

Applications and performance of artificial intelligence in dentistry and dental materials a scoping review

Background/purpose: Artificial intelligence (AI) has experienced rapid expansion in biomedical sciences, with increasing integration into dental practice and dental materials research. This scoping review aimed to provide a concise and structured overview of recent advances in AI and to identify the techniques employed in dentistry and dental materials science to enhance diagnosis, accuracy, detection, and clinical decision-making.

Materials and methods: A comprehensive electronic search was conducted in ScienceDirect, PubMed/MEDLINE, and Scopus for studies published between 2020 and 2025. Original research articles investigating AI applications in various dental specialties and dental materials science were screened according to predefined inclusion criteria. Thirty studies met the eligibility criteria and were included in this review. Data were extracted and synthesized based on study characteristics, AI techniques used, assessment methods, reported outcomes, and methodological quality.

Results: AI technologies have been widely implemented across multiple dental specialties, including restorative dentistry, prosthodontics, endodontics, orthodontics, oral and maxillofacial surgery, implantology, periodontology, and dental materials science. Deep learning models—particularly convolutional neural networks (CNNs)—were the most frequently applied techniques. Across studies, AI systems demonstrated high diagnostic accuracy, improved detection sensitivity, enhanced workflow efficiency, and promising predictive performance in treatment planning and biomaterial optimization.

Conclusion: Artificial intelligence represents a transformative advancement in dentistry. Current evidence indicates that AI-based systems significantly improve diagnostic precision and support clinical decision-making. However, despite their high performance, AI technologies remain complementary tools and cannot fully replace human expertise. Continued development, validation, and responsible clinical integration are essential for their future implementation in patient-centered dental care.

Rajae Naimi^{1*}
Azzeddine Er-Ramly²
Wiame Rerhrhaye³

¹ PhD student, The Center for Doctoral Studies, Laboratory of Odontological Biomaterials and Nanotechnology (OBN), Mohammed V University Faculty of Dental Medicine in Rabat, Morocco.

² Professor, Odontological Biomaterials and Nanotechnology Laboratory, Department of Fundamental Sciences, Faculté de médecine dentaire de Rabat, Université Mohammed V de Rabat Morocco.

³ Professor, Odontological Biomaterials and Nanotechnology Laboratory, Department of Orthopedics, Faculté de médecine dentaire de Rabat, Université Mohammed V de Rabat Morocco.

*Corresponding author

Received 2026, January 7

Accepted 2026, March 9

KEYWORDS Artificial intelligence dentistry, Machine learning, deep learning, neural networks, dentistry, dental medicine, dental biomaterials

Corresponding Authors*

Naimi Rajae, PhD student. Laboratory of Odontological Biomaterials and Nanotechnology (OBN). Mohammed V University Faculty of Dental Medicine, Rabat, Morocco | +212 0701177796 | rajae_naimi@um5.ac.ma |

Peer review under responsibility of Società Italiana di Endonzia

10.32067/GIE.2026.549

Società Italiana di Endonzia. Production and hosting by Helyx srl on behalf of Tecniche Nuove. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).



Introduction

Artificial intelligence (AI) has rapidly evolved over the past decades and is now transforming biomedical research and clinical practice. In dentistry, the integration of AI technologies has accelerated significantly, driven by advances in digital imaging, computational power, and data availability. (1) AI-based systems are increasingly applied to diagnostic imaging, treatment planning, predictive modeling, and workflow automation. (2)

Artificial intelligence encompasses several subfields, including machine learning (ML), deep learning (DL), and artificial neural networks (ANNs). (3) Among these, deep learning—particularly convolutional neural networks (CNNs)—has demonstrated remarkable performance in medical and dental image analysis. (4) These models are capable of automatically extracting complex features from radiographs, cone-beam computed tomography (CBCT), intraoral scans, and clinical photographs, enabling enhanced detection and classification of pathological conditions. (5)

In dentistry, AI applications span multiple specialties, including restorative dentistry, endodontics, orthodontics, oral and maxillofacial surgery, implantology, periodontology, prosthodontics, and dental materials science. (6) Reported applications include automated detection of dental caries, periapical lesions, periodontal bone loss, temporomandibular joint disorders, implant failure prediction, cephalometric landmark identification, prosthetic design optimization, and biomaterial performance prediction. (7)

In recent years, the number of publications exploring artificial intelligence in dentistry has increased substantially, reflecting growing scientific and clinical interest. However, reported applications vary considerably in terms of study design, dataset size, validation

protocols, and performance metrics. (8) This heterogeneity makes it challenging to draw comprehensive conclusions regarding the most effective AI techniques and their true clinical applicability. (9) A structured mapping of the existing evidence is therefore essential to identify prevailing trends, methodological gaps, and areas requiring further investigation. (10)

Despite the rapid expansion of research in this field, AI applications in dentistry remain heterogeneous in terms of methodologies, validation strategies, and clinical integration. (11) The growing number of studies highlights the need for a structured synthesis to clarify which AI techniques are currently employed and how they contribute to improving diagnostic accuracy, detection sensitivity, and decision-making processes. (12)

Therefore, the aim of this scoping review was to identify the artificial intelligence techniques used in dentistry and dental materials science and to evaluate their applications and performance in enhancing diagnosis, accuracy, detection, and clinical decision-making.

Materials and methods:

Focused question and study design

This scoping review was conducted and reported in accordance with the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) guidelines. The present analysis was guided by the following research question: "Which artificial intelligence techniques are employed in dentistry and dental materials science to enhance diagnosis, accuracy, detection, and decision-making processes?"

This review aimed to explore the influence of artificial intelligence (AI) across various branches of dentistry, including restorative dentistry, endodontic, orthodontics, oral and maxillofacial surgery, dental implantology, and dental materials science.

