REVIEW

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Strengths, Weaknesses, Opportunities, and Threats of AI Applications in Oral Cancer Screening in India: A Scoping Review

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Abstract

Background: Oral cancer is a significant health issue in the country, accounting for one-fourth of all cases worldwide. A shortage of specialized healthcare, limited access to screening tools, and diagnostic facilities are key contributors to delayed diagnosis. Artificial Intelligence can be a promising tool for the early screening of oral cancer. However, its application in India remains underexplored and lacks systematic evaluation. **Methods:** A scoping review was conducted using the Arksey and O'Malley (2005) framework and the approach by Peters et al. (2015). The PRISMA framework was adopted for selecting relevant studies on AI applications for oral cancer screening in India. Studies were systematically searched in PubMed, CINAHL, Scopus, and Google Scholar. Reviewers extracted relevant data and systematically mapped them to identify strengths, weaknesses, opportunities, and threats of AI applications in oral cancer screening within India. **Results:** Of the 265 identified studies, 33 were selected for final review. Various designs were used, including cross-sectional field evaluations, pilot and prospective studies, scoping and systematic reviews, narrative reviews, and experimental studies. AI methodologies demonstrated high diagnostic accuracy, with strengths in portability, scalability, and affordability in low-resource settings. Weaknesses reported were a lack of standardized data, limited digital literacy, and infrastructural gaps. AI models offer opportunities to enhance screening coverage, integrate multimodal datasets, and support personalized treatment planning. Key threats observed were data variability, lack of regulatory and ethical frameworks, and data privacy concerns. **Conclusion:** AI offers strengths in improving oral cancer screening in India through early detection and reducing inequities. Despite its promising strengths, AI faces challenges such as scalability, infrastructure gaps, and ethical issues when implemented for oral cancer screening in the Indian context. For the successful integration of AI, technological innovation, robust digital infrastructure, adequate workforce training, and regulatory guidelines are required.

Keywords: Artificial intelligence- Oral cancer- Screening- SWOT- Early detection

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Introduction

Oral cancer is one of the most pressing health issues in the country, ranking among the three most frequent types of cancer [1]. Approximately 77,000 new cases and 52,000 deaths per year are reported due to oral cancer, which is about one-fourth of all cases worldwide [2]. Delayed detection of oral cancer deteriorates the prognosis of the disease: 5-year overall survival rates in early-stage disease are 80 to 90%, dropping to 50 to 60% overall survival in advanced-stage disease. Unfortunately, most of the new cases are detected during the advanced stage [3].

Shortage of specialized healthcare, limited access to screening tools and diagnostic facilities, especially in rural areas, are key contributors to delayed diagnosis of disease in India [3, 4]. In addition, patient-related factors such as low awareness, fear of diagnostic procedures, socioeconomic inequalities, and inadequate educational levels further contribute to diagnostic delays [5]. The Majority of the diagnostic tools tend to be urban-focused, which expands the rural–urban disparity in early detection and care [4].

Artificial Intelligence has developed as a promising solution to fill these gaps. Smartphone-based imaging, deep learning algorithms, and large, annotated cytology datasets are new AI technologies that offer affordable, scalable solutions for early detection. A study recently showed high diagnostic performance using AI to evaluate photographs taken by frontline workers. At the policy level, ICMR has proposed a research project

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on AI-enabled, point-of-care systems for early cancer screening [6]. Currently, the Telangana government has initiated a pilot AI-enabled screening intervention project for oral, breast, and cervical cancers that creates high-resolution images and combines this intervention with training of the workforce and consistent rollout of initiatives across districts [7].

Despite these developments, AI has not been systematically evaluated in oral cancer screening. The study was conducted to evaluate AI's strengths, weaknesses, opportunities, and threats by using the SWOT framework to inform effective implementation strategies. A SWOT analysis can potentially inform decision-makers, researchers, and practitioners on how to utilise AI to reinforce early cancer detection, reduce health inequities, and, most importantly, decrease high rates of oral cancer-related mortality in India.

