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Narrative Review

Artificial intelligence in predictive, personalized, and regenerative endodontics: A narrative review of emerging paradigms

Rhythm Bains[1], Nishi Singh[1], Nagendra Pratap Singh[2]

[1]Department of Conservative Dentistry & Endodontics, King George's Medical University, Lucknow, Uttar Pradesh, [2]Department of CSE, Dr B R Ambedkar National Institute of Technology, Jalandhar, Panjab, India.

ABSTRACT

Artificial intelligence (AI) is revolutionizing contemporary endodontics by enabling data-driven precision, predictive accuracy, and biologically oriented regenerative care. This narrative review explores the expanding role of AI across predictive prognosis, personalized treatment planning, and regenerative endodontics. In predictive endodontics, AI-powered algorithms—especially those based on machine learning and deep learning—are enhancing diagnostic accuracy, radiographic interpretation, and outcome prediction by integrating clinical, radiographic, and biological datasets. Predictive learning models can identify risk factors for endodontic failure, estimate periapical healing trajectories, and aid clinicians in making evidence-based decisions.

In the realm of personalized endodontics, AI facilitates individualized treatment strategies by analyzing patient-specific data, including pulp vitality, microbial profiles, and systemic health parameters. Such precision-based approaches enable clinicians to move beyond conventional "one-size-fits-all" protocols, optimizing therapeutic choices, including instrumentation techniques, obturation methods, and material selection, to suit individual patient biology. AI-integrated chairside decision support systems further refine patient management through real-time analytics and predictive feedback loops.

Regenerative endodontics, which seeks to restore the vitality and function of the pulp-dentin complex, stands to benefit immensely from AI applications. Machine learning models are being used to identify optimal scaffold designs, predict cellular responses, and simulate outcomes of regenerative procedures. Integrating AI with bioinformatics and stem cell research can accelerate the development of biologically responsive materials and treatment protocols for proper tissue regeneration.

This review emphasizes that AI-driven predictive analytics and personalized regenerative strategies collectively signify a paradigm shift in endodontic care—from empirical to intelligent, from reactive to proactive. As AI becomes increasingly embedded within digital workflows, the synergy between computational intelligence and biological understanding promises to transform the scope and precision of endodontic therapy in the near future.

Keywords: Artificial intelligence, Deep learning, Machine learning, Predictive learning models, Regenerative endodontics

INTRODUCTION

Artificial intelligence (AI) has rapidly emerged as a transformative force across healthcare, including dentistry, where it is reshaping diagnostic precision, treatment planning, and prognostic evaluation [Table 1]. In endodontics, the integration of AI—particularly through machine learning (ML), deep learning (DL), and neural network models—has enabled clinicians to harness complex datasets derived from clinical, radiographic, and biological sources, thereby enhancing decision-making accuracy and efficiency.[1,2] By simulating human cognitive processes such as learning, reasoning, and problem-solving, AI systems are capable of interpreting imaging data, predicting treatment outcomes, and personalizing patient care in ways that surpass traditional analytical methods.[3]

***Corresponding author:** Nishi Singh, Conservative Dentistry & Endodontics, King George's Medical University, Lucknow, Uttar Pradesh, India. drnishisingh@kgmcindia.edu

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Table 1: Commercial AI tools in dentistry/endodontics

AI Tool / Platform	Primary function in endodontics/dentistry	Notes / Key features
Diagnocat AI (Diagnocat Inc., USA)	Automatic detection of periapical lesions, root canal anatomy segmentation, and caries detection on panoramic and CBCT images	Cloud-based platform; integrates with PACS ; provides automated report generation and lesion labeling
Overjet dental AI (Overjet Inc., USA)	Detection and quantification of caries, periapical lesions, and restorations on radiographs	Works on bitewing and periapical images; provides risk scoring and reporting for clinical decision support
VideaHealth / VideaAI dental platform	Lesion detection, root morphology assessment, and risk scoring	Supports both intraoral and CBCT images; research partnerships with academic dental institutions
Pearl AI (Pearl Inc., USA)	Caries and periapical pathology detection: clinical decision support	AI-assisted workflow integration for general dentists; automates annotations and risk reports
Dental monitoring AI Only orthodontics	Patient data integration, personalized treatment planning, and decision support	Includes predictive analytics for risk stratification; early clinical adoption in research settings
3D Endo software	3D CBCT segmentation of root canal systems and periapical lesions	Used primarily in academic studies; integrates DL models for endodontic planning
Dental segmenter extension	CBCT image segmentation, lesion classification, and canal tracing	Open-source academic software; applied in multiple endodontic imaging studies
RegenHU / CELLINK Bio X™	AI-assisted 3D bioprinting for regenerative endodontics scaffolds	AI guides scaffold architecture optimization; primarily preclinical/regenerative research

