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Artificial Intelligence in the Early Detection and Diagnosis of Oral Cancer: A Systematic Review

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Abstract

Background: Oral cancer remains a significant global health burden, often diagnosed at advanced stages, leading to high morbidity and mortality. The quality of life and survival rates are significantly increased by early identification. ***Purpose:*** This systematic review is to assess the available data on artificial intelligence's potential to aid in the early detection and diagnosis of oral cancer. It focuses on evaluating the clinical applicability, sensitivity, specificity, and diagnostic accuracy of AI-based tools in contrast to traditional diagnostic techniques. ***Study selection:*** A systematic literature search was performed using PUBMED, MEDLINE, EMBASE, and COCHRANE Library with language restriction to English. The search was carried out incorporating the published literature till 2026 using the MeSH (medical subject heading) terms. A literature search was done out of 245 publications, related to search strategy, 57 full articles, which were related to the study, were acquired for further inspection. Out of the 49 articles, 6 articles met the inclusion criteria. Information related to study characteristics, types of AI models used, imaging techniques, and reported diagnostic performance was collected and reviewed. ***Results:*** The reviewed studies demonstrate that AI models, particularly convolutional neural networks, exhibit high diagnostic accuracy in evaluating clinical photographs, histopathology, radiographs, and autofluorescence images. Many reports showed sensitivity and specificity above 85%, signifying ability of AI to differentiate malignant and potentially malignant lesions from benign conditions. ***Conclusion and Relevance:*** Artificial Intelligence serves as a promising adjunct in the early detection and diagnosis of oral cancer, offering high diagnostic accuracy and improved support for clinical decision-making without replacing professional expertise. This review highlights the potential of artificial intelligence to enhance early and accurate detection of oral cancer, which can significantly improve patient survival and treatment outcomes. It also underscores the role of AI as a supportive clinical tool that can increase diagnostic consistency and aid clinicians in timely decision-making.

Keywords: Artificial Intelligence, Oral Cancer, Early Detection.

INTRODUCTION

Oral cancer is a common malignancy worldwide, with over 377 000 cases diagnosed and 177 000 deaths per year. According to Surveillance, Epidemiology, and End Results (SEER) Program data, the 5-year survival rate of oral cancer decreases as the disease progresses, from 86.3% in the localized stage to 39.3% in the distant stage. [1] Oral cancer is the sixth most common malignancy in the world. Oral cancer is of major concern in Southeast Asia primarily because of the prevalent oral habits of betel quid chewing, smoking, and alcohol consumption. [2] On average, the rates for men are currently twice as high as for women, although there are exceptions, such as in Taiwan, where the male/female ratio is 10:1. The risk of developing oral cancer increases with age, and most cases occur in people over the age of 50 y. [3]

Artificial intelligence (AI) is a technology that utilizes machines to mimic intelligent human behaviour. To appreciate human-technology interaction in the clinical setting, augmented intelligence has been proposed as a cognitive extension of AI in health care, emphasizing its assistive and supplementary role to medical professionals. [4] Over the past decade, artificial intelligence (AI), including the recently launched ChatGPT, has sparked significant anticipation regarding its potential value within the field of health sciences. By using various algorithms, AI is able to perform image recognition, data mining, and deep learning, which can effectively solve the big data processing challenges in the medical field. However, due to the numerous types of oral mucosal lesions, screening and diagnostic methods, and the corresponding detection devices, there is still limited large-scale research on the AI diagnosis of OPMD and oral cancer. [5] Machine learning (ML) is a subset of artificial intelligence. ML predicts the outcome based on the dataset provided to it using algorithms, such as artificial neural networks (ANN). These networks mimic the human brain and have interconnected artificial neurons that receive and analyze data signals. [6] Herefore, although both of these subsets of AI are "intelligent," deep learning requires much more data than a traditional machine learning algorithm, while machine learning performs better with fewer data sets that are clearly labelled or structured with regard to a gold standard or specific criteria of interest. Both approaches are used for intelligent image analysis, depending on the application and data sets that are available. Manual interpretation of medical images is very time-consuming, requires considerable specialist expertise, and is prone to inaccuracy. [7] CNN-based models were particularly effective in histopathological image analysis, leveraging deep feature extraction to improve classification accuracy.[8] In recent years, the convergence of computer vision and artificial intelligence (AI) has sparked a paradigm shift in medical diagnostics.

