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A Bibliometric Analysis of Artificial Intelligence Research Published in Endodontic Journals

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Abstract

The aim was to identify and analyse publication trends, bibliometric indicators, and research characteristics of artificial intelligence studies published in Endodontic journals. An advanced search was performed in "Web of Science All Databases" and "Scopus" employing the keywords "Endodontics", "Endodontic", "Artificial Intelligence", and "AI". Articles published in journals containing the terms "Endodontic", "Endodontics", or "Endodontology" were included. A total of 214 authors contributed to the 48 analyzed studies. Mohammad-Rahimi, H., and Nosrat, A., were the most productive authors. The United States contributed the highest number of publications. The *Journal of Endodontics* was the primary outlet. Publications increased sharply between 2024 and 2025. Basic research predominated, with radiology as the dominant study field. Deep learning was the most frequently used AI methodology, particularly convolutional neural networks for radiographic diagnosis and segmentation. AI research in endodontics has expanded markedly in recent years, driven predominantly by advances in deep learning and imaging analysis.

Keywords: Artificial Intelligence; Bibliometrics; Deep Learning; Endodontics

Introduction

Bibliometrics, defined by Pritchard [1] as "the application of mathematics and statistical methods to books and other media of communication," represents a powerful quantitative and descriptive approach for assessing scientific productivity and research dynamics. By applying statistical tools to publication and citation data, bibliometric methods enable researchers to identify publication trends, influential studies, collaboration networks, and emerging topics that shape the evolution of a specific field [2]. The first bibliometric analysis in endodontics, performed by [3], presented an analysis of the one hundred most cited articles in endodontic journals. Since then, other bibliometric studies have been conducted to identify the scientific production characteristics in endodontics [4-7].

According to Sheikh *et al.* [8], artificial intelligence (AI) refers to "systems that exhibit intelligent behavior by analyzing their environment and taking actions with a certain degree of autonomy to achieve specific goals." In broad terms, AI aims to emulate essential human cognitive functions such as learning, reasoning, adaptation, and decision-making through algorithms capable of processing vast amounts of data and identifying complex patterns [9]. The field comprises several specialized branches. Among them, machine learning (ML) focuses on developing algorithms that learn from data without explicit programming, while deep learning (DL) employs multilayered neural networks to extract high-level abstractions from complex datasets. Natural language processing (NLP) enables computers to understand and generate human language, whereas "Computer Vision" allows them to interpret and analyze visual information such as images and videos [10].

Collectively, these subfields enable machines to perceive, reason, and act intelligently across a wide range of contexts.

Endodontics has experienced rapid technological development in recent decades [11]. Among these advances, AI is driving a paradigm shift toward more accurate, predictable, and data-driven clinical practices. It has emerged as one of the most transformative innovations to enhance clinical decision-making and improve the precision and efficiency of endodontic care by offering new possibilities for image analysis, diagnosis, treatment planning, and prediction of clinical outcomes [12]. Beyond clinical applications, AI also contributes to research and education in endodontics. Virtual simulations, automated assessment systems, and predictive models are redefining specialist training and clinical practice by providing evidence-based support tools. However, the integration of these technologies raises ethical and technical challenges related to data privacy, model interpretability, and their seamless incorporation into clinical workflows [13]. The purpose of the present study was to identify and analyse publication trends, bibliometric indicators, and research characteristics of artificial intelligence studies published in Endodontic journals.

Materials and Methods

Search strategy

An advanced search in Web of Science "All Databases" (WoS) and Scopus was performed on September 1st, 2025, to identify the articles about AI in endodontics. For the search strategy, both the terms "(Endodontics OR Endodontic) AND (Artificial Intelligence OR AI)" were employed in the abovementioned databases. The following journals containing the term "Endodontic", "Endodontics" or "Endodontology" were included: *Australian Endodontic Journal*, *International Endodontic Journal, Iranian Endodontic Journal*, *Journal of Conservative Dentistry and Endodontics*, *Journal of Endodontics*, *Oral Surgery Oral Medicine Oral Pathology and Oral Radiology* (formerly known as *Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontology*). Original scientific articles, reviews, and case reports published in the English language were included. Editorials, letters to the editor, meeting reports, and short communications were excluded. No year of publication restriction was established.