AI: Artificial intelligence, CBCT: Cone-beam computed tomography PACS: Picture archiving and communication systems, DL: Deep learning

Predictive analytics, powered by AI, provide clinicians with tools to assess endodontic prognosis and caries risk by analyzing radiographs, cone-beam computed tomography (CBCT) scans, and patient records to detect subtle patterns indicative of disease progression or potential for healing.[4] These technologies not only assist in early diagnosis but also enable risk stratification and outcome prediction, leading to proactive and minimally invasive management strategies.[5] In parallel, personalized endodontics represents a paradigm shift from conventional standardized protocols toward individualized, data-driven care. AI enables customization of treatment modalities by integrating patient-specific parameters—such as pulpal status, microbiome characteristics, and systemic health indicators—into algorithmic models for clinical decision support.[6]

Furthermore, the advent of AI-assisted regenerative endodontics marks a frontier where biological science converges with computational intelligence. AI algorithms facilitate the optimization of scaffold architecture, the prediction of stem cell behavior, and the mapping of molecular pathways to accelerate the regeneration of the pulp-dentin complex.[7,8]

Collectively, AI-driven technologies promise to redefine the landscape of endodontic practice by promoting precision, predictability, and biological integration.[9]

Unlike previous reviews, which describe AI models in general terms, this review focuses on the function-oriented synthesis of AI models in endodontics. This narrative review aims to synthesize current evidence on the applications of AI models in predictive prognosis, personalized treatment, and regenerative endodontics.

METHODOLOGY

This narrative review was conducted to collate literature on the applications of AI in predictive prognosis, personalized treatment, and regenerative endodontics. A structured literature search was performed across major electronic databases, including PubMed, Scopus, Web of Science, and Google Scholar, for articles published between 2010 and 2025. The search terms included combinations of "artificial intelligence," "machine learning," "deep learning," "predictive analytics," "personalized endodontics," and "regenerative endodontics."

Studies were screened for relevance to endodontic diagnostics, prognosis prediction, individualized treatment planning, and regenerative applications involving AI-based tools or algorithms. Both experimental and review articles were included; non-English language papers were excluded. The selected studies were thematically analyzed under three main domains namely: (1) AI in Predictive Prognosis – including diagnostic imaging, outcome prediction, and risk assessment models, (2) AI in Personalized Endodontic Care – focusing on individualized treatment planning and decision-support systems and (3) AI in Regenerative Endodontics – addressing biomaterial optimization, cellular modeling, and tissue engineering applications.

Findings were synthesized qualitatively to highlight emerging trends, current limitations, and future research directions. Emphasis was placed on translational potential and integration of AI into clinical endodontic workflows.

AI in predictive prognosis

AI has emerged as a transformative tool in predictive prognosis and treatment planning within endodontics and caries management. ML and DL algorithms are capable of analyzing large volumes of clinical and radiographic data to identify subtle patterns that are often imperceptible to human clinicians. In endodontics, AI-assisted diagnostic systems have demonstrated superior performance in detecting periapical lesions and vertical root fractures on CBCT and periapical radiographs.[10,11] According to a recent systematic review, the accuracy of AI for detecting vertical root fractures ranges from 73.6% to 96.6%, and the accuracy of AI applied over CBCT data is even higher in the case of untreated root canals. However, when it comes to detecting root fractures in instances of obturated root canals, AI applications significantly outperform traditional radiographs.[12]

