

ARTIFICIAL INTELLIGENCE AND ITS CLINICAL IMPLICATIONS AND ACCURACY IN RESTORATIVE DENTISTRY: A NARRATIVE REVIEW

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ABSTRACT

In this narrative review, the researchers examine the clinical implications and accuracy of AI applications used in restorative dentistry. Such topics of interest are caries detection and classification, detection of the finish line and margin in crown preparation, prediction of restoration failure, and linkage with CAD/CAM and prosthodontic workflows. The objective of the review is to summarize the available evidence, assess the validity of the diagnosis, and discuss whether AI can transform restorative practice. Recent research indicates that AI models are always highly diagnostic, and in some instances, they perform better than junior clinicians in caries recognition. It has also been demonstrated that AI-based systems can reliably detect restorative margins and predict the occurrence of restoration failure, which is beneficial in long-term treatment planning. Furthermore, in the field of prosthodontics, it has been suggested that the application will lead to higher efficiency and accuracy in implant-supported restorations and in the creation of crowns. AI has a huge potential to improve restorative dentistry as a complementary measure to improve clinician performance and patient care. To support successful translation to clinical applications, further validation using large-scale studies, integration into digital workflows, and resilient ethical models will be required.

Key words: Artificial intelligence, Restorative dentistry, Caries detection, Deep learning, Clinical accuracy, Prosthodontics.

Introduction

Artificial intelligence (AI) is an emerging field of computer science whose purpose is to enable machines to perform tasks that normally require human intelligence, such as perception, reasoning, and decision-making [1, 2]. Within AI, subsets of particular importance are machine learning (ML) (allowing systems to learn patterns from data); deep learning (DL) using multilayer artificial neural networks; convolutional neural networks (CNNs) which are well suited to interpreting radiographs and clinical images; and natural language processing (NLP) allowing interpretation of clinical notes and patient data [3, 4]. AI applications have been widely embraced in all dental specialties, such as diagnostics, imaging techniques, risk prediction, treatment planning, and individual treatments [5, 6]. AI has shown helpful in helping clinical decision-making in restorative dentistry, particularly in the area of caries identification, where DL and CNN models have been demonstrated to be just as accurate as clinicians, if not more so [7, 8]. Similarly, AI-based platforms have been developed for restoration design and finish line detection with precision margin identification and enhanced CAD/CAM workflow [9, 10]. Apart from design, AI is also being used to forecast restoration and implant failure, to help clinicians intervene early and plan treatments [11, 12].

In addition, recent clinical reviews and meta-analyses

further demonstrate that AI platforms improve diagnostic accuracy in detecting caries and pathologies associated with restorations, reduce chair-side time, and improve reproducibility [13-15]. Although performance is consistent, there is evidence of some variation in performance based on datasets, algorithms, and clinical settings when using AI tools [16, 17]. Some evidence highlights the importance of AI as a complement to clinical knowledge rather than a full substitute, to ensure ethical, safe, and patient-centred care [18, 19]. In spite of the increasing literature, no evidence about the accuracy and clinical implications of AI in restorative dentistry has been summarized. The literature available has focused on single studies (e.g., caries detection or finish line analysis) without contextualizing the findings into a wider clinical framework. As such, this narrative review seeks to address this gap by providing a synthesis of the recently emerging evidence (2019-2025) on the subject of AI in restorative dentistry by evaluating its diagnostic accuracy, restorative uses, and clinical effects [20-29].

Aims of the study

The primary goal of this narrative review is to explain how artificial intelligence (AI) will be used in the present and future to restore dentistry. Specifically, the review will be aimed at assessing the role of AI in diagnostic processes related to caries detection, margin, and restoration failure prediction [8, 9, 11]. Through the gathering of existing evidence, we wish to establish the clinical validity and

reliability of AI models when compared to traditional diagnostic and restorative approaches [16, 17]. Moreover, broader clinical implications of workflow optimality, decision support, and transition to clinical routine will be discussed within the framework of this review [4, 10]. Finally, the review also considers gaps where AI can help future research and technological development in bridging the gap between technology and patient-centred restorative care [6, 14].