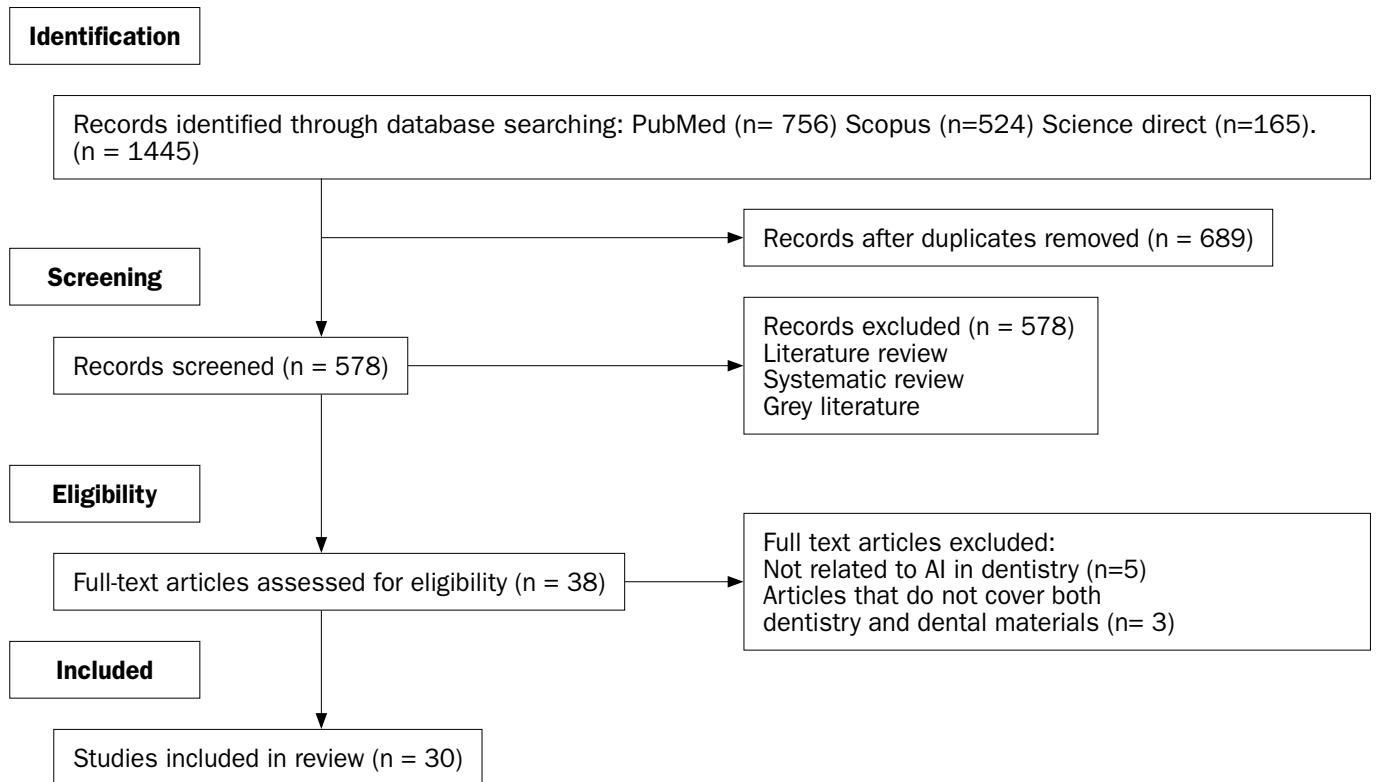


Figure 1
The PRISMA flow diagram for the literature search conducted in this study.

Eligibility Criteria

Relevant articles were selected according to predefined inclusion criteria:

- 1) Articles written in English,
- 2) Articles published between 2020 and 2025,
- 3) Original research articles related to artificial intelligence in dentistry,
- 4) Prospective studies,
- 5) Clinical trials,
- 6) Studies related to advances in dental materials,
- 7) In vitro investigations involving AI applications.

Exclusion criteria

- Letters to the editor, editorials and comments, grey literature, case reports, and articles related to other medical specialties.
- Full texts of eligible studies were retrieved and analyzed. Data extraction focused on study characteristics, AI techniques used, assessment methods, and reported outcomes.

Search strategy

The electronic search was conducted using the following databases:

- Science Direct
- PubMed/MEDLINE
- Scopus

The search targeted articles published between 2020 and 2025. A free-text search strategy was applied using combinations of the following keywords: (Artificial intelligence), (AI in dentistry), (machine learning), (deep learning), (neural networks), (dental medicine), (dental biomaterials).

To ensure comprehensiveness, references of selected articles were manually screened. Titles and abstracts were carefully reviewed for relevance.

Study selection process

The screening process was conducted by the authors. Titles and abstracts were evaluated for eligibility, and full-text articles were assessed when necessary. Discrepancies were resolved through