Failure to locate canals during endodontic treatment is one of the most common causes of endodontic treatment failure.[13] It is estimated that 93% of all missed canals are located on the maxillary first molars, and 44% on the maxillary second molars.[14,15] Convolutional neural networks (CNNs) can classify tooth and root canal morphologies with remarkable accuracy, thereby enhancing preoperative assessment and case selection.[16] Albitar *et al*.[17] Conducted a study to develop a deep learning model to automatically detect and segment unobturated mesial buccal 2 (MB2) canals on endodontically obturated maxillary molars depicted in CBCT studies. The scans were de-identified, and selected CBCT scans were imported into the image segmentation software ITK-SNAP. They concluded that the AI algorithm had the potential to identify both obturated and unobturated canals in endodontically treated teeth; however, it was still somewhat affected by metallic artifacts, variations in canal calcifications, and the applied configuration. In a recent narrative review, Ahmed *et al*. discussed the AI applications in the study of root and canal anatomy, and also highlighted that a significant challenge is the lack of larger datasets to provide more accurate deep learning models.[18]

Predictive analytics in endodontics enable the estimation of treatment outcomes by integrating patient-specific data such as lesion size, systemic conditions, and procedural variables. For instance, models based on artificial neural networks (ANNs) have been shown to predict root canal treatment success rates and postoperative pain outcomes with high reliability. ANN is a system that imitates the human brain's structure and function, enabling the analysis of complex relationships between various predictors.[19] Gao *et al*.[20] Conducted a study to evaluate the accuracy of the back propagation (BP) artificial neural network model for predicting postoperative pain following root canal treatment, and it yielded an accuracy of 95.60% for the prediction of postoperative pain following RCT.

In caries management, AI-driven systems analyze intraoral images to quantify lesion activity and caries risk, facilitating minimally invasive and preventive care. AI-based Dental caries risk assessment tools can predict the chances of developing new carious lesions within a specified time frame, as well as the probability of changes in the size or activity of existing lesions.[21] This approach not only helps prepare specific preventive measures for high-risk individuals but also identifies low-risk patients to avoid unnecessary restorations and surgical intervention. Presently, three AI-based techniques have been proposed for caries detection. These include image-based caries detection using AI, AI-assisted caries-risk assessment, and the Integration of AI with Computer-Aided Diagnosis (CAD) systems.[22] In a recent systematic review and meta-analysis, Abbott *et al*.[23] assessed AI platforms, machine learning methodologies, and associated accuracies used in detecting dental caries from clinical images and dental radiographs. Based on the evidence synthesized, they concluded that AI had superior sensitivity and equal specificity in detecting dental caries from clinical images compared to bitewing radiography. As datasets expand and algorithms evolve, predictive AI models are expected to become indispensable in risk-based endodontic and caries management strategies.

Lee *et al*.[24] conducted a study to establish an effective artificial intelligence (AI)-based module for accurate tooth prognosis decisions, based on the Harvard School of Dental Medicine's comprehensive treatment planning curriculum. This tooth prognosis AI scoring tool integrated parameters such as lesion size, root morphology, and systemic health to predict the likelihood of treatment success. They concluded that an AI-based machine-learning algorithm can be a helpful tool to determine tooth prognosis in consideration of the treatment plan. Similarly, in a study by Kazimierczak *et al*.[25] the authors evaluated the diagnostic performance of Diagnocat (Diagnocat Ltd., San Francisco, CA, USA) for assessing endodontic treatment outcomes using panoramic radiographs Such predictive tools promote data-informed decision-making and enhance patient communication.

AI in personalized endodontic care

AI enables a paradigm shift from standardized to personalized endodontic therapy by leveraging patient-specific biological, radiographic, and procedural data. Personalized endodontic care involves tailoring treatment modalities to the unique pulpal and periapical microenvironment of each patient.[26] Machine learning algorithms integrate variables such as tooth anatomy, systemic comorbidities, microbial diversity, and genetic markers to determine individualized treatment protocols.[27] Genomics in dentistry is used to assess genetic predisposition to oral diseases. Genetic testing can identify patients who may be at higher risk for dental caries due to genetic factors that influence enamel strength or saliva composition.[28] By integrating clinical databases with patient genomics and biomarker profiles, AI contributes to the emerging field of precision endodontics, aligning treatment decisions with individual biological responses.[29] Such approaches enhance therapeutic predictability and patient satisfaction, supporting a more personalized and outcome-oriented model of dental care.