Materials and Methods

This study was carried out as a narrative review due to its appropriateness as a method to synthesise a wide range of forms of evidence and provide a broad perspective on the clinical applications of artificial intelligence (AI) in restorative dentistry. A systematic literature search to find studies was performed in PubMed, Scopus, and Google Scholar, with searches restricted to publications in the period 2019 to 2025 to reflect the most recent advances [30-34].

The search strategy included the most relevant keywords such as "artificial intelligence," "deep learning," "machine learning," "caries detection," "restorative dentistry," "prosthodontics," "restoration failure prediction," "finish line detection," and "CAD/CAM". Studies were assessed for relevance by title and abstract, and full-text review was completed for those studies that seemed to discuss the role of AI in restorative dental practice [35-40].

Inclusion criteria were studies discussing AI applications in restorative dentistry including diagnostic areas (caries detection, caries classification, [7, 8, 12-14], restorative design (margins/finish line) [9, 10], CAD/CAM and prosthodontic applications [19]. Narrative reviews, systematic reviews, clinical studies and experimental trials were included if they were focused on AI in restorative contexts [1-4, 17].

Studies without any relation to the topic of dentistry, including orthodontics and radiology-only diagnostic applications without a restorative point of view, were excluded [5, 6, 18, 41].

Results and Discussion

To find relevant studies, a search was conducted that identified 20 relevant studies published between 2019 and 2025 that examined the use of artificial intelligence (AI) applications in restorative dentistry. Studies included were on caries detection and classification, finish line detection, restoration failure prediction, prosthodontic applications, and systematic and narrative reviews. The results are summarised in **Table 1**, and are further discussed below..

Caries detection and classification

Convolution neural networks (CNNs) as artificial intelligence (AI) models demonstrated a high diagnostic performance in the detection of caries. Gunece *et al.* (2023) compared CNN models to junior dentists and found that AI had a higher accuracy than junior dentists and can be used as a diagnostic aid in clinical practice [8]. Also, Ahmed *et al.* (2025) reported high sensitivity and specificity of radiograph-based AI analysis to detect and classify caries for early preventive treatment [7]. Meta-regression analyses of the studies also confirmed these findings: Luke and Rezallah reported pooled diagnostic accuracies of >85% which indicates high evidence for the incorporation of AI in routine caries detection [13, 42].

Finish line detection and restoration design

Two recent studies showed the value of AI in crown preparation. Mahrous (2025) reported that the accuracy of the AI algorithm for finishing line detection is reliable, and Sawangsri *et al.* (2025) compared the performance of AI-based CAD/CAM systems with that of a dental technician, and there were no differences in terms of accuracy of contour creation for restoration purposes [9, 10]. These results indicate AI could be used to decrease variability and increase accuracy in restorative workflows.

Restoration failure prediction

Zhang *et al.* (2023) used deep learning with radiographs and obtained the prediction accuracies of more than 80% for restoring failure [11], which illustrated the feasibility of prognostic evaluation using AI. Additionally, Erkul (2025) promoted the potential of AI to maximize long-term treatment planning and showed promising results in the application of AI for both margin identification and restoration failure prediction [12].

Prosthodontics

In the case of fixed prosthodontics, Lerner *et al.* (2020) tested an AI-assisted workflow in implant-supported zirconia crowns and found high survival rates with time efficiency compared to a conventional workflow [19]. All this highlights how AI is facilitating the prosthodontic workflow while ensuring clinical success.

General reviews and overviews

Larger reviews [1, 3] provided narrative and systematic overviews on AI in dentistry. Both reviews encompassed the exponential growth of the application of AI while acknowledging the limitations, such as diversity in data sets and requirements for standardization. These reviews provide necessary context for assessing progress and identifying gaps in restorative applications. Overall, the included studies provided consistent evidence that AI can be used to increase diagnostic accuracy and increase efficiency within the restorative workflow, as well as assist with clinical decision-making.