Materials and Methods

The methodology of scoping review was developed using the framework proposed by Arksey and O'Malley [8] and the approach by Peters et al. [9]. We conducted the study using the PRISMA flowchart for selecting relevant studies. This review was followed by five steps: Step 1-Developing the research questions; Step 2-Identifying relevant studies; Step 3-Selecting studies; Step 4-Charting data; and Step 5-Collating, summarising and reporting results [10].

Search Strategy

Electronic databases were searched from February to July 2025. The studies published within 10 years were included in the review. The following terms were used for the literature search: "artificial intelligence", "machine learning", "deep learning", "AI tools", "oral cancer", "oral precancer", "oral potentially malignant disorders", "screening", "early detection", and "India". A systematic search was conducted using Google Scholar, PubMed/ Medline, and Scopus. Studies written in English were considered. We also included studies referenced in selected articles to avoid missing further literature.

Study selection and Inclusion criteria

Studies were eligible for scoping review: reported on oral cancer or potentially malignant oral conditions in India, and described or evaluated AI-based approaches such as deep learning, machine learning, smartphone-based tools, or cytology/image analysis, and were written in English. All reviewers independently screened the titles or abstracts to identify relevant studies that met the inclusion criteria. The authors independently reviewed and retrieved the full-text articles that met the inclusion criteria. All articles selected in this scoping review were based on consensus between all reviewers.

Data abstraction

Each article was evaluated, and relevant data were extracted by the same reviewers independently using a standardised extraction template. All articles selected for the final review were analysed and discussed among all reviewers.

Data Analysis

The extracted data were synthesised descriptively and systematically mapped using a SWOT (Strengths, Weaknesses, Opportunities, and Threats) framework to examine the application of AI in oral cancer screening in India.

Results

Studies were searched from February 2025 to August 2025. 216 studies were identified from the primary database search. Citation chaining was also performed to avoid missing literature. Backwards citation chaining was used to identify literature from reference lists of selected studies, while forward citation chaining was used to track new studies that cite the primary studies. Through this process, 42 relevant studies were added to this review.

A total of 265 studies (including 223 from primary search and 42 from citation chaining) were reviewed and analysed. After duplicate studies were removed, 258 potentially relevant studies were selected for screening. These studies were screened based on their titles and abstracts, yielding 234 full-text articles. After careful evaluation, 201 studies were excluded for the following reasons: not specific to oral cancer; not focused on Artificial Intelligence (AI); not focused on screening or detection; and not in the Indian context. After reviewing all studies, 33 studies were selected for final review. Figure 1 represents the PRISMA framework used for the literature search process.

This scoping review examined the research landscape of AI applications in oral cancer screening in the Indian context. These studies used various designs such as cross-sectional field evaluations, pilot and prospective studies, scoping and systematic reviews, narrative reviews and experimental studies. AI methodologies, diagnostic performance, and implementation challenges were investigated, with special focus on deep learning approaches and smartphone-based technologies designed for low-resource settings. These studies reported diagnostic accuracy, usability by frontline workers, and integration into healthcare and histopathology systems, socio-economic influences, and ethical considerations. Supplementary Table 1 presents the summarised characteristics of included studies.

The literature was reviewed from selected studies and analysed using the SWOT framework. The SWOT (Strengths, Weaknesses, Opportunities and threats) of AI applications in oral cancer screening were segregated in the Indian context. SWOT analysis of AI applications in oral cancer screening is shown in Table 1.

Strengths

The study found that AI model diagnostic accuracy was the most prominent strength. Deep learning methods, such as convolutional neural networks (CNNs) and transformer-based models, demonstrated high sensitivity and specificity in diagnosing oral potentially malignant disorders [4, 11-14]. Studies emphasized that integrating

Table 1. Summarized SWOT Framework of AI Applications in Oral Cancer Screening in India