Furthermore, AI-assisted decision support systems enable risk stratification, allowing clinicians to take a patient-need-based approach to individualized patient care and prognoses.[30] The integration of predictive analytics into electronic dental records could facilitate continuous learning models that refine prognostic accuracy over time. Predictive learning models also aid clinicians in determining the prognosis of retreatment or regenerative procedures for specific cases, thereby minimizing overtreatment or procedural errors. Furthermore, real-time AI-powered chairside systems can interpret intraoperative data—such as working length measurements or canal curvatures—to dynamically adjust treatment strategies in real-time.[31] The integration of AI into clinical decision support systems (CDSS) is advancing precision treatment planning by suggesting appropriate instrumentation techniques, irrigants, and obturation protocols tailored to each case.[32]

AI in regenerative endodontics

Regenerative endodontics seeks to restore the natural function and vitality of the pulp-dentin complex through biological regeneration rather than replacement. AI technologies are playing an increasingly crucial role in this domain by optimizing scaffold design, modeling cellular behavior, and selecting growth factors.[33] Deep learning algorithms simulate stem cell proliferation, differentiation, and signaling responses under various biological conditions, enabling the prediction of the most favorable regenerative outcomes. Additionally, AI models can analyze gene expression data and predict the conditions for differentiating mesenchymal stem cells (MSCs) into odontoblast-like cells.[34] AI-driven bioinformatics tools analyze gene expression data to identify key molecular pathways involved in the regeneration of dentin and pulp. Computational modeling aids in designing biomimetic scaffolds with optimal porosity, mechanical strength, and degradation profiles, thereby enhancing tissue regeneration.[35]

Moreover, AI aids in digital multifactorial analysis to assess regenerative success, providing objective and reproducible measures of tissue healing.[36] It integrates patient demographic data, medical and dental histories, radiographic and microbiological profiles, and treatment protocols. The integration of AI into regenerative endodontics represents a paradigm shift in how clinicians select cases, predict outcomes, and plan treatments. Currently, regenerative endodontic procedures are unpredictable due to the complex interplay of various biological, patient-specific, and procedural variables.[36] AI has also shown promising results in automatically scoring periapical healing, root maturation, and dentinal wall thickening, key indices of regenerative success. These findings suggest that AI may become a crucial tool in standardizing prognostic assessments and reducing subjectivity within conventional methods. For clinicians, AI-informed predictions can improve case selection and treatment planning efficiency. The integration of AI with nanotechnology and 3D bioprinting further accelerates the development of intelligent biomaterials and patient-specific regenerative therapies.[35] The convergence of AI with regenerative biology represents the next frontier in endodontic innovation, promising to redefine treatment success from mere symptom resolution to functional biological restoration.

Challenges & limitations

AI-based predictive learning models in endodontics rely heavily on the quality and diversity of training datasets. Most existing datasets are limited in size, region-specific, or lack standardized labeling, which restricts the generalizability of algorithms across diverse patient populations.[18] Image-based AI tools trained on CBCT or radiographic data may misinterpret artifacts or variations in imaging protocols, leading to false predictions.[37] Additionally, outcome prediction models often utilize retrospective data with incomplete clinical variables, which limits their ability to account for complex biological and procedural interactions that influence endodontic success.[38] Integration of AI into chairside practice also requires sophisticated infrastructure, data management systems, and clinician training—factors that are often lacking in clinical settings.[39]

Personalized endodontics demands the integration of multi-dimensional data—including radiographic, clinical, genomic, and microbiological inputs—into cohesive AI frameworks. However, such data fusion remains challenging due to inconsistent data formats and limited interoperability among dental software systems.[40] Ethical concerns related

