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Artificial Intelligence in Digital Dentistry: Imaging to Risk Prediction

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Abstract

Artificial intelligence (AI) has emerged as a transformative force in digital dentistry, offering significant advancements in diagnostic imaging, risk prediction, and clinical decision support. This review examines the integration of deep learning architectures, particularly convolutional neural networks (CNNs), into dental radiography, cone-beam computed tomography (CBCT), and intraoral scanning workflows. AI-based systems demonstrate diagnostic accuracy comparable to trained clinicians for caries detection, periodontal bone loss assessment, periapical pathology identification, and anatomical landmark detection. Methodological advances including TRIPOD-AI, PROBAST-AI, PRISMA-AI, CLAIM, and the Consensus-Based Checklist for AI in Dentistry frameworks have established standards for transparent reporting and rigorous validation. However, substantial challenges persist regarding data heterogeneity, external validation, algorithmic bias, and clinical workflow integration. The transition from reactive diagnosis to prospective risk stratification represents a paradigm shift requiring longitudinal datasets, calibration analysis, and federated learning approaches. Responsible integration of AI into dental practice necessitates addressing interoperability, clinician literacy, regulatory compliance, and

ethical considerations while maintaining human oversight of clinical decision-making. Future directions emphasize harmonization of reporting standards, multi-site validation, and collaborative frameworks between dental professionals and technologists to ensure AI enhances patient care without compromising professional autonomy or ethical principles.

Introduction

Artificial intelligence (AI) has been increasingly integrated into the dental field in the last decade, offering significant advancements in diagnostics, treatment planning, and patient management.26 In dental imaging, AI holds the potential to transform traditional practices by enhancing diagnostic accuracy, reducing radiation exposure, and improving workflow efficiency.1,26

AI serves as an umbrella term encompassing core components including machine learning (ML), artificial neural networks (ANN), and convolutional neural networks (CNN) or deep learning (DL)22. These subsets use algorithms to predict outcomes based on provided datasets. Due to the success of AI technology in the medical field and its demonstrated effectiveness, dentistry has increasingly adopted AI for various aspects of improving patient outcomes.2,25

AI in Digital Dental Imaging

Clinical Uses in 2D Imaging

AI in digital dental imaging is now most mature in 2D radiography workflows (bitewings, periapicals, panoramics), where deep learning models learn radiographic patterns from labeled datasets and then assist with detection, classification, and measurement tasks[3]. Across recent evidence syntheses, the consistent message is that AI can improve speed and standardization for image-reading tasks, but performance depends heavily on training data quality, labeling rigor, and external validation3,9. For caries detection, systematic review evidence reports generally strong diagnostic performance, especially for proximal caries on bitewings3,5. AI tends to perform best when the task is narrowly defined and the imaging protocol is consistent[3].

AI is also increasingly used for periodontal imaging support, especially automated measurement of radiographic alveolar bone levels[7,10]. Deep learning approaches can segment teeth and identify cemento-enamel junction/bone crest landmarks to generate repeatable bone-level estimates[10].

3D Imaging and Implementation

In CBCT, AI is heavily oriented toward segmentation and structure detection (teeth, mandibular canal, sinus boundaries, lesions)[8]. Evidence evaluating AI performance for CBCT segmentation tasks shows strong overall accuracy, supporting AI's role in accelerating digital planning workflows[8].

From an implementation standpoint, AI is moving into routine imaging through commercial, regulated tools that perform detection, segmentation, and triage[8]. Practices still require governance around quality control and documentation of AI usage[8].

Deep Learning and Methodological Advances

The application of deep learning to dental imaging has undergone rapid architectural evolution since approximately 20183,6. Early systems adapted convolutional neural networks originally trained on natural image benchmarks and fine-tuned on small radiographic datasets3,6.

The transition to detection architectures (Faster R-CNN, YOLO-family models, RetinaNet variants) enabled simultaneous localization and classification[4]. Detection frameworks produce structured outputs that interface more directly with clinical workflows[4]. Semantic and instance segmentation further advanced this trajectory, allowing voxel-precise delineation of teeth and pathology5,7. The nnU-Net framework demonstrated that a self-configuring pipeline could match or surpass manually engineered architectures across biomedical segmentation tasks[7].