Data extraction

Four independent researchers (BMCR, OAGA, DMCE, & JARG) analyzed the title, abstract, and if necessary, the complete article to determine the relation to AI in endodontics. When the main topic was not AI in endodontics, the article was excluded. The information extracted from each article was the title, authors, journal, and year of publication, country and institution of contribution, type of study, endodontic study field, applied AI, and keywords. A list of the top ten most cited articles was identified according to the number of citations in WoS.

The country and institution of contribution were identified based on the corresponding author's affiliation [4, 14-16]. When there were multiple corresponding authors in an article, only the last corresponding author's affiliation was considered [17]. When a corresponding author had two institutional affiliations, only the first affiliation was considered.

Data analysis

Microsoft Excel (Version 16, Microsoft, Redmond, USA) was used to record and analyze data. VOSviewer software (Version 1.6.20) (Centre for Science and Technology Studies, Leiden University, The Netherlands) was employed to create the co-authorship map and the keyword co-occurring map.

Results

The search strategy retrieved 170 publications, 119 from Scopus and 51 from WoS. After removing duplicated records and applying inclusion and exclusion criteria, a total of 48 articles were included in this study (Fig. 1).

Authors

Among the 214 identified authors, 2 participated in 8 articles, 2 in 6 articles, 1 in 5 articles, 2 in 4 articles, 6 in 3 articles, 20 in 2 articles, and 181 authors contributed to one article (Fig. 2). Mohammad-Rahimi, Hossein (*n*=8) and Nosrat, Ali (*n*=8) were the most prolific followed by Dianat, Omid (*n*=6) and Setzer, Frank C (*n*=6) (Table 2).

Country and institutions

Based on the corresponding author's affiliation, a total of 21 countries (Table 3) and 34 institutions (Table 4) contributed to the publications on AI in endodontics. Fig. 3 shows the geographical distribution of the papers.

Journal

The articles were published in 6 journals. Most of the articles were published in the *Journal of Endodontics* (*n*=28), followed by the *International Endodontic Journal* (*n*=12), *Australian Endodontic Journal* (*n*=4), the journal *Oral Surgery Oral* Medicine, *Oral Pathology Oral Radiology and Endodontology* (*n*=2), the *Iranian Endodontic Journal* and the *Journal of Conservative Dentistry and Endodontics* had one publication each (Fig. 4).