Table 2: AI tools used in predive, personalized, and regenerative endodontics

AI Tool / Model	Primary function	Domain of application	Commercial / Research platform / Software	Uses of AI models
CNNs	Detection and segmentation of periapical lesions, root morphology, and canal anatomy from radiographs or CBCT images.	Diagnosis / predictive analysis	Diagnocat AI (Diagnocat Inc., USA); VideaAI Dental Platform (VideaHealth, USA); Overjet Dental AI (Overjet Inc., USA)	CNNs are ideal for the extraction of visual features in diagnostic imaging. So they help in the diagnosis of root canal anatomy and the accurate detection of periapical lesions.
Deep learning (U-Net, ResNet, DenseNet variants)	Image classification, root canal identification, and outcome prediction from 2D/3D data.	Diagnosis / predictive prognosis	Dental Segmentor. 3D Endo software	U-Net used for image segmentations, ResNet for deep learning, and Densenet for data transfer. These models enhance canal tracing treatment predications and treatment outcomes.
Machine learning models	Prognosis prediction, success/failure modeling, and retreatment risk estimation based on clinical variables.	Predictive analysis	SVM, Random forest, XGBoost	Machine learning models analyze non-image data applications, demographics & clinical parameters to identify predictive factors for treatment success.
ANNs	Predicting pulpal status, canal complexity, and treatment outcomes using multi-parametric data.	Predictive/ diagnostic	MATLAB Deep learning Toolbox	ANNs help in multifactorial diagnosis and prognostic predictions in endodontics by mimicking the human brain.
Radiomics and texture analysis (AI-driven)	Quantitative image feature extraction from CBCT for differentiating cystic vs granulomatous lesions.	Diagnosis / Predictive	PyRadiomics, 3D slicer MIM maestro commercial radiomics-enabled imaging analysis tool	Radiomics interprets lesion types to improve diagnostic precision by converting images into quantifiable data and extracting subtle texture and intensity patterns.
NLP and decision-support systems	Integration of patient data, history, and imaging into personalized treatment recommendations.	Personalized endodontics	Dentognostics AI dental monitoringAI	NLP analyzes clinical & patient data. NLP with a decision support system provides a personalized treatment plan and patient-specific care.
Predictive analytics platforms (Clinical data mining)	Risk stratification and patient-specific prognosis prediction using integrated clinical datasets.	Personalized and predictive	DataRobot AI Cloud, H2O.ai, Google AutoML	Predictive analytics platforms predict risks and outcomes, supporting personalized endodontic care.
Reinforcement Learning Model	Simulation-based learning.	Personalized endodontics / Workflow optimization	Unity ML-agents toolkit	These models can optimize clinical workflows, simulate procedural steps, and support experiential learning environments for students and practitioners.
GANs	Synthetic data generation for CBCT augmentation and scaffold microarchitecture simulation.	Regenerative endodontics	StarGAN	GANs applied to simulate biomaterial microstructures in regenerative studies, aiding innovation where real data are scarce.
Computational AI modelling (Predictive bioengineering)	Predicting stem cell differentiation, biomaterial behavior, and regenerative potential.	Regenerative endodontics	COMSOL multiphysics Sim4Life (ZMT Zurich MedTech) BioSPICE (bioinformatics simulation platform)	Computational AI models support the design and optimization of regenerative endodontic therapies and biomaterial selection by simulating biological and material responses under various conditions.
AI-integrated 3D bioprinting software	Designing scaffolds for pulp–dentin complex regeneration with optimized microstructure.	Regenerative endodontics	BioCAD, RegenHU 3DDiscovery™, CELLINK Bio X™ with AI-assisted printing algorithms	AI-Integrated 3D bioprinting software helps in the fabrication of a scaffold with optimized geometry, porosity, and material distribution in regenerative endodontics and biomaterial research.

CNNs: Convolutional neural networks, CBCT: Cone-beam computed tomography, ANNs: Artificial neural networks, NLP: Natural language processing, GANs: Generative adversarial networks to data sharing, patient consent, and cybersecurity further complicate the implementation of large-scale initiatives.[41] Another major limitation is the "black box" nature of deep learning algorithms, which makes it difficult for clinicians to interpret how AI arrives at specific recommendations, thereby reducing clinical trust and accountability.[42] Moreover, AI models may perpetuate diagnostic bias if trained on non-representative datasets, potentially compromising treatment equity across populations.[43]

In regenerative endodontics, AI applications are still in a research phase. Challenges arise in translating in-silico predictions of scaffold design, stem cell behavior, or molecular signaling into reproducible biological outcomes. Current computational models often simplify complex biological systems, limiting their predictive accuracy in real-world regenerative environments.[7] Additionally, high costs of computational modeling, lack of standardized validation frameworks, and limited interdisciplinary collaboration between AI scientists and dental biologists hinder progress. Regulatory and ethical oversight for AI-guided tissue engineering remains underdeveloped, posing barriers to clinical translation.

Overall, while AI offers significant promise in enhancing predictive, personalized, and regenerative endodontics, its potential is constrained by issues of data quality, algorithm transparency, ethical governance, and translational validation. Overcoming these limitations will require standardized data-sharing protocols, explainable AI models, regulatory clarity, and multidisciplinary collaboration to ensure that AI augments rather than replaces clinical expertise in endodontic care. Table 2 summarizes the AI tools used in predictive, personalized, and regenerative endodontics.