With an emphasis on the diagnostic performance, techniques used, and possible drawbacks of AI applications in this setting, this systematic review seeks to thoroughly assess the available data on the role of AI in the early detection and diagnosis of oral cancer.

METHODOLOGY

In accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement, this systematic review was carried out.

Data Extraction

Key study characteristics, such as author, publication year, sample size, AI model used, comparator groups, and diagnostic performance metrics (accuracy, sensitivity, and specificity), were gathered using a standardised data extraction form in an Excel sheet (Microsoft Corporation, Redmond, Washington, United States). Two reviewers separately extracted the data to guarantee accuracy and consistency.

Search Strategy: An extensive literature search was conducted using PUBMED, MEDLINE, EMBASE, and COCHRANE databases. The keywords used for the search included "oral cancer," "oral potentially malignant disease (OPMDs)," 'early detection' "artificial intelligence," and "diagnostic tools." The search was limited to published literature till 2025 and incorporated the aforementioned MeSH terms. Only randomized controlled trials were included in this study. Exclusion criteria comprised articles not in English, those with only an abstract available and poorly designed studies. CRD420261331005

RESULT

Database searches yielded 245 records in total. 121 duplicate records were eliminated, and 124 research moved on to the title and abstract screening stage. Based on their applicability, 72 of these studies were eliminated, leaving 49 research for retrieving the entire text. However, paywall constraints prevented the retrieval of 27 papers, leaving only 22 studies that were evaluated for eligibility. After a thorough analysis, three research were eliminated as case reports or conference abstracts, seven studies were eliminated as review articles or editorials, and sixteen papers were eliminated for not being based on AI models. In the end, 6 studies were included in this systematic review since they satisfied the inclusion requirements.