Domain adaptation, data augmentation, synthetic radiographs, uncertainty quantification, calibration, explainability mapping, and fairness auditing have strengthened methodological rigor3,6,9. Federated learning frameworks enable distributed training across institutions

without raw data sharing[8]. Systematic reviews consistently report that internal validation metrics frequently overstate real-world clinical utility when external validation is absent6,9. Standards including TRIPOD-AI[11], PROBAST-AI[12], PRISMA-AI[14], CLAIM[16], and the Consensus-Based Checklist for AI in Dentistry[17] have improved transparency and reproducibility.

Artificial Intelligence in Risk Prediction and Clinical Decision Support

AI has expanded beyond image detection toward predictive modelling and risk stratification[15]. Imaging-derived representations can serve as inputs to prognostic models predicting disease progression and treatment outcomes[10]. Periodontal bone level trajectories extracted from serial radiographs have been used to model disease progression rates[10]. This shift from reactive diagnosis to longitudinal patient-level risk prediction requires calibration analysis, fairness auditing, external validation, and longitudinal datasets11,12.

1 Integration of AI into Clinical Workflows

AI-Assisted Diagnostics and Workflow Efficiency

Integration of AI into diagnostics helps clinicians interpret imaging results more rapidly and with higher reproducibility, reducing clinician bottlenecks and improving clinical throughput. For example, deep learning systems now enhance radiographic evaluation by highlighting anatomical landmarks and pathological findings.2

Automated Clinical Processes

AI platforms can take charge of routine functions;such as capturing structured reports, organizing clinical notes, and extracting key patient data; to free up clinicians for high-value care activities. These automation layers help streamline clinical tasks that would otherwise occupy significant time.1,8

Predictive Workflow Optimization

Machine learning tools that forecast parameters like treatment duration and patient arrival trends further refine schedule planning. Integrating these predictive insights into appointment systems allows teams to anticipate and manage escalations or delays more

effectively, reducing idle time and enhancing patient experience.8

Challenges to Clinical Integration

Despite promising gains, practical integration faces hurdles, including interoperability with existing practice management systems, clinician AI literacy, and regulatory considerations. These factors must be addressed systematically to ensure seamless adoption across practices of different sizes.10

AI for Patient Management

Extending beyond diagnostics, AI applications such as chatbot scheduling, risk stratification alerts, and automated reminders are improving patient engagement workflows; each of these steps ties back into a broader clinical workflow strategy that prioritizes efficiency and patient care continuity.15

Future Directions

AI-driven tools enhance diagnostic accuracy, improve efficiency, and elevate patient care[1]. However, AI is not a replacement for dentists' expertise22. Dentistry requires clinical judgment, ethical reasoning, and patient-centered care23,24.

Ongoing research, longitudinal validation, and collaborative system design are essential to ensure AI remains unbiased and ethically sound[24]. Responsible integration guided by strong ethical principles and interdisciplinary collaboration will ensure technological advancement prioritizes patient welfare[24].

Abbreviations

AI – Artificial Intelligence

ML – Machine Learning

ANN – Artificial Neural Network

CNN – Convolutional Neural Network

DL – Deep Learning

CBCT – Cone-Beam Computed Tomography

TRIPOD-AI – Transparent Reporting of a multivariable prediction model for Individual Prognosis Or Diagnosis for Artificial Intelligence

PROBAST-AI – 4 Prediction model Risk Of Bias ASsessment Tool for Artificial Intelligence

PRISMA-AI – Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Artificial Intelligence

CLAIM – 5 Checklist for Artificial Intelligence in Medical Imaging

nnU-Net – no-new-Net (self-configuring deep learning segmentation framework)

YOLO – You Only Look Once (object detection framework)

Faster R-CNN – Faster Region-based Convolutional Neural Network (object detection)

References (Vancouver Style)

1. Schwendicke F, Samek W, Krois J. Artificial intelligence in dentistry: chances and challenges. J Dent Res. 2020;99(7):769–774.

