disease progression, and treatment response without requiring invasive tissue sampling [6]. Additionally, proteomic and metabolomic analyses have facilitated the identification of novel biomarker candidates by examining alterations in protein expression profiles and metabolic pathways associated with cancer development. These approaches have shown promise in improving the sensitivity and specificity of oral cancer diagnosis and may contribute to the development of personalized diagnostic strategies in the future [7].

© 2026 IJIRCCE | Volume 14, Issue 6, June 2026 DOI: 10.15680/IJIRCCE.2026.1406017

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 9.927| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

3.2 Point-of-Care Testing Technologies: - Recent technological advancements have accelerated the development of point-of-care testing platforms for oral cancer screening. Portable diagnostic devices are increasingly being designed to provide rapid, accurate, and user-friendly diagnostic solutions that can be utilized in primary healthcare and community-based settings [8]. These devices minimize dependence on sophisticated laboratory infrastructure and facilitate screening in rural and underserved populations. In addition, telemedicine and mobile health technologies have emerged as powerful tools for expanding access to oral healthcare services. Through digital platforms, healthcare professionals can remotely collect patient information, evaluate oral lesion images, and provide specialist consultations, thereby improving access to timely diagnosis and treatment recommendations in geographically isolated regions [9].

3.3 Artificial Intelligence and Machine Learning in Oral Cancer Detection: - Artificial intelligence (AI) and machine learning technologies have become increasingly important in oral cancer detection and risk assessment. Deep learning models, particularly Convolutional Neural Networks (CNNs), have demonstrated remarkable accuracy in lesion classification, image analysis, and automated screening applications [3]. By analysing complex imaging patterns and large datasets, AI-based systems can assist clinicians in identifying subtle abnormalities that may be overlooked during routine examination. Beyond image-based diagnosis, predictive analytics combines demographic, behavioural, genetic, and clinical data to estimate an individual's risk of developing oral cancer [10]. Such personalized risk prediction models support targeted screening strategies, optimize healthcare resource allocation, and contribute to more effective preventive oral healthcare programs. As AI technologies continue to evolve, they are expected to play an increasingly central role in enhancing diagnostic accuracy, reducing diagnostic delays, and supporting clinical decision-making in oral oncology.

Diagnostic Technique	Invasive	Cost	Accuracy	Early Detection Capability	Accessibility
Visual Examination	No	Low	Moderate	Low	High
Biopsy	Yes	High	Very High	Moderate	Moderate
Histopathology	Yes	High	Very High	Moderate	Moderate
PET Scan	No	Very High	High	High	Low
MRI	No	Very High	High	High	Low
Optical Imaging	No	Medium	High	High	Moderate
Salivary Biomarkers	No	Medium	High	High	High
Liquid Biopsy	No	High	High	Very High	Moderate
AI-Based Screening	No	Medium	High	Very High	High
Portable Diagnostic Devices	No	Low	Moderate-High	High	Very High
Telemedicine Platforms	No	Low	Moderate	Moderate	Very High

Table 2. Comparative Analysis of Emerging Oral Cancer Detection Technologies

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 9.927| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

IV. RESEARCH GAP ANALYSIS

Although considerable progress has been made in oral cancer detection through advanced imaging technologies, molecular diagnostics, artificial intelligence, and biomarker-based approaches, several limitations continue to hinder their widespread clinical implementation. Many existing diagnostic techniques are expensive, require specialized infrastructure, and are primarily available in well-equipped healthcare facilities. Furthermore, despite promising results reported in various studies, the large-scale clinical validation and standardization of these technologies remain limited, restricting their routine use in oral cancer screening programs. Additionally, most current approaches focus on a single diagnostic modality rather than integrating multiple sources of diagnostic information to improve accuracy and reliability. There is still a need for cost-effective, accessible, and user-friendly diagnostic solutions capable of providing rapid and early detection, particularly in resource-limited settings. Future research should focus on developing integrated diagnostic systems that combine advanced imaging, molecular biomarkers, artificial intelligence, and point-of-care technologies to enhance screening efficiency and improve patient outcomes.