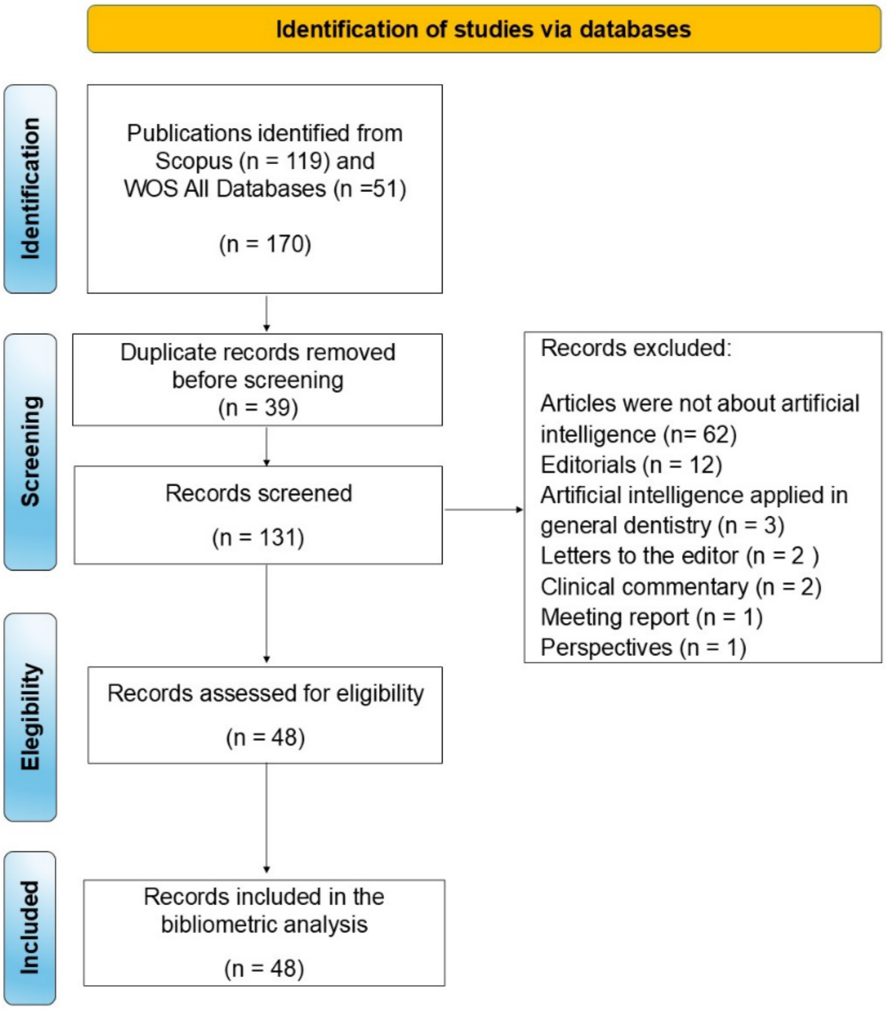

Figure 1. Article selection process flowchart

Year of publication

The articles analyzed were published between 2008 and September 1st, 2025. The year with the most publications was 2024 (*n*=16), followed by 2025 (*n*=16), 2023 (*n*=4), 2021 (*n*=4), 2022 (*n*=3), and 2020 (*n*=2). In the years 2019, 2012 and 2008 there was only one publication per year (Fig. 5).

Type of study

The type of study was classified as either basic research or review. Most of the articles analyzed corresponded to basic research (*n*=35), whereas 13 publications were review articles.

Study field

Regarding the endodontic perspective, the articles were classified in six study fields: "clinical knowledge", "endodontic education", "endodontic outcome", "general view", "radiology", and "microscopic imaging". The dominant study field was "radiology" (*n*=26), followed by clinical knowledge (*n*=10) and general view (*n*=6) (Table 5).

Keywords

A total of 238 keywords were obtained. Among the keywords, "artificial intelligence" (*n*=38), "humans" (*n*=27), "deep learning" (*n*=20), "cone-beam computed tomography" (*n*=18), "endodontics" (*n*=19), and "neural networks, computer" (*n*=10) highlight the highest number of occurrences (Fig. 6).

Top ten most-cited

The ten most cited articles about AI in endodontics are listed in Table 6.

Discussion

This study aimed to identify the characteristics and trends of the articles on AI in endodontics published in Endodontic journals. WoS and Scopus database were used to perform the search strategy. A total of 48 articles were included. Among the 214 authors, Mohammad-Rahimi Hossein and Nosrat Ali were the