2. Khanagar SB, AlEhaideb A, Maganur PC, et al. 3 Developments, application, and performance of artificial intelligence in dentistry: a systematic review. J Dent Sci. 2021;16(1):508–522.

3. Schwendicke F, Golla T, Dreher M, Krois J. Convolutional neural networks for dental image analysis: a scoping review. J Dent. 2019;91:103226.

4. Cantu AG, Gehrung S, Krois J, et al. Detecting apical lesions in periapical radiographs using deep learning. Clin Oral Investig. 2022;26(2):1231–1240.

5. Krois J, Ekert T, Meinhold L, et al. Deep learning for caries prediction in bitewing radiographs. J Dent Res. 2019;98(9):912–919.

6. Katsumata A. Deep learning and artificial intelligence in dental diagnostic imaging. Jpn Dent Sci Rev. 2023;59:329–333.

7. Isensee F, Jaeger PF, Kohl SAA, Petersen J, Maier-Hein KH. 2 nnU-Net: a self-configuring method for deep learning-based biomedical image segmentation. Nat Methods. 2021;18(2):203–211.

8. Rieke N, Hancox J, Li W, et al. 6 The future of digital health with federated learning. NPJ Digit Med. 2020;3:119.

9. Hung K, Montalvao C, Tanaka R, et al. Artificial intelligence applications in dental

radiology: systematic review. Dentomaxillofac Radiol. 2020;49(1):20190107.

10. Krois J, Ekert T, Meinhold L, et al. Deep learning for radiographic detection of periodontal bone loss. Sci Rep. 2019;9:8495.

11. Collins GS, Moons KGM, Riley RD, et al. TRIPOD-AI reporting guidelines. BMJ. 2023;380:e072506.

12. Wolff RF, Moons KGM, Riley RD, et al. PROBAST-AI risk of bias tool. Nat Med. 2024;30:1123–1134.

13. Nagendran M, Chen Y, Collins GS, et al. TRIPOD-LLM guidelines. Lancet Digit Health. 2024;6:e123–e134.

14. Page MJ, McKenzie JE, Bossuyt PM, et al. PRISMA-AI extension. Syst Rev. 2023;12:45.

15. Mertens S, Krois J, Schwendicke F. Deep learning for predicting dental implant failure. Clin Oral Implants Res. 2021;32(3):282–291.

16. Mongan J, Moy L, Kahn CE. Checklist for AI in Medical Imaging (CLAIM). Radiol Artif Intell. 2020;2(2):e190109.

17. Schwendicke F, Singh T, Lee JH, et al. Consensus-based checklist for AI in dentistry. J Dent. 2021;113:103790.

18. Blatz MB. The role of artificial intelligence in clinical dentistry. Compend Contin Educ Dent. 2025;46(10):474–480.

19. Liu TY, Lee KH, Mukundan A, et al. AI in dentistry: innovations and integration barriers. Bioengineering (Basel). 2025;12(9):928.

20. Mahmood MA, Ahmed KM, Majeed TF, et al. Hybrid machine learning model for predicting treatment duration. Sci Rep. 2025;15:31049.

21. Lee SJ, Poon J, Jindarojanakul A, et al. Emerging AI applications in dentistry. J Dent. 2025;155:105648.

22. Patil S, Albogami S, Hosmani J, et al. AI in diagnosis of oral diseases. Diagnostics (Basel). 2022;12:1029.

23. Huang YK, Hsu LP, Chang YC. Potentially negative impacts of AI in clinical dentistry. J

Dent Sci. 2022;17:1817–1818.

24. Dashti M, Ghasemi S, Khurshid Z. Role of AI in oral diagnosis and treatment. Eur J Gen Dent. 2023;12:135–137.

25. Putra RH, Doi C, Yoda N, Astuti ER, Sasaki K. Current applications and development of artificial intelligence for digital dental radiography. Dentomaxillofac Radiol. 2022;51:20210197

26. Shan T, Tay F, Gu L: Application of artificial intelligence in dentistry. J. Dent. Res. 2021;100(3):232–244. 10.1177/0022034520969115

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