Table 1. AI Applications in Restorative Dentistry

Application	Study	Model/Method	Reported Accuracy	Clinical Implication
Caries detection	Güneç <i>et al.</i> (2023) [8]	CNN vs junior dentists	AI > clinicians	Faster and more reliable diagnostics
Caries classification	Ahmed <i>et al.</i> (2025) [7]	AI radiograph analysis	High sensitivity & specificity	Early detection & prevention
Systematic evidence	Luke and Rezallah (2025) [13]; Abbott <i>et al.</i> (2025) [14]	Meta-analysis	Pooled accuracy >85%	Strong evidence for clinical adoption
Finish line detection	Mahrous (2025) [9]; Sawangsri <i>et al.</i> (2025) [10]	AI-based CAD/CAM	Comparable to technicians	Improves restoration accuracy
Restoration failure	Zhang <i>et al.</i> (2023) [11]; Erkul (2025) [12]	Deep learning	>80% predictive accuracy	Supports decision-making
Prosthodontics (Zirconia)	Lerner <i>et al.</i> (2020) [19]	Retrospective	High survival rate	Time-efficient prosthesis fabrication
General reviews	Corbella <i>et al.</i> (2021) [1]; Ding <i>et al.</i> (2023) [3]	Narrative/Systematic	N/A	Overview of advances & gaps

AI in caries detection and classification

Caries detection is one of the most popular applications of artificial intelligence (AI) in restorative dentistry. Recent data suggests that AI models are capable of diagnosing disease with higher accuracy than clinicians, in particular, junior dentists. Guney Cimen, Fuseli, and Bercoglu (2023) demonstrated that CNNs were able to produce diagnostic performance equivalent to, if not better than, a less-experienced practitioner, suggesting that AI could be a welcome addition to clinical training and decision making. In addition, results have been further consolidated by systematic evidence from meta-analyses. Luke and Rezallah (2025) and Abbott *et al.* (2025) have [13, 14], on the other hand, published pooled diagnostic accuracies of over 85% across heterogeneous data, further reflecting the generalisability of the developed AI-based diagnostic systems across heterogeneous datasets. Other reviews have also highlighted the possibility of AI standardising the diagnosis process, removing inter-examiner variability and subjectivity. Overall, both articles [7, 18] were sensitive and specific in caries detection, which suggests that AI may be utilized to identify and prevent the initial stages of caries. Such clinically meaningful implications include increased patient outcomes due to the ability to intervene early, increased confidence in diagnoses, and reduced subjectivity in decision making, which subsequently can establish patient trust in restorative care.

AI in restorative margins and finishing line detection

One of the keys to restorative success, particularly with fixed prosthodontics, is margin detection, since errors may lead to microleakage, secondary caries, and premature failure. Traditionally, margin detection is very technician - and clinician - skill dependent. But recent technological advances seem to indicate that AI can reduce variability and increase accuracy. Mahrous (2025) proved that AI

models can be used to detect finishing lines with high accuracy [9], whereas Sawangsri *et al.* (2025) showed that the results from AI-based CAD/CAM systems are comparable to the results from skilled dental technicians [10]. These insights further solidify the important position AI plays in optimizing restorative workflows. AI-powered CAD/CAM integration reduces human error, standardizes margin detection, and shortens laboratory turnaround time. Clinically, this means better restoration fit, better longevity, and better efficiency for practitioners and laboratories.

Prediction of restoration failure

Beyond detection and design, AI has proved to be a useful tool in predicting restoration lifespan. Zhang *et al.* (2023) applied deep learning to radiographs and reported accuracies for restoration failure greater than 80%. Similar to Erkul (2025) [11, 12], AI was regarded as an aid to long-term treatment planning, where an important part of the development of AI is considered the prediction of restoration failures and margin detection. Clinicians can also use predictive models for restoration outcomes to proactively select restorative materials, identify patients at high risk of failure, and participate in preventive care. Such predictive modeling is consistent with evidence-based dentistry, which uses big data in clinical decision-making to reduce the percentage of treatment failures while increasing patient satisfaction.

