

The use of artificial intelligence in the diagnosis of oral carcinoma

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Abstract

Introduction: Artificial intelligence (AI) is poised to transform the medical field significantly. Machine learning (ML) and deep learning (DL) techniques are increasingly utilized to improve the diagnosis, management, and treatment of oral lesions, including oral squamous cell carcinoma (OSCC). The high incidence and mortality associated with OSCC underscore the critical need for early and accurate diagnostic tools. AI offers advanced methodologies for enhanced diagnostic precision and operational efficiency, addressing the limitations of traditional techniques.

Materials and Methods: This scoping review systematically explores current AI applications focused on oral lesions. Studies included addressed AI in diagnosing and managing OSCC, published in English or Italian. A comprehensive search was conducted across electronic databases (PubMed, Scopus, and Web of Science). The data regarding study characteristics, AI types, methodologies, and outcomes were extracted. **Discussion:** AI shows immense potential in optimizing oral carcinoma diagnosis and treatment processes, as evidenced by various studies. For instance, deep learning techniques have demonstrated high accuracy in identifying oral carcinoma and analyzing histological data. AI systems can streamline diagnosis, dramatically reducing waiting times and enhancing reliability. Additionally, AI applications extend to prognosis and staging, with methodologies showcasing promising accuracies for the clinical management of neoplasms.

Results: Integrating AI in the diagnosis of oral lesions has resulted in accuracy rates exceeding 99% and significantly reduced diagnostic waiting times. Machine learning models effectively detect subtle anomalies and offer diagnostic performance that matches or surpasses expert clinical pathologists. The use of automatic classifiers has improved early diagnosis and operational efficiency in clinical practice, addressing traditional challenges and reducing diagnostic errors.

Conclusions: Incorporating AI in diagnosing and managing oral lesions presents significant opportunities for improving clinical outcomes with high accuracy and speed. Continuous research and development are needed to refine these systems and ensure their effective implementation in clinical practice. Collaboration among interdisciplinary teams is crucial for ensuring data security and meeting the needs of healthcare professionals in future AI developments.



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Introduction

In recent years, artificial intelligence (AI) has emerged as one of the most promising technologies in the medical field, with the potential to radically transform the diagnosis, management, and treatment of numerous diseases (1, 2). In particular, dentistry has seen a growing use of machine learning (ML) and deep learning (DL) techniques, which have significantly improved the ability to analyze large amounts of clinical and radiographic data (3). This technological progress has opened new perspectives for early diagnosis and management of oral lesions, including potentially malignant ones, such as oral squamous cell carcinoma (OSCC).

Oral carcinoma, one of the most common head and neck cancers, is a particularly relevant pathology due to its high incidence and mortality rates. Despite the scientific advancements in cancer biology and the development of increasingly sophisticated diagnostic techniques, long-term outcomes for patients with OSCC remain unsatisfactory, mainly due to late diagnosis (4). In this context, AI provides innovative tools that can significantly enhance the accuracy and timeliness of diagnoses, thereby reducing the risk of diagnostic errors and optimizing therapeutic pathways.

The importance of early intervention is well-documented in the scientific literature: timely diagnosis can significantly reduce the mortality associated with oral carcinoma and improve patients' quality of life (4). However, the limitations of traditional diagnostic techniques, mainly based on visual examination and histopathological analysis, have stimulated the search for more advanced tools (5). In this context, artificial intelligence emerges as a valuable resource, capable of overcoming some of the most critical barriers in the early diagnosis of oral lesions (6). Through predictive models and machine learning algorithms, AI can analyze large amounts of clinical data, radiographic images, and genomic signals with unprecedented precision [3, 7, 8, 9].

In particular, machine learning models and convolutional neural networks (CNNs) have demonstrated effectiveness in analyzing radiographic images and automatically classifying suspicious lesions, achieving higher accuracy than traditional methods. The use of CNN for diagnosing oral carcinoma, for example, has shown very high accuracy rates in distinguishing between benign and malignant lesions, suggesting that these tools could become an integral part of clinical practice in the future (10). AI is not limited to diagnosis: advanced algorithms can analyze genomic and clinical data on a large scale, contributing to the personalization of therapies and improving patient outcomes (11).