V. CONCLUSION AND FUTURE WORK

Early detection remains the cornerstone of effective oral cancer management. Emerging technologies such as advanced optical imaging, molecular diagnostics, artificial intelligence, portable diagnostic devices, and telemedicine have significantly enhanced the ability to identify oral malignancies at earlier stages. Among these innovations, AI-assisted diagnostics and biomarker-based screening methods appear particularly promising due to their high sensitivity, non-invasive nature, and potential for large-scale implementation. Continued research, clinical validation, and healthcare infrastructure development will be essential for successful integration of these technologies into routine clinical practice. Their widespread adoption may substantially reduce oral cancer morbidity and mortality worldwide.

The future of oral cancer detection is expected to be significantly influenced by advancements in artificial intelligence, molecular diagnostics, and digital healthcare technologies. The integration of AI-based diagnostic systems with advanced imaging modalities and biomarker analysis has the potential to improve diagnostic accuracy, reduce human error, and facilitate earlier detection of malignant lesions. Furthermore, the development of non-invasive diagnostic techniques such as salivary biomarker analysis and liquid biopsy may provide reliable alternatives to conventional biopsy procedures, enabling rapid screening and continuous patient monitoring. As research progresses, these technologies are expected to support personalized diagnostic approaches and improve clinical decision-making in oral oncology. In addition, the emergence of portable point-of-care devices, telemedicine platforms, and cloud-based healthcare systems is likely to enhance accessibility to oral cancer screening, particularly in rural and underserved regions. Future innovations in nanotechnology, biosensors, and smart diagnostic devices may enable real-time detection of cancer-associated biological changes with higher sensitivity and specificity. The successful integration of these technologies into routine clinical practice will require multidisciplinary collaboration, large-scale clinical validation, and cost-effective implementation strategies. Such developments have the potential to transform oral cancer management by promoting early diagnosis, improving patient outcomes, and reducing the global burden of the disease.

REFERENCES

1. Siegel RL, Miller KD, Jemal A. Cancer statistics. CA Cancer J Clin. 2023;73(1):17–48.
2. Macey R, Walsh T, Brocklehurst P, et al. Advances in optical imaging technologies for the detection of oral cancer. Oral Oncology. 2022;112:105043.
3. Esteva A, Kuprel B, Novoa RA, et al. Deep learning-enabled medical computer vision. NPJ Digital Medicine. 2021;4:5.
4. Park SY, Lee JH, Kim YS, et al. Enhanced imaging techniques for oral cancer diagnosis: PET and MRI innovations. J Oral Oncol. 2022;78:102067.
5. Zhang L, Xiao L, Zhou X, et al. Salivary biomarkers for early detection of oral cancer. J Dent Res. 2021;100(10):1103–1112.
6. Crowley E, Di Nicolantonio F, Loupakis F, Bardelli A. Liquid biopsy: Monitoring cancer genetics in the blood. Nat Rev Clin Oncol. 2020;17(4):231–248.
7. Gupta N, Kaur H, Kumar R, et al. Proteomics and metabolomics in oral cancer detection. Oral Diseases. 2021;27(2):394–404.

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 9.927| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

8. Liu H, Gao Z, Cai Y, Lin C. Development of portable diagnostic devices for rapid screening of oral cancer. Biosens Bioelectron. 2020;168:112558.
9. Smith AC, Armfield NR, Croll J, Gray LC. The role of telemedicine and mobile health applications in oral oncology care. Telemed e-Health. 2022;28(4):489–498.
10. Topol EJ. High-performance medicine: The convergence of human and artificial intelligence. Nat Med. 2019;25(1):44–56.
11. Varma S, Balaji V, Madhavan HN. Training healthcare professionals in advanced diagnostic technologies for oral cancer. Oral Oncology. 2021;113:105162.
12. Kumar A, Singh B, Singh S, Jain S. Strategies for integrating innovative diagnostic tools into clinical practice. J Clin Oncol. 2020;38(5):423–432.
13. Ginsburg O, Bray F, Coleman MP, et al. Economic considerations of advanced diagnostic tools in oral oncology. Lancet Oncol. 2021;22(3):365–374.
14. Narayanan A, Mishra S, Saini R, et al. Emerging technologies in early detection of oral cancer. Oral Diseases. 2022;28(1):14–25.

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

INNO SPACE SJIF Scientific Journal Impact Factor

doi crossref

निस्केयर NISCAIR

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN COMPUTER & COMMUNICATION ENGINEERING

9940 572 462 6381 907 438 ijircce@gmail.com

www.ijircce.com

Scan to save the contact details