Prosthodontics and implant-supported restorations

Even prosthodontics is not exempt, and where AI has been applied, it has been successfully utilized for implant-supported restorations. Lerner *et al.* (2020) reported that fixed implant prosthodontics workflow using AI-assisted virtual restoration design not only achieved high survival rates of zirconia crowns but also had better time efficiency

than conventional methods [19]. Additionally, implant survival prediction has been another potentially helpful application of survival analysis. All that has been mentioned points to the ground-breaking capabilities of AI within the context of the field of prosthodontics - optimization of work and reduction of costs, and a step toward a moment when the success of implants will no longer be a trade-off.

Accuracy vs. clinician performance

Other common themes running through the literature include the comparison between AI performance and performance by human clinicians. Gunece *et al.* (2023) showed the superiority of AI to junior dentists for caries detection, and Ahmed *et al.* (2025) reported diagnostic accuracies comparable to and better than those of practising clinicians [7]. However, even with these encouraging results, most authors would agree that AI cannot be considered as a substitute for clinical knowledge. Instead, its best place is as a support - to help dentists in diagnostics, design, and planning - while leaving the judgment and patient-centered care in the hands of the clinician [16, 17].

Challenges and ethical considerations

Despite significant advancements, there are still some challenges that are preventing the widespread clinical implementation of AI in restorative dentistry. One key limitation is that most studies are performed on single-centre or small-scale data [1, 2], which may not necessarily represent a representative sample of global diversity. Another argument made is that underrepresented populations will have lower accuracy due to bias in training data because biased samples exist. Further, implementation into clinical workflows is also slow due to the difficulty in learning for dentists, as well as the infrastructure requirements. There are also urgent ethical and regulatory risks (data security, medicolegal requirements, and algorithm explainability). Ding *et al.* (2023) and Semerci and Yardici (2024) noted that there are still medico-legal and regulatory issues to be resolved before adoption can be achieved and that patient privacy must be honored [3, 4].

Future perspectives

As mentioned by Luke and Rezallah (2025) and Abbott *et al.* (2025) [13, 14], large-scale multicentre validation trials are needed to ensure that the AI systems are reliable and generalisable to different populations and in different environments. Further, the combination of AI with digital dentistry from intraoral scanners, CAD/CAM systems, and even smart devices may streamline restorative workflows. Another promising avenue is the development of personalized AI models, which are trained on individual patient characteristics and can predict outcomes for specific patients. Pitchika *et al.* (2024) highlighted the possibility of personalized diagnostics using AI and suggested that similar models could be applied to

restorative care in order to tailor treatment planning at the individual level [5]. In conclusion, the results of this study show that AI is not only accurate but also clinically useful in restorative dentistry.

Conclusion

Artificial intelligence (AI) has been a disruptive technology in the area of restorative dentistry, demonstrating a high accuracy in caries detection, restoration margin determination, and restoration failure prediction. There is no denying the fact that AI systems have shown their potential to accelerate and enhance workflows, increase the accuracy of diagnoses, and assist clinicians in making evidence-based restorative treatment choices. These advances have clinical implications. It can be used to assist in reducing diagnostic variation, enhance CAD/CAM restorative processes, and contribute to long-term treatment planning using predictive modelling. Such improvements eventually lead to workflow efficiency, higher restoration reliability, and patient trust in therapy outcomes. Nonetheless, there are significant limitations. The ethical issues of AI are data privacy and transparency, and AI models are vulnerable to changes in the data set, which reduces their external validity. The barrier to routine integration in the dental practice has also been the delay in acceptance of the regulations. Because of these reasons, AI should not be viewed as a tool that replaces the clinician, but rather as an extension of his skills. In order to introduce this process into practice successfully and safely in the future, the immediate need is an appropriate validation on a larger multicenter, a stronger ethics code, and multidisciplinary cooperation. Under these kinds of protections, AI may be an effective ally in restorative dentistry, but not one that replaces clinical judgement without undermining the utilitarian ethos of care.

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