Strengths	Supporting Evidence
High diagnostic accuracy using DL models	CNNs and Transformer-based models reported sensitivity/specificity >80% in detecting oral lesions.
	App-based model achieved sensitivity 85.3%, specificity 88% [4].
	Fluorescence-AI tool showed sensitivity 100%, overall accuracy 90% [11].
Smartphone and m-health based tools for rural settings.	AI tools using Smartphone-acquired images proved viable for low-resource, point-of-care screening by frontline health workers in community settings.
	MobileNet achieved 82% sensitivity on-device; VGG19 cloud model reached 87% sensitivity.18
	App-based AI enabled frontline workers in rural PHCs to screen effectively [4].
	Mobile-based “Deep Oral Augmented Model” reached ~96% validation accuracy [14]
Support for early detection in remote areas	AI shows promise in aiding early detection where specialist access is minimal, enabling prompt referral and intervention.
Histopathology applications	Studies showed AI reduces inter-observer variability and improved reproducibility.22,23
	Studies reported Multimodal AI integrating imaging with clinical data, enhanced early detection [15].
Adaptability to diverse clinical data and workflows	Multiple studies reported AI’s ability to integrate with various screening and diagnostic processes.
	m-Health imaging empowered frontline workers and supported remote diagnosis [26].
Weaknesses	Supporting Evidence
Limited large-scale validation	Most studies were pilot, cross-sectional, or technical; real-world validation limited [14,19].
Variability in image quality	AI accuracy dropped when images captured by non-specialists [13,18].
Infrastructure and digital literacy gaps	Limited connectivity and poor digital literacy hinder usability in rural areas [21,25].
Lack of standardized datasets	Absence of large, diverse, annotated oral cancer datasets reduces reproducibility [12,27]
Ethical/privacy concerns	Few studies addressed data protection and governance [24,28].
Opportunities	Supporting evidence
Expansion of screening in underserved populations	Smartphone and app-based AI tools enabled low-cost, wide-reach screening [4,18,29].
Integration of multimodal data	Combining imaging + demographic + clinical data improved diagnostic accuracy [15].
Precision medicine approaches	AI for biomarker discovery supports personalized detection and treatment [30].
	AI-assisted fluorescence imaging supports lesion stratification [11].
Alignment with national initiatives	Indian Council of Medical Research (ICMR) and Telangana state pilot projects demonstrate policy-level support.
Threats	Supporting Evidence
Dependence on dataset quality and heterogeneity	Image variability and protocol differences reduced AI reliability [27,32].
Weak governance and regulation	Lack of robust regulatory frameworks risks misuse, privacy breaches [28,31].
Over-reliance on AI tools	Authors warned of clinicians using AI as a replacement rather than support, risking patient safety [24].
Scalability challenges	Limited interoperability and poor system-level adoption impede deployment [21,25].

multiple data sources (imaging, clinical history and demographics) with AI technologies through hybrid and multimodal approaches can lead to a more accurate diagnosis and improved patient outcomes [15-17].

Smartphone-based tools and m-Health applications were also highlighted in studies, which were considered as portable, scalable, and cost-effective screening solutions for low-resource settings [4, 18-21]. Studies have shown advantages of AI applications in histopathology, indicating whole-slide image analysis and deep learning pipelines were able to minimise inter-observer variability, offer objective grading of dysplasia, and improve prognostic stratification [22-24]. The study’s findings have collectively shown strong technical capabilities and adaptability of such applications, further enhancing early detection pathways in India.

Weaknesses

Despite the strengths of AI applications in oral cancer screening being noted, this scoping review also identified weaknesses. Most of the studies were at the pilot or development stage, with limited evidence available for real-world integration [14, 19, 21, 25]. Socio-economic and infrastructural challenges, such as a lack of awareness