Integrating AI into clinical practice also offers the potential to improve operational efficiency, reduce the workload of healthcare professionals, and automate repetitive or highly technical processes, such as analyzing histopathological images (12). The ability to automatically detect anomalies or subtle changes

in diagnostic images also reduces the risk of human error, allowing faster and more accurate diagnoses. In addition to improving accuracy, these technologies have the potential to democratize access to high-quality diagnoses, allowing even less experienced professionals to benefit from the advanced decision support offered by AI systems.

Despite the promises and results, significant challenges remain to be addressed to ensure the widespread and safe adoption of artificial intelligence in dentistry.

Among the main critical issues are the quality and representativeness of the data used to train the algorithms, the need to validate the results on a large scale and in real clinical contexts, and ethical issues related to transparency and the use of personal data. Regulation and acceptance by the medical community are key aspects that will determine the future of AI in dental practice.

This scoping review aims to systematically explore the current state of AI applications in dentistry, with a particular focus on diagnosing and managing potentially malignant oral lesions. It will evaluate the various AI techniques currently used and their implications for clinical practice, highlighting areas where AI has had a significant impact and those that need further development. The review will also identify the main knowledge gaps in the existing literature and provide suggestions for future research in this field.

In summary, this paper provides a detailed overview of the application of AI in dentistry and oral lesions, examining the progress made to date and the challenges still to be addressed. Given this technology's potential to revolutionize the diagnosis and management of oral diseases, this scoping review aims to contribute to the definition of a clear and updated framework for the opportunities and limitations associated with integrating AI in dental clinical practice.

Materials and methods

Inclusion and Exclusion Criteria

The studies included in this review had to meet the following criteria: address the topic of artificial intelligence (AI) applied to diagnosing and managing oral lesions, with a particular focus on oral squamous cell carcinoma (OSCC). Scientific articles published in English and Italian, including experimental studies, reviews, and meta-analyses, were considered. The studies needed to include clinical, genomic, or histological data related to OSCC. Articles that did not specifically address the use of AI in oral oncology, case reports, and low-quality studies with limited evidence were excluded.

Sources of Information and Research Strategy

The research utilized electronic databases, including PubMed, Scopus, and Web of Science. The search strategy combined keywords and MeSH terms like "oral squamous cell carcinoma," "artificial intelligence," "machine learning," "deep learning," "diagnosis," "prognosis," and "oral lesions." Studies published up to March 2024 were included in the analysis. The research was conducted without year restrictions as long as the studies met the specified inclusion criteria.

Study Selection

Two independent reviewers examined the titles and abstracts of the identified studies, and those considered relevant were included for a full-text review. Discrepancies in selection were resolved by consensus or through the involvement of a third reviewer. Articles that did not provide sufficient data or did not meet the inclusion criteria were excluded.

Data Extraction and Synthesis

The following data were extracted for each included study: study characteristics (year of publication, country), type of AI used, analysis methodology, and main results. The data were synthesized using a summary table to facilitate comparison between studies and identify recurring themes and gaps in the literature.

Quality Assessment of Studies

The quality of the included studies was assessed using specific criteria for scoping reviews. The transparency of methods and reproducibility of results were examined. Studies with well-defined methodologies and reproducible results were considered high quality.

Discussion

Artificial intelligence (AI) is revolutionizing numerous sectors, demonstrating extraordinary potential in optimizing processes, improving efficiency, and providing innovative solutions. This article examines how AI can be optimally utilized to enhance the approach to oral carcinoma, from diagnosis to treatment, by drawing on studies presented in the literature.

The literature includes both clinical and histological studies on diagnosis. For clinical studies, Aubreville et al. (13) reported results that, using deep learning, they could identify oral carcinoma in over a thousand images with confocal laser endomicroscopy with an accuracy of 88.3% and a specificity of 90%.

For histological studies, one of the most significant works was that of the researcher Das et al., who published three articles: In 2015 (14), they developed a model based on the evaluation of the level of keratinization, which is highly indicative of the pathology, using the Chan-Vese segmentation algorithm, which showed an accuracy of 95.08%. In 2018 (15), they introduced an innovative two-stage approach, the first for segmentation and the second for detecting keratin pearls, achieving an accuracy of 96.88%. In 2019 (16), they created an algorithm capable of automatically segmenting and analyzing nuclei from histological images, demonstrating incredible speed and lower memory consumption than existing methodologies.