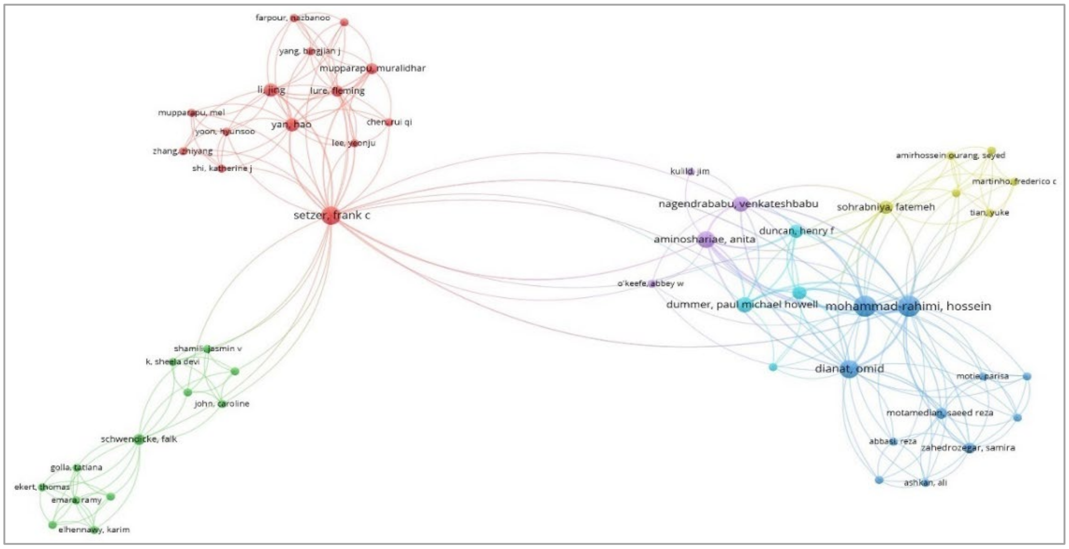

Figure 2. VOSviewer co-authorship map showing the largest network of authors (*n*=51) in publications on AI in endodontics, data until September 2025

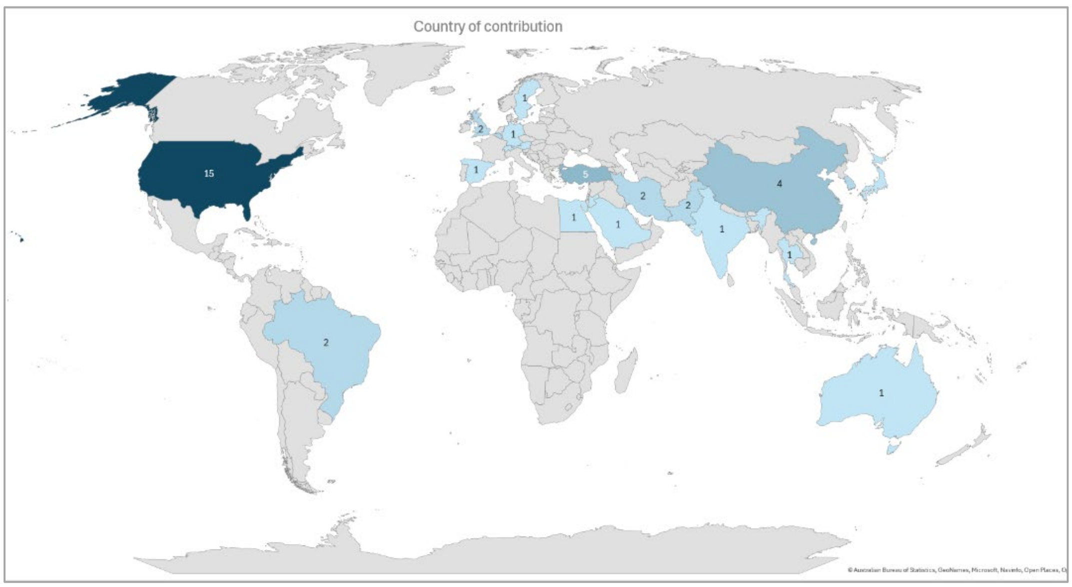

Figure 3. Geographic distribution of publications on AI in endodontics according to the country of affiliation of the corresponding author, data until September 2025

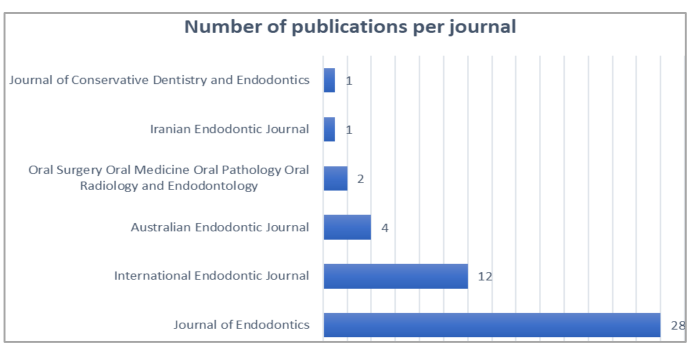

Figure 4. Journal distribution of the articles on AI in endodontics, data until September 2025