First author and date of publication	Scope of application	Objective of the study	No. of images/ photographs for testing	Assessment methods	Results
Kuwada C (2020) (13)	oral and maxillofacial surgery	This study aimed to verify and compare the performance of three deep learning systems when classifying supernumerary teeth on panoramic radiographs.	550 panoramic radiographs	Three learning models were created by using AlexNet, VGG-16, and DetectNet	The results showed that, in general, DetectNet produced the highest values for diagnostic accuracy
Lee J H (2020) (14)	Oral Pathology	Evaluating fully deep convolutional neural network method (R-CNN) for automated tooth segmentation on panoramic radiographs is the focus of this study.	846 images	deep learning method using the mask R-CNN model was implemented	Panoramic dental images were successfully automated using the proposed method, that performed excellently
S Yamaguchi (2020) (15)	restorative materials	This study aimed to evaluate the usefulness of the convolutional neural network (CNN) deep learning method for predicting the probability of CAD/CAM composite resin crown detachment.	8 640 images	convolutional neural network (CNN)	This study that demonstrated excellent performance in predicting the probability of CAD/CAM crown detachment using 3D stereolithography models of dies scanned from patients
KS Lee (2020) (16)	oral and maxillofacial surgery	The aim of the present study was to develop an artificial intelligence (AI) based diagnostic tool with the capacity for automatic detection of temporomandibular joint (TMJ) osteoarthritis from cone beam computed tomography (CBCT) image.	3 514 images CBCT	deep neural network model. (RNN)	The employment of a deep The employment of a deep neural network model has enabled the automated detection of ATM from sagittal CBCT image.
Anselmo Garcia Cantu (2020) (17)	Periodontics	The utilization of deep learning algorithms for the identification of radiographic caries lesions.	3686 radiographs	applied a convolutional neural network (U-Net)	It has been demonstrated that deep neural networks exhibit a higher degree of accuracy in identifying carious lesions when compared to the dentists.
Mengxun Li (2020) (18)	cosmetic dentistry	The objective of this study is to develop an automated system that will enable the efficient labeling and integration of information into facial and intraoral images	50 images	The system relies on ROI detection, tooth segmentation, and registration.	The proposed algorithm demonstrated an 96.0% (263/274) recognition rate of teeth. The findings of this study demonstrate that the proposed automated system facilitates dentists in circumventing the arduous image integration process.

Table 1A

First author and date of publication	Scope of application	Objective of the study	No. of images/ photographs for testing	Assessment methods	Results
Félix Kunz (2020) (19)	orthodontics	The study compared AI-generated cephalometric radiographs with those of human experts.	1792 cephalometric radiographs	Use of a customized convolutional neural network	Almost no statistically significant differences were found between AI assessments and the human reference method.
Yoshiko Arijji (2020) (20)	Oral and maxillofacial surgery	This study aims to clarify the diagnostic performance of computed tomography. This is in the extranodal extension of cervical lymph node metastases. The study uses deep learning classification.	703 CT images	Five learning models were created using a neural network "AlexNet"	In terms of extranodal extension, the diagnostic performance of deep learning was significantly superior to that of radiologists. Deep learning achieved an accuracy of 84.0% for extranodal extension.
Henriette Lerner (2020) (21)	Dental material	The present study has been devised for the purpose of outlining a protocol for the use of artificial intelligence in the fabrication of monolithic zirconia crowns (MZC)	106 implant-supported MZC	based on the proprietary ScanPlanMakeDone protocol.	The results demonstrated that following the implementation of the MZC, the quality of fit, interproximal and occlusal contact, and aesthetic integration, were all found to be excellent.
Toshihito Takahashi (2021) (22)	Prosthodontic	A convolutional neural network (CNN) method has been developed for the classification of images of partially edentulous arches.	1184 images	A CNN method for classifying images has been developed.	The employment of a convolutional neural network (CNN) has facilitated the classification and prediction of dental arches. The diagnostic accuracy was 99.5% for the maxilla and 99.7% for the mandible
Kühnisch J (2021) (23)	caries diagnostics	The aim of this diagnostic study was twofold. Firstly, a deep learning approach with convolutional neural networks (CNNs) was developed for caries detection and categorization. Secondly, the diagnostic performance was compared with respect to expert standards.	2.417 anonymized photographs	Develop a deep learning approach with convolutional neural networks (CNNs)	The present study demonstrated that the CNN demonstrated an 92.5% success rate in accurately identifying caries in images.

Table 1B



First author and date of publication	Scope of application	Objective of the study	No. of images/ photographs for testing	Assessment methods	Results
Frank C Setzer (2021) (24)	endodontic	This study set out to achieve two key objectives. Firstly, a deep learning (DL) algorithm was used to automate the segmentation of cone-beam computed tomography (CBCT) images. Secondly, it aimed to detect periapical lesions.	Cone beam computed tomography (CBCT) images n = 20	Application of a deep learning (DL) algorithm	The DL algorithm has demonstrated excellent results in terms of lesion detection accuracy.
Chihiro Tanikawa (2021) (25)	orthodontic treatment	The objective of the present study was to develop two artificial intelligence (AI) systems with the capability to predict three-dimensional facial topography subsequent to orthognathic surgery and orthodontic treatment	137 oral photographs	The development of two AI systems that combine deep learning and a genetic model (GMM)	The system for predicting facial morphology after treatment was successfully developed using a combination of GMM and deep learning.
Qiwen Cui, BS (2021) (26)	prosthodontics	The objective of this prospective study to construct a computerized decision support (CDS) model that utilizes electronic dental records to predict dental extraction treatment.	4135 EDRs (electronic dental records)	CDS model	The CDS model employed for the purpose of dental extraction treatment has demonstrated a high level of proficiency in terms of decision-making as evidenced by the analysis of EDRs.
Hamdan MH (2022) (27)	Dentomaxillofacial	The present study aims to examine the efficacy of utilizing the Denti.AI system in assisting dentists in the detection of apical radiolucencies on periapical radiographs.	Sixty-eight intraoral periapical radiographs	Denti.AI system	The study demonstrated that the DL technology (Denti. AI) has the capacity to augment the capabilities of dental professionals in detecting apical radiolucencies in intraoral radiographs
Preda F (2022) (28)	Oral diseases	The present study investigated the accuracy consistency and time efficiency of a novel deep convolutional neural network (CNN) model for automated maxillofacial bone segmentation.	144 scans	A three-dimensional (3D) U-Net (CNN) model was developed, and the automated segmentation obtained was compared to a manual approach.	It is recommended that the proposed CNN model be used for the efficient, accurate and consistent automated segmentation of the maxillofacial complex using CBCT data.