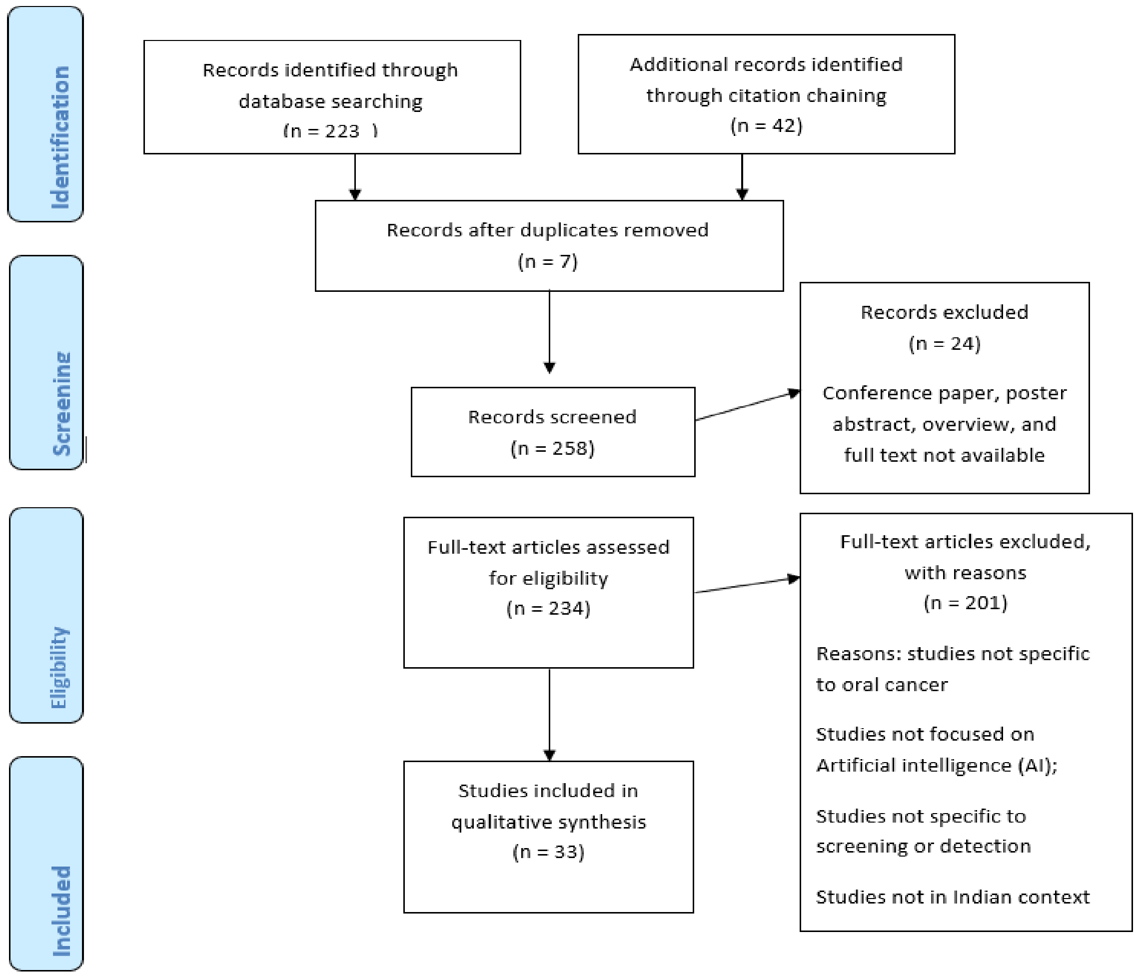

Figure 1. PRISMA Framework for Literature Search Process

and limited healthcare resources in rural and low-income settings, were also identified [4, 20, 26]. In addition, the lack of digital infrastructure, poor internet connectivity, and limited digital literacy further hinder the reach and adoption of AI technologies, particularly in rural settings [21, 25]. Although AI-based telemedicine and m-health initiatives were proposed to address these gaps, ongoing training of healthcare workers and smooth integration into existing healthcare systems will be required [4, 18]. Additionally, the study reported a lack of standardised, large-scale, publicly available datasets for oral cancer imaging. This limitation affects the reproducibility of models and benchmarking across the studies [12, 27]. Few studies have shown that algorithmic bias and a lack of data privacy protections are impeding trust and the widespread adoption of AI models [24, 28]. Overall, these factors can reduce the effectiveness of mobile-based systems in real-world scenarios.