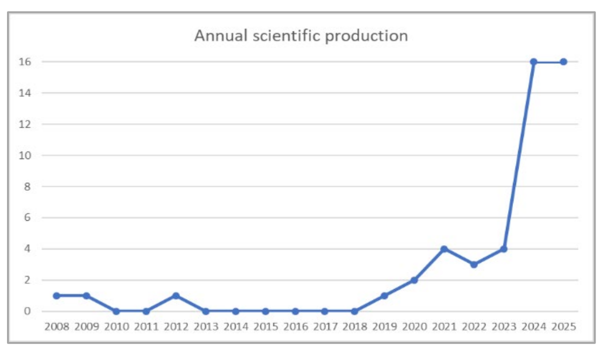

Figure 5. Year of publication of the articles on AI in endodontics, data until September 2025

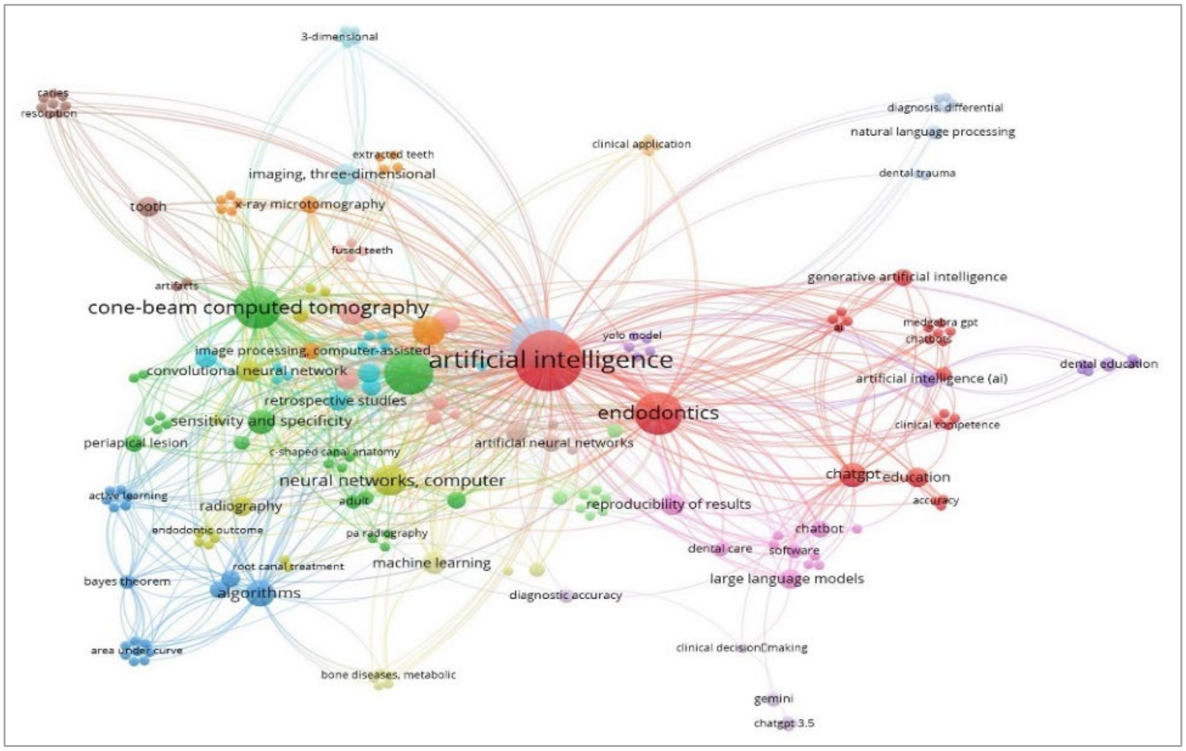

Figure 6. VOSviewer keywords co-occurrence network map. A total of 17 clusters and a maximum of 800 lines

most productive with eight articles each; both authors participated in five reviews and three basic research articles published between 2023 and 2025 with a total of 173 citations in WoS. Dianat Omid and Setzer Frank were the second most prolific authors with six publications each. Dianat Omid collaborated in four reviews and two basic research articles, which were published in 2023 and 2024 and sum 172 citations in WoS. Setzer Frank contributed to four basic research articles and two review articles published between 2020 and 2025, and 250 times cited in WoS.