Figure 1: Oral cancer involving tongue and gingivobuccal complex

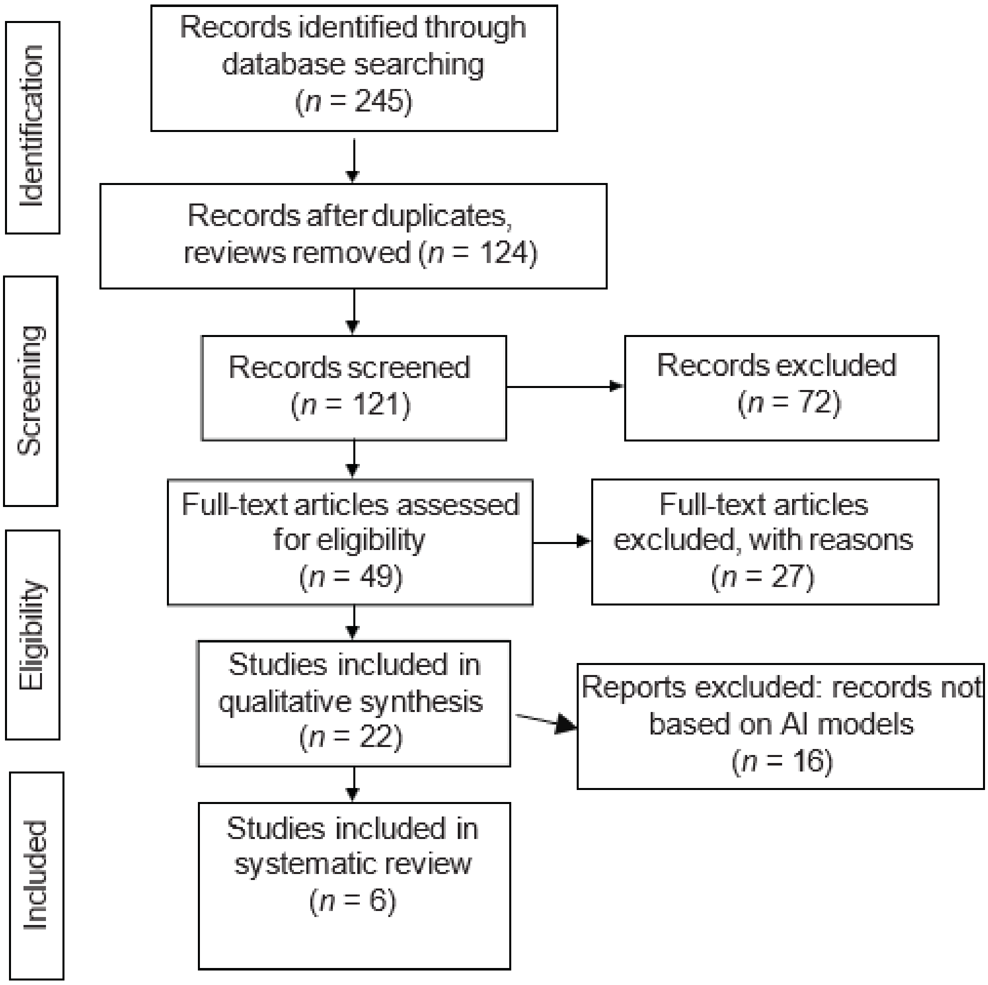

Figure 2: PRISMA Flow Diagram of the Study

Table 1: Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Population	Studies involving patients with suspected or confirmed oral cancer or oral potentially malignant disorders (OPMDs), where AI-based methods were used for detection or diagnosis	Studies involving non-oral cancers, animal models, or in-vitro experimental studies.
Intervention	Studies utilizing artificial intelligence–based techniques for the detection or diagnosis of oral cancer or oral potentially malignant disorders (OPMDs).	Studies not using artificial intelligence–based methods for detection or diagnosis of oral cancer or oral potentially malignant disorders (OPMDs).
Comparator	Studies comparing AI-based diagnostic methods with conventional diagnostic approaches or expert clinical/histopathological assessment.	Studies without a comparator or without comparison to conventional diagnostic methods or expert assessment.
Outcome measures	Studies reporting diagnostic performance outcomes such as accuracy, sensitivity, specificity, for AI-based detection of oral cancer or OPMDs	Studies not reporting diagnostic performance outcomes (e.g., accuracy, sensitivity, specificity)
Study design	Original research studies evaluating AI-based methods for the detection or diagnosis of oral cancer or OPMDs.	Studies not met inclusion criteria
Language	English	Non-English studies without available translations

Table 2: Characteristics of the included studies and performance matrix of different AI models

Author	Publishing year	Controls used	AI model	Performance (%)		
				Accuracy	Sensitivity	Specificity
Huang *et al.,* [14]	2023	Benign and malignant mucosa	CNN+ISSA	97.33	87.34	Not reported
Ding *et al.,* [18]	2023	Benign and malignant mucosa	MLSO+SVM	96.94	97.7	92.37
Alanazi *et al.,* [16]	2022	Benign and malignant mucosa	NASNet	92.59	95	Not reported
Shamim *et al.,*[15]	2022	Benign and malignant mucosa	VGG19	98	89	97
Xue *et al.,*[11]	2022	Benign and malignant mucosa	ResNet	98	100	99.6
Morikawa T *et al.,* [17]	2020	Malignant and normal oral mucosa	Oralook and IllumiScan	Not reported	98%	85.4%

