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Review Article

Artificial Intelligence in Contemporary Dentistry: Current Applications with an Emphasis on the Early Detection of Oral Cancer

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Abstract
Artificial intelligence (AI) has become a practical part of dental diagnosis and treatment planning. Deep learning models built on convolutional neural networks can now interpret radiographs, clinical photographs and histopathology slides with an accuracy comparable to that of experienced clinicians. This review examines how these tools are currently used in dentistry, with particular focus on the early detection of oral cancer and oral potentially malignant disorders (OPMDs), where delayed diagnosis remains a leading cause of poor survival. Recent studies have produced smartphone-based screening systems, real-time lesion detectors, and models that grade histological risk, with several reporting sensitivity and specificity above 0.85. The review also covers other applications including caries detection on radiographs, endodontic and periodontal assessment, cephalometric analysis, implant planning and the emerging use of large language models. It further considers the main barriers to wider adoption, such as limited datasets, weak external validation, and unresolved ethical and regulatory concerns. For now, AI is best viewed as a support tool that strengthens, rather than replaces, clinical judgment.

Keywords: *artificial intelligence, deep learning, convolutional neural network, oral cancer, oral potentially malignant disorders, dental radiology.*

1. Introduction

Artificial intelligence refers to computer systems that perform tasks ordinarily thought to require human reasoning including recognizing patterns, sorting images and generating predictions. Within this field, machine learning enables a system to get better at a task by drawing on data rather than following preset rules, while deep learning relies on multi-layered neural networks that learn relevant features straight from raw input. Convolutional neural networks (CNNs), a class of deep network built for images, have proven particularly well suited to the image-based nature of dental diagnosis. [1,2].

Every day, dentistry produces large amounts of image data: intraoral and panoramic radiographs, cone-beam computed tomography (CBCT) scans, clinical photographs and histopathology slides. That abundance makes the field a natural candidate for image-based AI. Recent evidence syntheses bear out this momentum. A review of 116 systematic reviews reported that AI models achieved diagnostic accuracy ranging from 82% to 95% across dental specialties, along with a pooled sensitivity of 0.85 and specificity of 0.93 for diagnostic tasks [1]. Comparable reviews note steady uptake across diagnosis, treatment planning and workflow automation [2,3].

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Oral cancer lends this work a distinct urgency. It ranks among the most common cancers worldwide and accounts for a substantial portion of head and neck cancer deaths, with much of that burden concentrated in low- and middle-income countries [4,5]. Survival can reach 75–90% when lesions are caught early, yet most cases are still identified at an advanced stage owing to low public awareness, delayed referral and inconsistency in how examinations are carried out [5]. This gap, between what early detection is capable of and what routine screening actually achieves, is precisely the space that AI-assisted tools aim to fill.

This article reviews the current applications of AI in dentistry. It begins with early oral cancer and OPMD detection, then examines other clinical domains where the technology is now in use, and closes with the main limitations that shape how these tools should be interpreted.

2. Applications of Artificial Intelligence in Dentistry

2.1 Early detection of oral cancer and oral potentially malignant disorders

Most of the recent work has focused on screening for OPMDs such as leukoplakia, erythroplakia and oral lichen planus, and on telling these apart from outright cancer. Since many of these lesions can be seen on the surface of the mucosa, models trained on clinical photographs can help with screening without any invasive step.

Several groups have shown that this method works beyond the laboratory. A 2025 study built deep learning models that screened for OPMDs and oral cancer using images taken on smartphones through both native and cloud-based apps, a setup meant for community and low-resource settings where specialists are hard to find [4]. Earlier groundwork established the basic method, using a two-stage CNN pipeline to first detect and then classify oral lesions from photographs in near real time, and presenting it as a low-cost, non-invasive screening aid [6]. Newer detection models built on the YOLO architecture have been trained to pinpoint OPMDs on intraoral images, showing usable performance even with modest datasets [7].

Pooled evidence backs up this trend. A systematic review and meta-analysis of AI applied to oral cancer and OPMD imaging found diagnostic performance strong enough to warrant further clinical testing, though it noted that most of the included studies were retrospective [8]. A wider scoping review of AI in oral cancer traced its use spanning both diagnosis and prognosis, including the prediction of malignant transformation risk in leukoplakia from histological images [9]. The work has also reached beyond ordinary photography: real-time digital oral microscopy and confocal laser endomicroscopy, when combined with neural networks, can bring out cellular features such as nuclear size, pleomorphism, and cell crowding that signal early malignant change [10].