The geographical distribution of publications shows a clear predominance of the United States (n=15), followed by Turkey (n=5) and China (n=4). Belgium, Brazil, Iran, Pakistan, South Korea, and the United Kingdom produced two publications each, while several other countries contributed only one. This pattern reflects a concentration of research in technologically advanced regions and a persistent global disparity in scientific productivity. This concentration raises important concerns regarding external validity and applicability, as models are trained predominantly on data from high-income regions, which may not be generalizable to settings with different patient demographics, disease prevalence, or imaging protocols. This geographic clustering also raises concerns about a digital divide, suggesting that the evolution of AI may primarily benefit populations and infrastructures in high-income regions. Such disparity risks limiting the generalizability of models globally and hindering adoption in developing nations where access to advanced hardware, such as cone-beam computed tomography (CBCT), remains restricted. Addressing this imbalance requires international collaborative networks, the sharing of multicenter datasets, inclusive data governance, and the development of scalable AI solutions to ensure that technological advancements result in equitable improvements in global endodontic care. This geographic and institutional concentration underscores a significant challenge for equitable AI translation. Research output is heavily skewed toward high-resource settings with advanced imaging infrastructure (*e.g.*, CBCT), which are often used to train and validate models. This creates a dual risk: first, of developing algorithms with inherent bias, as they may not generalize to populations with different disease prevalence, anatomy, or image acquisition standards; and second, of exacerbating a ‘translational divide’ where AI tools are designed for and accessible only to well-resourced clinical environments. Future efforts must prioritize the creation of diverse, multicenter datasets and the development of computationally efficient or frugal AI models that can function effectively with lower-cost imaging modalities to ensure global relevance and adoption.

Table 1. Articles about AI in endodontics, including year of publication, title, author, journal, study type, study field, AI, and primary AI task

Year	Author	Journal	Study type	Study field	Artificial intelligence	Primary AI task
2008	Suebnukarn *et al.* [18]	OOO	BR	Endodontic outcome	Bayesian network	Prediction
2012	Saghiri *et al.* [19]	JOE	BR	Radiology	Artificial Neural Network	Detection
2019	Ekert *et al.* [20]	JOE	BR	Radiology	CNN, DL	Detection
2020	Orhan *et al.* [21]	IEJ	BR	Radiology	CNN type U-Net	Detection
2020	Setzer *et al.* [22]	JOE	BR	Radiology	Multilabel U-Net	Detection
2021	Lahoud *et al.* [23]	JOE	BR	Radiology	CNN+Feature Pyramid Network	Segmentation
2021	Aminoshariae *et al.* [24]	JOE	RA	General view	ANN, CNN, ML, DL, PNN, CBR	Multi-purpose (review)
2021	Sherwood *et al.* [25]	JOE	BR	Radiology	U-Net, Residual U-Net, Xception U-Net	Segmentation & Classification
2021	Lin *et al.* [26]	JOE	BR	Radiology	U-Net Network (DL)	Segmentation
2022	Umer & Habib [27]	JOE	RA	General view	ML, ANN, CNN, DL, PNN	Multi-purpose (review)
2022	Kirnbauer *et al.* [28]	JOE	BR	Radiology	Spatial Configuration-Net + U-Net 3D	Detection
2022	Yang *et al.* [29]	JOE	BR	Radiology	Deep Convolutional Neural Network	Classification
2023	Sadr *et al.* [30]	JOE	RA	Radiology	ResNet, U-Net, Faster/YOLO, Dense Unet, AlexNet, GoogLeNet, VGG16	Detection (review)
2023	Lee *et al.* [31]	JOE	BR	Radiology	DCNN with self-attention (PRESSAN-17)	Prediction
2023	Marwaha [32]	JCDE	RA	General view	CNN/ANN	Multi-purpose (review)
2023	Farajollahi *et al.* [33]	AEJ	RA	Radiology	DL/CNN, U-Net, Faster/Mask R-CNN	Detection (review)
2024	Suárez *et al.* [34]	IEJ	BR	Clinical knowledge	ChatGPT	Generation
2024	Mohammad-Rahimi *et al.* [35]	IEJ	BR	Clinical knowledge	GPT-3.5	Generation
2024	Aminoshariae *et al.* [36]	JOE	RA	Endodontic education	AI for education (AI/ML/DL; AR/VR for training)	Multi-purpose (review)
2024	Mohammad-Rahimi *et al.* [13]	IEJ	RA	General view	ML/DL	Multi-purpose (review)
2024	Ourang *et al.* [37]	IEJ	RA	General view	ML/DL	Multi-purpose (review)
2024	Mohammad-Rahimi *et al.* [38]	JOE	BR	Radiology	Self-supervised contrastive learning (DINO, BYOL, MoCo v2, *etc.*)	Detection
2024	Özbay *et al.* [39]	AEJ	BR	Radiology	Mask R-CNN model (DL)	Detection
2024	Asgary [40]	IranEJ	RA	General view	CNN/ANN	Multi-purpose (review)
2024	Huang *et al.* [41]	JOE	BR	Radiology	Bayesian U-Net (DL)	Segmentation
2024	Adnan *et al.* [42]	OOO	BR	Radiology	U-Net, Mak RCNN	Segmentation &