AI: artificial intelligence; CNN: convolutional neural network; ISSA: improved sparrow search algorithm; MLSO: multi-objective Lichtenberg search optimization; SVM: support vector machine; NASNet: neural architecture search network; OPMD: oral potentially malignant disorder; VGG: Visual Geometry Group; ResNet: residual neural network

DISCUSSION

Early diagnosis by general dentists is considered likely to improve the outcomes of SCC and oral cancer.[17] A number of crucial tactics have been developed to improve oral cancer detection performance.[10,11] Despite a lack of accessible data, the use of AI in OSSC detection has produced encouraging results, with F1 scores of 94.9% and accuracy levels of up to 99%.[12,13]

AI-based models have demonstrated strong performance in detecting oral cancer despite the limitation of relatively small datasets, which average around 1,200 images per study and range from approximately 105 to 7,148 images. The collection of medical imaging data, particularly for oral cancer, is inherently time-consuming and resource-intensive, making smaller datasets a common challenge in this field. Nevertheless, several methodological strategies have improved diagnostic performance. The incorporation of attention mechanisms has shown promise by enabling models to focus on clinically relevant regions of images, thereby enhancing detection capability. Recent studies also suggest that attention transformers and similar architectures can be effectively trained even on limited datasets. In addition, ensemble learning has produced encouraging outcomes by combining predictions from multiple models, with some studies reporting accuracy rates exceeding 96%. Image enhancement and preprocessing techniques, including adaptive histogram equalization and discrete wavelet transform–based enhancement, have further improved model performance. Among various architectures, VGG-19 has consistently demonstrated high accuracy due to its strong capability for extracting complex image features relevant to oral cancer detection. Figure 2 shows oral cancer involving the tongue and gingivobuccal complex, presenting as an irregular ulceroproliferative lesion with areas of erythema and surface ulceration. The lesion appears extensive with surrounding tissue involvement, suggesting locally advanced malignancy requiring prompt clinical evaluation and management.

Despite these promising developments, several limitations remain. A major challenge is the limited availability of large, standardized datasets, many of which lack biopsy-confirmed diagnostic verification. The commonly used benchmark datasets, such as those available on platforms like Kaggle, are relatively small and may have reliability concerns, restricting the generalizability of findings across different clinical settings. Consequently, preprocessing and data augmentation techniques—including rotation, flipping, and cropping—are frequently applied to compensate for limited data. By concentrating computing resources on pertinent visual regions, a recent study that included attention mechanisms demonstrated the new possibilities that emerge, greatly enhancing detection skills.[18] Another important concern in AI-assisted diagnosis is the risk of false-positive and false-negative results. False negatives may delay diagnosis and treatment, while false positives can lead to unnecessary anxiety and additional procedures. Strategies such as follow-up evaluation of suspicious lesions, robustness testing under varied imaging conditions, and expert validation through human-in-the-loop systems can help improve the reliability and clinical applicability of AI-based diagnostic models. The general high accuracy rates seen are a result of its capacity to extract intricate features from images, which is in line with the requirements of oral cancer detection. [14-16]

CONCLUSION

Prevention screening programmes for other cancers have proven to be effective in early detection.[9] Recent advancements in the use of artificial intelligence for oral cancer detection are highlighted in this systematic study. With multiple studies indicating sensitivity and accuracy exceeding 95%, the results show that AI techniques, especially deep learning and computer vision models like convolutional neural networks, exhibit exceptional diagnostic performance. Techniques like multi-task learning, texture-based analysis, and ensemble learning further boost diagnostic capacity, indicating that AI may increase detection accuracy even when trained on comparatively little datasets.

However, the use of AI in the diagnosis of oral cancer is still in its infancy and needs more validation through larger, well planned clinical trials. Developing reliable models, standardised datasets, and clinically proven algorithms should be the main goals of future research. AI has the ability to help doctors with early diagnosis, enhance diagnostic judgement, and eventually improve patient outcomes in the treatment of oral cancer with further developments.

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