Opportunities

AI technologies may offer an opportunity to enhance screening coverage, reduce late-stage diagnoses, and ultimately improve patient outcomes in underserved communities. These technologies have the potential to expand access to screening services and to deliver cancer care equitably by empowering frontline workers to achieve rapid, effective triage [4, 18, 29]. Another potential is enhancing integration capability by using multimodal datasets. Integrating AI with multiple screening techniques enhanced diagnostic accuracy and produced a more thorough assessment [15, 19]. AI models have potential in histopathology by predicting malignant transformation and informing prognostic assessments [11, 22, 23]. In addition, studies have shown that AI can analyse genetic and proteomic data to identify biomarkers associated with oral cancer and to recommend personalised treatment planning for a specific type of cancer, thereby creating further opportunities for precision medicine approaches in oral cancer care [27, 30]. While these applications are in the early stages of implementation in India, the literature emphasises the potential of AI tools for future advancements and eventual integration into national cancer control strategies.

Threats

Studies showed potential threats that may hinder the ethical and sustainability of AI applications in oral cancer screening. A significant threat identified across the studies was the dependence of AI performance on data quality and heterogeneity. Studies reported biases due to poor image quality, variability across datasets, and inconsistent imaging protocols, which affect reliability and AI performance in real-world settings [13, 14, 18, 27]. Another threat was a lack of regulatory and ethical guidelines in using AI applications. Due to a lack of strong policies, these applications can lead to its misuse, unclear accountability, and breaches of patient confidentiality [28, 31]. Additionally, the study findings have raised concerns regarding the over-dependence of clinicians on AI applications for diagnostic purposes by using them as a substitute rather than a supportive tool. Excessive dependence may bias clinicians' medical decision-making and adversely affect patient safety [24, 32].

Discussion

The purpose of this scoping review was to critically analyse the use of AI for oral cancer screening in India. We included 33 studies that explored a wide range of AI applications used for India's oral cancer screening. The majority of studies have demonstrated the high diagnostic potential of AI for detecting oral cancer and potentially malignant disorders, especially with convolutional neural networks (CNNs) and deep learning models. At the same time, the findings also reported challenges regarding scalability, real-world integration, and socio-ethical considerations.

The most prominent findings across the studies were the strong diagnostic accuracy of AI applications. CNN and Transformer-based deep learning models have achieved higher performance metrics in oral cancer detection, consistent with global evidence for deep learning in cancer diagnostics [43, 44]. However, AI systems experienced a decrease in performance in rural or underserved populations, where images were often taken by frontline workers rather than specialists. This decline is due to poor image quality and variability in the use of the imaging method by non-specialists. Similar findings were reported in previous studies, indicating that low performance of AI was attributed to low image quality, variability of data acquisition, and limited training [45, 46]. These findings emphasised the importance of improving image capture quality, increasing training for frontline staff, and building better AI models in order to achieve reliable performance in real-world environments.

Study findings highlighted the role of Smartphone-based and mHealth applications, which enhanced the accessibility and usability of AI models in resource-limited areas. AI-based m-health applications can further increase accessibility by offering rapid and affordable alternatives to traditional screening methods, while also enhancing the training of frontline workers. This finding is consistent with studies conducted in low- and middle-income countries, where smartphone-based applications were used to address shortages of specialists and promote early detection [47, 48]. In rural India, these applications were found to be effective in screening for oral cancer, where accessibility to healthcare and screening services is lacking. Despite these advantages, several studies reported barriers, such as problems with the capturing of images, variable diagnostic performance among frontline workers, and the need for continued technical assistance as well as training for sustained implementation of m-health applications. Similar findings have been reported in previous studies that poor image quality and an inadequately trained workforce may reduce AI performance in the community [49, 50]. Together, evidence emphasized the need for systematic investment in digital literacy, infrastructure, and workforce development to achieve widespread implementation of AI applications in oral cancer screening.

The use of AI in pre-existing healthcare systems has both opportunities and constraints. This scoping review highlighted that AI systems can improve referral pathways, facilitate telehealth, and enhance specialist workflows by triaging and resource allocation. These findings are consistent with other studies, which reported that AI-supported referral pathways and integration of telehealth can optimise specialist time and promote early diagnosis [51, 52]. However, evidence regarding AI's integration into real-world settings remains limited. In the Indian context, challenges such as poor interoperability, slow regulatory approval, and limited system-level adoption were largely unaddressed. Similarly, findings observed in previous studies conducted in developing countries, where infrastructural and governance barriers slowed the large-scale deployment of AI use [53]. Therefore, there is a need for strong policy support, robust infrastructure, and operational guidelines to effectively implement AI tools for oral cancer screening.