Conclusion & future scope

AI is progressively redefining endodontic science by integrating data-driven precision with biologically grounded treatment approaches. Through predictive analytics, AI facilitates accurate diagnosis, outcome prediction, and risk assessment in both endodontic and caries management, enabling clinicians to adopt proactive and minimally invasive strategies. Its role in personalized endodontic care enhances decision-making by incorporating patient-specific variables such as pulpal status, systemic factors, and radiographic features, thereby advancing the concept of precision dentistry.[3] In regenerative endodontics, AI contributes to optimizing biomaterial design, predicting cellular responses, and personalizing regenerative protocols, thereby accelerating progress toward the regeneration of a functional pulp-dentin complex.

Despite these advancements, several challenges remain before AI can achieve full clinical integration. Data heterogeneity, lack of standardized datasets, ethical considerations regarding patient privacy, and the need for regulatory validation hinder large-scale adoption. Additionally, AI algorithms must be trained on diverse populations to ensure clinical applicability and avoid bias. Bridging the gap between computational models and clinical translation will require interdisciplinary collaboration among dental clinicians, bioengineers, and data scientists.

The future of AI in endodontics lies in the development of integrated clinical decision support systems that can perform real-time analytics, image-guided therapy, and outcome prediction. The fusion of AI with digital workflows, augmented reality, and 3D bioprinting is likely to yield intelligent, patient-specific treatment paradigms. Moreover, advances in explainable AI (XAI) will enhance clinician trust and accountability by making algorithmic decisions transparent and interpretable.

In essence, AI-driven predictive, personalized, and regenerative endodontics represent not merely technological augmentation but a paradigm shift toward truly intelligent dental therapeutics. As evidence matures, AI will become an indispensable ally in achieving precision, predictability, and biological restoration in endodontic care.

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REFERENCES

1. Schwendicke F, Samek W, Krois J. Artificial intelligence in dentistry: chances and challenges. J Dent Res. 2020;99:769–74. doi: 10.1177/0022034520915714.
2. Bajwa J, Munir U, Nori A, Williams B. Artificial intelligence in healthcare: transforming the practice of medicine. Future Healthc J. 2021;8:e188–e194. doi: 10.7861/fhj.2021-0095.
3. Quinn TP, Senadeera M, Jacobs S, Coghlan S, Le V. Trust and medical AI: the challenges we face and the expertise needed to overcome them. J Am Med Inform Assoc. 2021;28:890–4. doi:

10.1093/jamia/ocaa268.
4. Jadhav S, Warke PS, Joshi S, Netto G, Gore S. Predictive analytics in endodontics: machine learning approaches for treatment success and failure prediction. In: 2025 5th International Conference on Expert Clouds and Applications (ICOECA). 2025. p. 865–71.
5. Dixon D, Sattar H, Moros N, Kesireddy SR, Ahsan H, Lakkimsetti M, *et al*. Unveiling the influence of AI predictive analytics on patient outcomes: A comprehensive narrative review. Cureus. 2024;16:e59954. doi: 10.7759/cureus.59954.
6. Harun D, Mazumder M, Shikder D, Karim D, Hera D. Predictive machine learning models for necessity of supplemental anesthesia in endodontic treatment. Med Res Arch. 2024;12(4). doi:10.18103/mra.v12i4.5296
7. Saberian E, Jenča A, Jenča A, Zare-Zardini H, Araghi M, Petrášová A, *et al*. Applications of artificial intelligence in regenerative dentistry: promoting stem cell therapy and scaffold development. Front Cell Dev Biol. 2024;12:1497457. doi: 10.3389/fcell.2024.1497457.
8. Mackay BS, Marshall K, Grant-Jacob JA, Kanczler J, Eason RW, Oreffo ROC, *et al*. The future of bone regeneration: integrating AI into tissue engineering. Biomed Phys Eng Express. 2021;7:052002. doi: 10.1088/2057-1976/ac154f.
9. Fukuda M, Inamoto K, Shibata N, Ariji Y, Yanashita Y, Kutsuna S, *et al*. Evaluation of an artificial intelligence system for detecting vertical root fracture on panoramic radiography. Oral Radiol. 2019;36:337–43. doi: 10.1007/s11282-019-00409-x.
10. Surlari Z, Budală DG, Lupu CI, Stelea CG, Butnaru OM, Luchian I. Current progress and challenges of using artificial intelligence in clinical dentistry—A narrative review. J Clin Med. 2023;12:7378. doi: 10.3390/jcm12237378.
11. Kositbowornchai S, Plermkamon S, Tangkosol T. Performance of an artificial neural network for vertical root fracture detection: an ex vivo study. Dent Traumatol. 2013;29:151–5. doi: 10.1111/j.1600-9657.2012.01148.x.
12. Karobari MI, Adil AH, Basheer SN, Murugesan S, Savadamoorthi KS, Mustafa M, *et al*. Evaluation of the diagnostic and prognostic accuracy of artificial intelligence in endodontic dentistry: a comprehensive review of literature. Comput Math Methods Med. 2023;2023:7049360. doi: 10.1155/2023/7049360.
13. Tabassum S, Khan FR. Failure of endodontic treatment: the usual suspects. Eur J Dent. 2016;10:144–7. doi: 10.4103/1305-7456.175682.
14. Carmo WDD, Verner FS, Aguiar LM, Visconti MA, Ferreira MD, Lacerda MFLS, *et al*. Missed canals in endodontically treated maxillary molars of a Brazilian subpopulation: prevalence and association with periapical lesion using cone-beam computed tomography. Clin Oral Investig. 2021;25:2317–23. doi: 10.1007/s00784-020-03554-4.
15. Wolcott J, Ishley D, Kennedy W, Johnson S, Minnich S, Meyers J. A 5-year clinical investigation of second mesiobuccal canals in endodontically treated and retreated maxillary molars. J Endod. 2005;31:262–4. doi: 10.1097/01.don.0000140581.38492.8b.
16. Musri N, Christie B, Ichwan SJA, Cahyanto A. Deep learning convolutional neural network algorithms for the early detection and diagnosis of dental caries on periapical radiographs: a systematic review. Imaging Sci Dent. 2021;51:237. doi: 10.5624/isd.20210074.
17. Albitar L, Zhao T, Huang C, Mahdian M. Artificial intelligence (AI) for detection and localization of unobturated second mesial buccal (MB2) canals in cone-beam computed tomography (CBCT). Diagnostics (Basel). 2022;12:3214. doi: 10.3390/diagnostics12123214.
18. Ahmed HMA, Al-Maswary A, Habaebi M, Tasdelen A, Al Husaini MA, Elnawawy H, *et al*. Artificial intelligence in the study of root and canal anatomy: a comprehensive review on applications, advantages, challenges, and future directions. Eur Endod J. 2025;10:343–64. doi: 10.14744/eej.2025.37232.
19. Han HG, Wang LD, Qiao JF. Efficient self-organizing multilayer neural network for nonlinear system modeling. Neural Netw. 2013;43:22–32. doi: 10.1016/j.neunet.2013.01.015.
20. Gao X, Xin X, Li Z, Zhang W. Predicting postoperative pain following root canal treatment by using artificial neural network evaluation. Sci Rep. 2021;11:17243. doi: 10.1038/s41598-021-96777-8.
21. Zhang JW, Fan J, Zhao FB, Ma B, Shen XQ, Geng YM. Diagnostic accuracy of artificial intelligence-assisted caries detection: a clinical evaluation. BMC Oral Health. 2024;24:1095. doi: 10.1186/s12903-024-04847-w.
22. Al-Khalifa KS, Ahmed WM, Azhari AA, Qaw M, Alsheikh R, Alqudaihi F, *et al*. The use of artificial intelligence in caries detection: a review. Bioengineering. 2024;11:936. doi: 10.3390/bioengineering11090936.
23. Abbott LP, Saikia A, Anthonappa RP. Artificial intelligence platforms in dental caries detection: a systematic review and meta-analysis. J Evid Based Dent Pract. 2025;25:102077. doi: 10.1016/j.jebdp.2024.102077.
24. Lee SJ, Chung D, Asano A, Sasaki D, Maeno M, Ishida Y, *et al*. Diagnosis of tooth prognosis using artificial intelligence. Diagnostics (Basel). 2022;12:1422. doi: 10.3390/diagnostics12061422.
25. Kazimierczak W, Wajer R, Wajer A, Kalka K, Kazimierczak N, Serafin Z. Evaluating the diagnostic accuracy of an AI-driven platform for assessing endodontic treatment outcomes using panoramic radiographs: a preliminary study. J Clin Med. 2024;13:3401. doi: 10.3390/jcm13123401.
26. Karthik L, Gade MKR, Kala T. Artificial intelligence in endodontics: redefining precision and possibilities. Acta Sci Dent Sci. 2025;9:01–03.
27. Chopra S. The future of personalized dentistry: integrating genomics, artificial intelligence, and precision medicine into clinical practice. J Dent Def Sect. 2025;19:1–3. doi: 10.4103/jodd.jodd_24_25
28. Iqbal MA, Islam SMS. Genomics in Personalized Dental Care. Update Dent. Coll J. 2024;14(1):1-3. doi: 10.3329/updcj.v14i1.73409
29. Sharma D, Bhandary S. Role of Genetic Markers in Dental Caries: A Literature Review. J Hlth Allied Sc NU 2023: 303-8. doi: 10.1055/s-0043-1771387
30. Karobari MI, Adil AH, Basheer SN, Murugesan S, Savadamoorthi KS, Mustafa M. Evaluation of the diagnostic and prognostic accuracy of artificial intelligence in endodontic dentistry: a comprehensive review of literature. Comput Math Methods Med. 2023;2023:7049360. doi: 10.1155/2023/7049360