Taken as a whole, these studies suggest a practical screening model in which a first-line AI tool marks suspicious lesions for specialist review. The recurring limitation is that most systems have been tested on curated image sets rather than in prospective clinical use, so their real-world sensitivity in an unselected population still needs to be confirmed.

2.2 Caries detection and radiographic diagnosis

Caries detection is the most mature of the imaging applications. CNNs trained on bitewing, periapical and panoramic radiographs can now identify carious lesions, often catching early interproximal ones that are easy to overlook by eye. A systematic review of deep CNNs applied to bitewing radiographs confirmed dependable performance across segmentation, classification, and detection tasks [11]. Individual models have pushed accuracy further: a ResNet-based architecture paired with an attention mechanism reached an F1 score of 0.886 and an area under the curve of 0.954 on periapical radiographs, outperforming junior dentists in the same comparison [12]. Reported accuracy on panoramic and intraoral images generally sits in the high-80% to low-90% range [13]. This level of consistency is one reason caries detection has moved from research into everyday clinical software faster than most other applications. Commercial systems are already being marketed for chairside radiographic analysis, which is part of why professional bodies have started issuing standards for validating these tools [3].

2.3 Endodontics, periodontology, and orthodontics

Beyond caries, AI is being applied throughout most clinical specialties. In endodontics, models assist with detecting vertical root fractures, estimating working length and identifying periapical lesions [14]. In periodontology, deep learning quantifies alveolar bone loss on radiographs and supports staging of periodontal disease. In orthodontics, AI automates cephalometric landmark identification, a traditionally slow and operator-dependent task, and has been tested as an aid for extraction decision-making in treatment planning [1,14]. In each of these areas the pattern is similar: the technology speeds up repetitive measurement and flags findings, while the final decision stays with the clinician.

2.4 Prosthodontics, implantology, and workflow

Digital dentistry has woven AI into both design and planning. Models now assist with implant position planning and with the automated design of crowns, prostheses, and restorations, working from intraoral scans and CBCT data [14]. Related tools take on automated tooth numbering, chart annotation and administrative tasks, easing the manual load on clinical staff while making records more consistent. By handling these repetitive steps, such systems free the clinician to spend more time on the parts of care that call for hands-on skill and judgment.

2.5 Generative AI and large language models

The most recent addition is generative AI and large language models (LLMs) such as ChatGPT, Gemini, and Copilot. Unlike image-focused CNNs, these systems handle text and increasingly, images together. Their reported dental uses include drafting structured treatment plans, answering clinical questions, aiding patient communication and education, and supporting documentation [15,16]. Comparative studies have assessed their diagnostic reasoning on oral medicine and periodontal cases, with results that are mixed but improving [16]. The recurring caution is that LLMs can give fluent yet incorrect answers, so their output needs to be checked before any clinical use, and patient-privacy safeguards must be in place whenever real case data is involved [3,15]. For this reason, these models are best treated as an aid to the clinician's own reasoning rather than a source of final answers.

3. Challenges and Limitations

The gains are real, but so are the limits. Most published models were trained on small, single-center datasets that may not capture the full range of patients, devices and imaging conditions found in practice, which increases the risk of bias and restricts how well the results carry over [2,3]. External and prospective validation is still uncommon, so laboratory accuracy tends to overstate real-world performance. Regulatory frameworks are also lagging behind; recent standards from professional and regulatory bodies call for independent validation datasets and clearer rules for image-analysis software used as a medical device [3]. Questions of liability, informed consent, data privacy, and clinician training remain unsettled, and there is a real need to fit these tools into existing dental software without slowing the clinician down. A further concern is that many models function as opaque "black boxes," offering little insight into how a given decision was reached, which makes clinical trust harder to earn. For these reasons, AI is best seen today as decision support that strengthens the practitioner rather than a substitute for clinical examination and judgment.

4. Conclusion

Artificial intelligence has established itself as a genuine part of modern dental diagnosis, and its clearest value so far lies in image-based tasks. In oral cancer and OPMD screening, deep learning offers a credible path to earlier detection, especially through low-cost, smartphone-based systems capable of carrying screening into communities that specialists rarely serve. Similar progress is evident in caries detection, endodontics, periodontology, orthodontics, and prosthetic planning, while large language models are beginning to take on a supporting role in clinical decision-making and patient communication. Whether this promise is fully realized will depend on larger and more varied datasets, careful prospective validation, and clear regulatory and ethical guidance. Applied within those boundaries, AI holds real potential to sharpen diagnostic accuracy, improve efficiency, and widen access to care, all while keeping the clinician firmly at the center of every decision.

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