Table 1C

First author and date of publication	Scope of application	Objective of the study	No. of images/ photographs for testing	Assessment methods	Results
Pavel Alekseevich Lyakhov (2022) (29)	Dental Implantology	The objective of this study is to develop a neural network system to evaluate the survival of dental implants.	1 646 oral photographs	Optimal linear neural network topologies have been developed on the basis of research into their functionality.	The results demonstrated that the neural network system developed possesses the capacity to predict the positive or negative outcome of a single implant procedure, however, its application as a comprehensive medical aid tool remains unfeasible.
Mihee Hong (2022) (30)	Orthodontics	Creation of an AI-based model for precise landmark identification in serial lateral cephalometric radiographs of class III patients who have had orthodontic treatment and orthognatic surgery.	302 digitized panoramic radiographs	algorithmme de réseau neuronal convolutif (CNN)	The total mean error was 1.17 mm. the cascaded convolutional neural network (CNN) algorithm proposed in this study demonstrated the potential for identifying landmarks from bone anatomy in lateral cephalograms.
Xuan Zhang (2022) (31)	Oral diseases	The development and evaluation of a deep learning system employing a convolutional neural network (ConvNet) for the purpose of detecting the presence of dental caries in oral photographs will be conducted.	3,932 oral photographs	A deep ConvNet was developed by adapting the singles shot MultiBox detector. The hard negative exploration algorithm was applied to automatically train the model.	The utilization of deep learning model has demonstrated considerable potential in the identification of dental caries in oral photographs.
Chunan Zhang (2023) (32)	Dental implant	The objective of this study was to develop a deep learning-based model for predicting dental implant failure.	529 periapical images	.ResNest-50 deep convolutional neural network (CNN)	The deep learning model exhibited an 87% prediction accuracy for implant malfunction
Zhang Yimeng (2023) (33)	pediatric dentistry	This study aimed to develop a machine learning model to determine the prevalence of molar incisor hypomineralisation (MIH) among children living in a region of central China affected by endemic fluorosis.	1568 samples	In this study, supervised machine learning and correlation analysis were used.	The incidence of MIH dereased with increasing severity of dental fluorosis (DF), as shown by the nomogram.

Table 1D



First author and date of publication	Scope of application	Objective of the study	No. of images/ photographs for testing	Assessment methods	Results
Anastasia Grymak (2023) (34)	Dental material	The aim of study is to develop algorithms that can predict the in vitro wear resistance of conventional prosthetic teeth that have been machined using CAD and printed in 3D.	Six prosthetic tooth materials	An LSTM model was developed	The LSTM model was successfully developed. It can reduce the duration of simulations. It can also reduce the number of samples required for wear testing of various dental materials.
Jun-Ho Cho (2024) (35)	restorative dentistry	A comparative analysis was conducted of the dental morphology, internal fit, occlusion, and proximal contacts of dental crowns generated by conventional software with two deep learning (DL)- based dental software systems	30 scans	The crowns were designed using two DL methods (AA and AD) and one technician method (NC).	The results indicated that the variations observed were attributable to internal adjustment, occlusion, and proximal contacts.
Seung-Hwan Ong (2024) (36)	forensic odontology	Utilizing deep learning and adopting Demirjian's methodology, this study endeavours to a dental development staging system.	5,133 panoramic radiographs	The proposed methodology includes three CNN model procedures: the Yolov5 detection model, U-Net, and EfficientNet.	The proposed deep learning approach can serve as a support tool for dentists.
Rabia Karakuş (2024) (37)	restorative dentistry	The objective of this study was to develop a system for the detection and classification of dental caries that is based on deep learning.	860 interproximal radiograph	The AI-based learning process was performed using the YOLOv8 algorithm.	The success rate for detecting occlusal, secondary, and interproximal caries was high, with an accuracy of 97.7% and a recall of the mean score was 93.2%, and the F1 score was 95.4%
Oana-Maria Butnaru (2025) (38)	Periodontology	The objective of this comparative study was to compare AI-assisted dental and periodontal diagnoses with those made by specialists and general dentists.	Six radiological images	The AI system used for diagnosis (Planmeca Romexis, version 6.4.7, Helsinki, Finland).	AI systems have significant potential as reliable tools for dental and periodontal assessment, complementing the expertise of human practitioners.
Allihaibi M (2025) (39)	endodontics	Evaluation of the performance of the diagnostic at AI platform in assessing endodontic treatment results on periapical radiographs compared to that of experienced clinicians.	376 teeth	IA (Diagnocat)	The results showed that evaluation of endodontic treatment outcomes requires clinical monitoring, and that the AI- driven platform is a complementary tool.

Table 1E

First author and date of publication	Scope of application	Objective of the study	No. of images/ photographs for testing	Assessment methods	Results
Yunus Balel (2025) (40)	Dental implantology	The objective of this study was to develop a deep learning model based on artificial intelligence (AI) that is capable of detecting and number implants.	32585 panoramic radiographs	deep learning models compared: YOLOv8, RetinaNet, Faster R-CNN, DETR, U-Net, Mask R-CNN, and DeepLab v3+	The AI model exhibited a high degree of accuracy in the detection and enumeration of dental implants in panoramic radiographs.
Pul U (2025) (41)	endodontics	Detection of periapical radiolucencies (PR) with and without artificial intelligence.	50 panoramic radiographs	dentalXrai Pro The software uses a convolutional neural network (CNN) architecture.	The use of AI assistance slightly improved the detection of periapical radiolucencies (RP), with junior dentists showing the most significant improvement.
Paniagua K (2025) (42)	Dental material	The aim of this study is to evaluate the effectiveness of AI models in predicting organoleptic properties (OP) in order to develop more sustainable composites while reducing time, effort and costs.	233 samples	Nine ML classification algorithms [SVM], Decision Tree, KNN classifier, [LGBM], Random Forest, Logistic Regression, Gaussian Naïve Bayes, [ELM], and [XGBoost])	Different AA models achieved better results depending on performance, with some performing better than others.