31. Asiri AF, Altuwalah AS. The role of neural artificial intelligence for diagnosis and treatment planning in endodontics: a qualitative review. Saudi Dent J. 2022;34:270–81. doi: 10.1016/j.sdentj.2022.04.004.
32. Elhaddad M, Hamam S. AI-driven clinical decision support systems: an ongoing pursuit of potential. Cureus. 2024;16:e57728. doi: 10.7759/cureus.57728.
33. Nosrati H, Nosrati M. Artificial intelligence in regenerative medicine: applications and implications. Biomimetics (Basel). 2023;8:442. doi:10.3390/biomimetics8050442.
34. Mackay BS, Marshall K, Grant-Jacob JA, Kanczler J, Eason RW, Oreffo ROC, *et al*. The future of bone regeneration: integrating AI into tissue engineering. Biomed Phys Eng Express. 2012;7:052002. doi: 10.1088/2057-1976/ac154f.
35. Bermejillo Barrera MD, Franco-Martínez F, Díaz Lantada A. Artificial intelligence aided design of tissue engineering scaffolds employing virtual tomography and 3D convolutional neural networks. Materials (Basel). 2021;14:5278. doi: 10.3390/ma14185278.
36. Andersson L. AI in predicting regenerative endodontic success rates. IRE Journals. 2022;6:405–13.
37. Machado ICP, Morais MO, Bicalho ALP, Ferrari PHP, Bueno JM, Junqueira JLC, *et al*. Prevalence and characterization of external cervical resorption using cone beam computed tomography. J Endod. 2024;50:164–72.e1. doi: 10.1016/j.joen.2023.11.003.
38. Krois J, Garcia Cantu A, Chaurasia A, Patil R, Chaudhari PK, Gaudin R, *et al*. Generalizability of deep learning models for dental image analysis. Sci Rep. 2021;11:6102. doi: 10.1038/s41598-021-85454-5.
39. Khan B, Fatima H, Qureshi A, Kumar S, Hanan A, Hussain J, *et al*. Drawbacks of artificial intelligence and their potential solutions in the healthcare sector. Biomed Mater Devices. 2023;8:1–8. doi: 10.1007/s44174-023-00063-2.
40. Najeeb M, Islam S. Artificial intelligence (AI) in restorative dentistry: current trends and future prospects. BMC Oral Health. 2025;25:592. doi:10.1186/s12903-025-05989-1.
41. Alami H, Lehoux P, Denis J-L, Motulsky A, Petitgand C, Savoldelli M, *et al*. Organizational readiness for artificial intelligence in health care: insights for decision-making and practice. J Health Organ Manag. 2021;35:106–14. doi: 10.1108/JHOM-03-2020-0074.
42. Singh A, Sengupta S, Lakshminarayanan V. Explainable deep learning models in medical image analysis. J Imaging. 2020;6:52. doi: 10.3390/jimaging6060052.
43. Chinta SV, Wang Z, Palikhe A, Zhang X, Kashif A, Smith MA *et al*. AI-driven healthcare: Fairness in AI healthcare: A survey. PLOS Digit Health. 2025 20;4:e0000864. doi: 10.1371/journal.pdig.0000864.

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