AI has the potential to play an essential role in precision medicine by analysing multimodal datasets (images, medical history, genetic data, and histopathology). This multimodal approach may discover biomarkers, group patients according to their risk, and suggest personalized treatment planning. Similarly, previous study has suggested that these approaches will lead to a more accurate diagnosis, optimize biomedical interventions, and inform personalized treatment planning [54]. This approach will not only focus on population-level screening but also provide individualized care through prognostic assessments and appropriate treatment options [55]. However, these applications are in early stages in India; evidence suggests that the utility of AI with precision medicine can improve the effectiveness of cancer treatment and disease outcomes by providing patient-specific interventions.

From a socio-economic standpoint, AI has the potential to reduce health disparities present in underserved populations by offering affordable and non-invasive screening for tobacco-related oral cancer. Similarly, a previous study reported that AI-based m-health tools can be used to provide diagnostic services in resource-limited areas [48]. However, challenges such as low digital literacy, cultural and economic constraints remain. Studies also raise concerns about ethical issues such as privacy and data breaches, biases in algorithms, and equitable delivery of AI tools within the healthcare system. Addressing these socioeconomic and ethical constraints is important to achieve safe and equitable access and to promote the widespread use of AI tools within the healthcare system.

Studies also noted the need for robust ethical and regulatory guidelines for effective integration of these applications into the healthcare system. Additionally, transparent algorithms, standardized datasets, and a robust policy framework are required for fostering patient confidence and ensuring safe use of these tools in oral cancer screening. However, the majority of the AI technologies remains in their nascent stages and is unregulated, and does not yet conform to moral standards. Similarly, research identified issues, noting that technological progress has outpaced policy, ethical principles, and regulatory frameworks, raising concerns about patient confidentiality and responsibility [56, 57]. Hence, India needs robust policies, open algorithms, and human oversight to implement safe and responsible AI in its oral cancer initiatives.

Mostly, AI tools are smartphone-based or captured by frontline workers, which may increase the risk of unauthorised access or misuse of confidential data. Therefore, it is important to implement strong data security measures, including robust data encryption, secure cloud storage, audit trails, and role-based access controls, to ensure the safe handling of patient information. General Data Protection Regulation (GDPR) of the European Union and the Health Insurance Portability and Accountability Act (HIPAA) of the United States have suggested principles such as informed consent, accountability, transparency, and data minimisation. Integrating such ethical measures into AI-enabled screening tools is essential to their responsible deployment in the healthcare system [58].

International polices have created ethical principles that can guide India's AI adoption pathway, like the NHS AI code of conduct in the UK, which includes principles such as transparency, data minimisation, risk management, and continuous monitoring of AI systems. Similarly, the US FDA has established a regulatory framework for software as a medical device (SaMD) to ensure its performance, safety, real-world observation, and increased surveillance. Singapore's Ministry has also adopted an AI governance framework focused on explainability, interoperability, and patient safety [59]. These policies can guide safe and effective implementation of AI in clinical practice. On the contrary, India lacks comprehensive, specific guidelines for AI use in healthcare, although initiatives by ICMR were showing early progress in the AI healthcare ecosystem [6]. Adopting these international policies can guide the responsible and ethical integration of AI into oral screening in India.

In conclusion, despite promising strengths in diagnostic performance and accessibility, there is a need to address challenges, such as scalability, infrastructural gaps, and ethical issues, to ensure the successful implementation of AI in oral cancer screening in the Indian context. Integrating AI into the real world requires technological innovation, strengthened digital infrastructure, workforce training, and regulatory guidelines. Data privacy, transparent algorithms, and equitable access to AI tools should be addressed to enable effective deployment of AI in oral cancer screening. AI can process multimodal data to identify biomarkers associated with oral cancer and to recommend personalised treatment planning for a specific type of cancer, thereby creating opportunities for precision medicine approaches in oral cancer care.

Author Contribution Statement

All authors contributed equally in this study.

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