Table 1F

discussion and consensus. The study selection process is illustrated in the PRISMA flow diagram.

Risk of Bias assessment

Although this review followed a scoping methodology, the methodological quality of the included studies was assessed qualitatively. Risk of bias was evaluated based on study design, sample size, validation methodology, dataset characteristics, and clarity of outcome reporting. Studies were categorized as having low, moderate, or high risk of bias accordingly.

Results

Study selection

The electronic search initially identified 1445 records (PubMed: 756; Scopus: 524; ScienceDirect: 165). After removal of duplicates and screening of titles and abstracts, 38 full-text articles were assessed for eligibility. Eight articles were excluded for not meeting the inclusion

criteria. Ultimately, 30 studies published between 2020 and 2025 were included in this scoping review. The study selection process is illustrated in the PRISMA flow diagram.

General characteristics of included studies

The included studies covered multiple dental specialties, including oral and maxillofacial surgery, restorative dentistry, prosthodontics, endodontics, orthodontics, periodontology, dental implantology, pediatric dentistry, forensic odontology, and dental materials science.

Most investigations focused on imaging-based applications, particularly panoramic radiographs, cone-beam computed tomography (CBCT), intraoral radiographs, and oral photographs. Deep learning models-especially convolutional neural networks (CNNs)-were the most frequently employed artificial intelligence techniques. Other reported approaches included

Table 1A-1F
The studies that have used AI based models in various specialties of dentistry and Dental material.



machine learning algorithms, recurrent neural networks (RNNs), long short-term memory (LSTM) models, object detection models (YOLO, Mask R-CNN), and clinical decision-support systems.

Diagnostic and predictive performance

The majority of studies evaluating AI in radiographic interpretation reported high diagnostic performance. Accuracy values frequently exceeded 85%, with several studies demonstrating results comparable to or exceeding those of experienced clinicians in detecting dental caries, periapical lesions, periodontal bone loss, temporomandibular joint disorders, and maxillofacial pathologies.

In implantology, predictive models for implant survival and failure demonstrated accuracy rates ranging approximately from 84% to 87%. Automated implant detection systems also showed high reliability in identifying and numbering implants on panoramic radiographs.

In orthodontics, AI-assisted cephalometric landmark identification achieved clinically acceptable precision, with reported mean errors close to 1mm. Systems developed for facial morphology prediction and growth assessment demonstrated promising predictive capabilities.

In prosthodontics, AI-based CAD/CAM systems achieved high accuracy in classifying partially edentulous arches and designing dental crowns.

In dental materials science, machine learning models successfully predicted wear resistance, debonding probability, and composite material performance, supporting accelerated biomaterial optimization.

Overall findings

Overall, the findings indicate that artificial intelligence applications in dentistry predominantly enhance diagnostic accuracy, detection sensitivity, workflow efficiency, and predictive modeling. Across specialties, AI sys-

tems consistently demonstrated high performance, particularly in imaging-based tasks and decision-support applications.

Discussion and conclusion

The present scoping review aimed to identify which artificial intelligence techniques are employed in dentistry and dental materials science and to evaluate how these technologies enhance diagnosis, accuracy, detection, and clinical decision-making processes.

The analysis of the included studies demonstrates that the most frequently used artificial intelligence techniques are machine learning (ML) and deep learning (DL) models, particularly convolutional neural networks (CNNs). Other architectures such as recurrent neural networks (RNNs), long short-term memory (LSTM) models, decision-support systems, and object detection algorithms (e.g., YOLO, Mask R-CNN) were also reported.⁽⁴³⁾ Overall, AI systems were mainly applied to imaging-based diagnostics, predictive modeling, digital workflow automation, and biomaterial optimization.

AI in diagnostic imaging and disease detection

The majority of the included studies focused on radiographic interpretation. CNN-based systems showed high diagnostic performance in detecting dental caries, periapical lesions, periodontal bone loss, temporomandibular joint disorders, maxillofacial pathologies, and Implant-related complications.

Several investigations reported that AI-assisted diagnosis improved clinician's performance, particularly among less experienced practitioners.⁽⁴⁴⁾ These findings suggest that AI enhances diagnostic accuracy, reduces inter-operator variability, and increases reproducibility. However, AI systems function primarily as clinical decision-support tools rather than replacing human expertise.



AI in dental implantology

AI in dental implantology represents one of the most rapidly expanding application fields of artificial intelligence in dentistry. Neural network systems and deep learning models have been developed to predict implant survival, detect implant failure from panoramic and periapical radiographs, and automatically identify and number implants. These predictive approaches contribute to improved risk assessment, prognosis estimation, and treatment planning. The integration of AI into implant workflows reflects a shift toward more data-driven and personalized therapeutic strategies. (45)

AI in orthodontics and craniofacial analysis

In orthodontics, AI applications mainly involve automated cephalometric landmark detection, growth and developmental assessment, and prediction of facial morphology after orthognathic surgery. CNN-based systems demonstrated accuracy comparable to experienced orthodontists while offering improved consistency and time efficiency. The ability of AI systems to reproduce landmark positioning with minimal variability may contribute to treatment standardization and improved longitudinal monitoring.

AI in prosthodontics and digital workflows

In prosthodontics, deep learning models have been integrated into CAD/CAM systems for classification of partially edentulous arches, crown morphology design, and automated integration of intraoral and facial images. These technologies enhance workflow automation, improve precision, and reduce manual workload in restorative procedures. The synergy between AI and digital dentistry represents a major advancement toward semi-automated restorative planning and fabrication.