One of the most surprising studies regarding the use of AI in early diagnosis is the one conducted by Fati et al. (17). This work highlights how AI can significantly reduce diagnosis waiting times from hours or days to just a few minutes. This rapid identification is crucial for proper patient health management, as a timely diagnosis is essential to improving the chances of recovery. Moreover, the study demonstrated an accuracy exceeding 99%, indicating that AI accelerates the diagnostic process and enhances its reliability.

Beyond the diagnostic aspect, AI systems have also been developed for cancer management, specifically for prognosis and staging. Studies conducted on various markers have shown that they can be prognostic indicators of the disease. The first is Chang's study (2013) (18), which developed a predictive system for oral carcinoma through an innovative approach. Unlike previous studies, this study used a hybrid combination of feature selection methodologies and machine learning techniques, integrating clinicopathological data (including demographic factors and information related to clinical and pathological stages) with genomic data, such as the expression of p53 and p63 proteins obtained from immunohistochemical slides. The analysis identified three optimal prognostic markers: alcohol consumption, tumor invasion, and p63 protein expression. This approach achieved an accuracy of 93.81% in predicting the one-year prognosis.

Another significant contribution was made by the study of Shaban et al. (2019), which used deep learning techniques to analyze the quantification of tumor-infiltrating lymphocytes (19). This study further highlighted how AI can improve diagnosis and provide essential prognostic information for the clinical management of neoplasms.

For the staging phase, AI has demonstrated its ability to develop automatic classifiers, which numerous researchers have tested in the field. Although various studies are in the literature, Rahman et al.'s (2020) work stands out for its exceptional accuracy (20).

The methodology adopted in the study involves a two-phase feature selection process, which combines the t-test and principal component analysis (PCA), and utilizes five different classifiers. The results are remarkable: Four of the classifiers analyzed showed an accuracy of over 99%. In particular, the decision tree achieved an accuracy of 99.4% using shape-related features. In comparison, both the Support Vector Machine (SVM) and logistic regression attained an accuracy of 100% regarding texture and color features. This methodology provides an essential perspective in monitoring the effectiveness of therapies, contributing to a more personalized and informed approach to managing oncology patients.

Results

Implementing artificial intelligence (AI) in diagnosing oral lesions has yielded significant improvements in accuracy and diagnostic times. AI-based image analysis has achieved accuracy rates exceeding 99%, and waiting times for diagnostic results have significantly decreased from days to just a few minutes (17). This improvement optimizes the diagnostic process, resulting in a more timely and precise approach to managing oral pathologies.

In particular, machine learning models have demonstrated remarkable effectiveness in detecting subtle anomalies (3, 21), suggesting that AI can identify details that might easily escape human examination. The analysis of clinical data and radiographic images has revealed that AI-based systems can provide diagnoses with accuracy rates comparable to or superior to those

obtained by expert clinical pathologists (22). Additionally, the use of automatic classifiers has yielded excellent results, enhancing early diagnosis (20).

The accuracy achieved in various studies highlights the potential of AI to overcome traditional diagnostic challenges. AI can also contribute to reducing diagnostic errors and increasing operational efficiency in clinical practice (3, 23).

Despite the promises and results achieved so far, significant challenges remain to be overcome to ensure the widespread and safe adoption of artificial intelligence in dentistry.

Among the main critical issues are the quality and representativeness of the data used to train the algorithms, the need to validate the results on a large scale and in real clinical contexts, and ethical issues related to transparency and the use of personal data. These issues are highlighted despite the development of numerous effective and efficient communication training methods for federated learning (24-25). Regulation and acceptance by the medical community are key aspects that will determine the future of AI in dental practice.

These results suggest that integrating artificial intelligence into the diagnosis and treatment of oral lesions represents a technological advancement and an opportunity to significantly improve clinical outcomes for clinical pathologists and, most importantly, cancer patients.

Conclusions

Integrating artificial intelligence in the diagnosis and management of oral lesions presents significant opportunities to enhance clinical outcomes with high accuracy and speed. However, continuous research is necessary to refine these systems and expand their applications, particularly in patient management. For a complete implementation, ensuring the simplicity of system interpretation and providing adequate training to healthcare personnel will be essential. An interdisciplinary collaboration will be necessary to ensure data security and meet professional needs in the development of future systems.

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