AI in dental materials science

In recent years, there has been an in-

creased interest in biomaterials for dental applications, with many new biomaterials being introduced for these purposes (46). The implementation of artificial intelligence (AI) in materials science has been a subject of considerable interest. Recent advancements in artificial intelligence have led to substantial enhancements in rational design and accelerated the identification of diverse biomaterials (47). In the contemporary era of rapid advancements in data processing and algorithms, machine learning and deep learning have emerged as pivotal methodologies for the identification of novel biomaterials prior to their actual production.

Within dental biomaterials research, machine learning and SLTM-based models have been employed to predict wear resistance, debonding probability, mechanical behavior, and organoleptic properties of restorative materials. AI contributes to accelerating material development, optimizing biomaterial performance, and reducing experimental time and cost.

Recent contributions continue to expand the scope of AI in dentistry. For example, a 2026 study published in *Applied Sciences* (DOI: 10.3390/app16010396) highlights the integration of explainable artificial intelligence models in dental diagnostics and materials research, emphasizing transparency, interpretability, and clinical applicability AI systems. (48)

The application of artificial intelligence (AI) in conjunction with three-dimensional printing techniques has yielded substantial benefits, particularly in the domain of prosthetics and device fabrication (55) (48). The advent of artificial intelligence (AI) has had a profound impact on the realm of 3D printing, particularly in the domain of manufacturing various types of implants and prosthetics. The combination of artificial intelligence with three-dimensional printing technologies further enhances precision in prosthetic fabrication and material customization.



Methodological considerations and limitations

Notwithstanding the promising findings, several limitations should be acknowledged. Many included studies were retrospective and based on relatively limited datasets, with heterogeneous validation protocols. External validation across different populations and imaging systems remains insufficient.

Furthermore, the complexity of AI systems, implementation costs, data privacy concerns, and ethical considerations must be carefully considered before large-scale clinical adoption. Standardized reporting guidelines and multicenter prospective studies are needed to strengthen the evidence base and enhance generalizability.

Overall, the findings of this review indicate that computerized neural networks and machine learning models provide substantial support for dental practitioners in diagnosis, treatment planning, and outcome prediction. Artificial intelligence is expected to play an increasingly important role in dentistry, particularly in personalized and patient-centered care.

Conclusion

This scoping review demonstrates that artificial intelligence is increasingly integrated across multiple dental specialties, including diagnostic imaging, implantology, orthodontics, prosthodontics, oral pathology, and dental materials science.

The most frequently employed techniques are machine learning and deep learning models, particularly convolutional neural networks, which enhance diagnostic accuracy, improve lesion detection, support treatment planning, and contribute to predictive modeling and biomaterial optimization.

Although many AI systems show performance comparable to human experts, current evidence supports their primarily as clinical decision-support tools rather than autonomous diagnos-

tic systems.

Despite promising results, challenges remain regarding data standardization, external validation, ethical considerations, and cost-effectiveness. Future research should focus on multicenter prospective studies and the development of explainable AI models to facilitate safe and responsible clinical implementation.

Artificial intelligence represents a transformative advancement in dentistry and dental materials science. With continued refinement and interdisciplinary collaboration, AI has potential to significantly improve precision, efficiency, and patient-centered care in modern dental practice.

Conflicts of interest

The authors declare that they have no conflicts of interest.

References

- Xu Y, Liu X, Cao X, Huang C, Liu E, Qian S, et al. Artificial intelligence: a powerful paradigm for scientific research. *Innovation (Camb)*. 2021;2(4):100179. doi:10.1016/j.xinn.2021.100179.
- Schwendicke F, Samek W, Krois J. Artificial intelligence in dentistry: chances and challenges. *J Dent Res*. 2020;99(7):769-774. doi:10.1177/0022034520915714.
- Corbella S, Srinivas S, Cabitza F. Applications of deep learning in dentistry. *Oral Surg Oral Med Oral Pathol Oral Radiol*. 2021;132(2):225-238. doi:10.1016/j.oooo.2020.11.003.
- Khanagar SB, Al-Ehaideb AA, Maganur PC, Vishwanathaiah S, Patil S, Baeshen HA, et al. Developments, application, and performance of artificial intelligence in dentistry: a systematic review. *J Dent Sci*. 2021;16(1):508-522. doi:10.1016/j.jds.2020.06.019.
- Sitaras S, Tsolakis IA, Gelsini M, Tsolakis AI, Schwendicke F, Wolf TG, et al. Applications of artificial intelligence in dental medicine: a critical review. *Int Dent J*. 2025 Jan 21;75(2):474-486. doi:10.1016/j.identj.2024.11.009.
- Fatima A, Shafi I, Afzal H, Torre Díez I, De Rioja Santos ML, Breñosa J, et al. Advancements in dentistry with artificial intelligence: current clinical applications and future perspectives. *Healthcare (Basel)*. 2022 Oct 31;10(11):2188. doi:10.3390/healthcare10112188.
- Li H, Sakai T, Tanaka A, Ogura M, Lee C, Yamaguchi S, et al. Interpretable AI explores effective components of CAD/CAM resin composites. *J Dent Res*. 2022 Oct;101(11):1363-1371. doi:10.1177/00220345221089251.

8. Raikar AS, Andrew J, Dessai PP, Prabhu SM, Jathar S, Prabhu A, et al. Neuromorphic computing for modeling neurological and psychiatric disorders: implications for drug development. *Artif Intell Rev.* 2024;57:318.
9. Kuwada C, Arijji Y, Fukuda M, Kise Y, Fujita H, Katsumata A, et al. Deep learning systems for detecting and classifying the presence of impacted supernumerary teeth in the maxillary incisor region on panoramic radiographs. *Oral Surg Oral Med Oral Pathol Oral Radiol.* 2020 Oct;130(4):464-469. doi:10.1016/j.oooo.2020.04.813.
10. Subramanian AK, Chen Y, Almalki A, Sivamurthy G, Kafle D. Cephalometric analysis in orthodontics using artificial intelligence: a comprehensive review. *Biomed Res Int.* 2022;2022:1880113. doi:10.1155/2022/1880113.
11. Khanagar SB, Al-Ehaideb A, Maganur PC, Vishwanathaiah S, Patil S, Baeshen HA, et al. Developments, application, and performance of artificial intelligence in dentistry: a systematic review. *J Dent Sci.* 2021;16(1):508-522. doi:10.1016/j.jds.2020.06.019.
12. Heboyan A, Yazdanie N, Ahmed N. Glimpse into the future of prosthodontics: the synergy of artificial intelligence. *World J Clin Cases.* 2023;11(33):7940-7942. doi:10.12998/wjcc.v11.i33.7940.
13. Kuwada C, Arijji Y, Fukuda M, Kise Y, Fujita H, Katsumata A, et al. Deep learning systems for detecting and classifying the presence of impacted supernumerary teeth in the maxillary incisor region on panoramic radiographs. *Oral Surg Oral Med Oral Pathol Oral Radiol.* 2020 Oct;130(4):464-469. doi:10.1016/j.oooo.2020.04.813.
14. Lee JH, Han SS, Kim YH, Lee C, Kim I. Application of a fully deep convolutional neural network to the automation of tooth segmentation on panoramic radiographs. *Oral Surg Oral Med Oral Pathol Oral Radiol.* 2020 Jun;129(6):635-642. doi:10.1016/j.oooo.2019.11.007.
15. Yamaguchi S, Lee C, Karaer O, Ban S, Mine A, Imazato S. Predicting the debonding of CAD/CAM composite resin crowns with AI. *J Dent Res.* 2020 Oct;98(11):1234-1238. doi:10.1177/0022034519867641.
16. Lee KS, Kwak HJ, Oh JM, Jha N, Kim YJ, Kim W, et al. Automated detection of TMJ osteoarthritis based on artificial intelligence. *J Dent Res.* 2020 Nov;99(12):1363-1367. doi:10.1177/0022034520936950.
17. Cantu AG, Gehrung S, Krois J, Chaurasia A, Rossi JG, Gaudin R, et al. Detecting caries lesions of different radiographic extension on bitewings using deep learning. *J Dent.* 2020 Sep;100:103425. doi:10.1016/j.jdent.2020.103425.
18. Li M, Xu X, Punithakumar K, Le LH, Kaipatur N, Shi B. Automated integration of facial and intraoral images of anterior teeth. *Comput Biol Med.* 2020 Jul;122:103794. doi:10.1016/j.compbiomed.2020.103794.
19. Kunz F, Stellzig-Eisenhauer A, Zeman F, Boldt J. Evaluation of a fully automated cephalometric analysis using a customized convolutional neural network. *J Orofac Orthop.* 2020 Jan;81(1):52-68. doi:10.1007/s00056-019-00203-8.
20. Paniagua K, Whang K, Joshi K, Son H, Kim YS, Flores M. Dental composite performance prediction using artificial intelligence. *J Dent Res.* 2025 Feb 14;104(5):513-521. doi:10.1177/00220345241311888.
21. Lerner H, Mouhyi J, Admakin O, Mangano F. Artificial intelligence in fixed implant prosthodontics: a retrospective study of 106 implant-supported monolithic zirconia crowns inserted in the posterior jaws of 90 patients. *BMC Oral Health.* 2020 Mar 19;20:80. doi:10.1186/s12903-020-1062-4.
22. Takahashi T, Nozaki K, Gonda T, Ikebe K. A system for designing removable partial dentures using artificial intelligence. Part 1. Classification of partially edentulous arches using a convolutional neural network. *J Prosthodont Res.* 2021 Feb 24;65(1):115-118. doi:10.2186/jpr.JPOR_2019_354.
23. Kühnisch J, Meyer O, Hesenius M, Hickel R, Gruhn V. Caries detection on intraoral images using artificial intelligence. *J Dent Res.* 2022 Feb;101(2):158-165. doi:10.1177/00220345211032524.
24. Setzer FC, Shi KJ, Zhang Z, Yan H, Yoon H, Mupparapu M, et al. Artificial intelligence for the computer-aided detection of periapical lesions in cone-beam computed tomographic images. *J Endod.* 2020 Jul;46(7):987-993. doi:10.1016/j.joen.2020.03.025.
25. Chihiro T, Takashi Y. Development of novel artificial intelligence systems to predict facial morphology after orthognathic surgery and orthodontic treatment in Japanese patients. *Sci Rep.* 2021 Aug 4;11:15853. doi:10.1038/s41598-021-95002-w.
26. Cui Q, Chen Q, Liu P, Liu D, Wen Z. Clinical decision support model for tooth extraction therapy derived from electronic dental records. *J Prosthet Dent.* 2021 Jul;126(1):83-90. doi:10.1016/j.prosdent.2020.04.010.
27. Hamdan MH, Tuzova L, Mol A, Tawil P, Tuzoff D, Tyndall DA. The effect of a deep-learning tool on dentists' performances in detecting apical radiolucencies on periapical radiographs. *Dentomaxillofac Radiol.* 2022 Sep 9;51(7):20220122. doi:10.1259/dmfr.20220122.
28. Preda F, Morgan N, Van Gerven A, Reis FN, Smolders A, Wang X, et al. Deep convolutional neural network-based automated segmentation of the maxillofacial complex from cone-beam computed tomography: a validation study. *J Dent.* 2022 Sep;124:104238. doi:10.1016/j.jdent.2022.104238.
29. Lyakhov PA, Dolgalev A, Lyakhova A, Muraev A, Zolotayev K, Semerikov D. Neural network system for analyzing statistical factors of patients for predicting the survival of dental implants. *Front Neuroinform.* 2022 Dec 7;16:1067040. doi:10.3389/fninf.2022.1067040.
30. Hong M, Kim I, Cho J, Kang K, Kim M, Kim S, et al. Accuracy of artificial intelligence-assisted landmark identification in serial lateral cephalograms of Class III patients who underwent orthodontic treatment and two-jaw orthognathic



- surgery. *Korean J Orthod.* 2022 Jul 25;52(4):287-297. doi:10.4041/kjod21.248.
31. Zhang X, Liang Y, Li W, Liu C, Gu D, Sun W, et al. Development and evaluation of deep learning for screening dental caries from oral photographs. *Oral Dis.* 2022 Jan;28(1):173-181. doi:10.1111/odi.13735.
 32. Zhang C, Fan L, Zhang S, Zhao J, Gu Y. Deep learning based dental implant failure prediction from periapical and panoramic films. *Quant Imaging Med Surg.* 2023 Jan 9;13(2):935-945. doi:10.21037/qims-22-457.
 33. Zhang Y, Wang Y, Zhang Z, Wang Y, Jia J. Study on machine learning of molar incisor hypomineralization in an endemic fluorosis region in central China. *Front Physiol.* 2023 Mar 15;14:1088703. doi:10.3389/fphys.2023.1088703.
 34. Grymak A, Tieh M, Yang A, Choi JE. Development of predictive algorithms for the wear resistance of denture teeth materials. *J Mech Behav Biomed Mater.* 2023 Aug;144:105984. doi:10.1016/j.jmbbm.2023.105984.
 35. Cho JH, Çakmak G, Yi Y, Yoon HI, Yilmaz B, Schimmel M. Tooth morphology, internal fit, occlusion and proximal contacts of dental crowns designed by deep learning-based dental software: a comparative study. *J Dent.* 2024 Feb;141:104830. doi:10.1016/j.jdent.2023.104830.
 36. Ong SH, Kim H, Song JS, Shin TJ, Hyun HK, Jang KT, et al. Fully automated deep learning approach to dental development assessment in panoramic radiographs. *BMC Oral Health.* 2024 Apr 6;24:426. doi:10.1186/s12903-024-04160-6.
 37. Karakuş R, Öziç MÜ, Tassoker M. AI-assisted detection of interproximal, occlusal, and secondary caries on bite-wing radiographs: a single-shot deep learning approach. *J Imaging Inform Med.* 2024 May 14;37(6):3146-3159. doi:10.1007/s10278-024-01113-x.
 38. Butnaru OM, Tatarciuc M, Luchian I, Tudorici T, Balcos C, Budala DG, et al. AI efficiency in dentistry: comparing artificial intelligence systems with human practitioners in assessing several periodontal parameters. *Medicina (Kaunas).* 2025 Mar 23;61(4):572. doi:10.3390/medicina61040572.
 39. Allilhaibi M, Koller G, Mannocci F. Diagnostic accuracy of a commercial AI-based platform in evaluating endodontic treatment outcomes on periapical radiographs using CBCT as the reference standard. *J Endod.* 2025 Jul;51(7):898-908.e8. doi:10.1016/j.joen.2025.03.007.
 40. Balel Y, Sağtaş K, Teke F, Kurt MA. Artificial intelligence-based detection and numbering of dental implants on panoramic radiographs. *Clin Implant Dent Relat Res.* 2025 Jan 23;27(1):e70000. doi:10.1111/cid.70000.
 41. Pul U, Tichy A, Pitchika V, Schwendicke F. Impact of artificial intelligence assistance on diagnosing periapical radiolucencies: a randomized controlled trial. *J Dent.* 2025 Sep;160:105868. doi:10.1016/j.jdent.2025.105868.
 42. Paniagua K, Whang K, Joshi K, Son H, Kim YS, Flores M. Dental composite performance prediction using artificial intelligence. *J Dent Res.* 2025 Feb 14;104(5):513-521. doi:10.1177/00220345241311888.
 43. Kraus RD, Epprecht A, Hämmerle CHF, Sailer I, Thoma DS. Cemented vs screw-retained zirconia-based single implant reconstructions: a 3-year prospective randomized controlled clinical trial. *Clin Implant Dent Relat Res.* 2019;21(4):578-585. doi:10.1111/cid.12735.
 44. Gehrke P, Bleuel K, Fischer C, Sader R. Influence of margin location and luting material on the amount of undetected cement excess on CAD/CAM implant abutments and cement-retained zirconia crowns: an in-vitro study. *BMC Oral Health.* 2019;19(1):111. doi:10.1186/s12903-019-0809-2.
 45. Lee C, Kashima K, Ichikawa A, Yamaguchi S, Imazato S. Influence of hydrolysis degradation of silane coupling agents on mechanical performance of CAD/CAM resin composites: in silico multi-scale analysis. *Dent Mater J.* 2020;39(5):803-807.
 46. Altalhi AM, Alharbi FS, Alhodaithy MA, Almarshedy BS, Al-Saaib MY, Al Jfshar RM, et al. The impact of artificial intelligence on dental implantology: a narrative review. *Cureus.* 2023;15(10):e47941. doi:10.7759/cureus.47941.
 47. Lahoud P, Diels S, Nicolaes L, Van Aelst S, Willems H, Van Gerven A, et al. Development and validation of a novel artificial intelligence driven tool for accurate mandibular canal segmentation on CBCT. *J Dent.* 2022 Jan;116:103891. doi:10.1016/j.jdent.2021.103891.
 48. Soltani P, Spagnuolo G, Angelone F, Rezaei Yazdi A, Mohammadzadeh M, Maisto G, Moaddabi A, Cernera M, Armogida NG, Amato F, Ponsiglione AM. Artificial Intelligence for Artifact Reduction in Cone Beam Computed Tomographic Images: A Systematic Review. *Applied Sciences.* 2026;16(1):396. <https://doi.org/10.3390/app16010396>