						Detection
2024	Alfadley *et al.* [43]	JOE	RA	Radiology	DL	Segmentation (review)
2024	de Araujo *et al.* [44]	JOE	BR	Clinical knowledge	ChatGPT-4	Classification
2024	Wu *et al.* [45]	JOE	BR	Radiology	VGG19, ResNet18, ResNet50 and EfficientNet-b5	Classification
2024	Yang *et al.* [46]	JOE	BR	Radiology	YOLOv7 + EfficientNet	Detection & Classification
2024	Chen *et al.* [47]	JOE	BR	Radiology	U-Net (CNN) and Swin-UNETR	Segmentation & Detection
2024	Ji *et al.* [48]	JOE	BR	Radiology	DL (BasicVSR; super-resolution)	Generation
2025	Fontenele & Jacobs [49]	IEJ	RA	Radiology	convolutional neural networks	Multi-purpose (review)
2025	Santos-Junior *et al.* [50]	IEJ	BR	Radiology	CNN on CBCT	Segmentation
2025	Abdulrab *et al.* [51]	JOE	BR	Clinical knowledge	LLM chatbots (ChatGPT-4o, MedGebra GPT-4o, Meta Llama 3, Gemini Advanced)	Generation
2025	Reader & Drum [52]	JOE	RA	Clinical knowledge	LLM (ChatGPT)	Generation (review)
2025	Arılı Öztürk *et al.* [53]	IEJ	BR	Clinical knowledge	ChatGPT-4 and ChatGPT-4o	Generation
2025	Mohammad-Rahimi *et al.* [54]	IEJ	RA	Endodontic education	NLP-based chatbots (LLMs; ML/DL)	Generation (review)
2025	Allihaibi *et al.* [55]	JOE	BR	Radiology	Diagnocat Platform (DL and CNNs)	Detection
2025	Allihaibi *et al.* [56]	IEJ	BR	Radiology	Diagnocat Platform (DL and CNNs)	Detection
2025	Aljamani *et al.* [57]	JOE	BR	Clinical knowledge	ChatGPT-3.5 and Gemini	Generation
2025	Ran *et al.* [58]	JOE	BR	Radiology	XGBoost LightGBM CatBoost	Detection & Classification
2025	Karataş *et al.* [59]	AEJ	BR	Microscopic imaging	YOLO	Detection
2025	Bubna *et al.* [60]	JOE	BR	Clinical knowledge	ChatGPT-4 API	Generation
2025	Ibrahim *et al.* [61]	IEJ	BR	Endodontic education	Siamese Neural Network (SNN)	Segmentation & Detection
2025	Jalali *et al.* [62]	JOE	BR	Clinical knowledge	Gemini Advanced, Gemini, Microsoft Copilot, GPT-3.5, GPT-4o, GPT-4.0, and Claude 3.5 Sonnet	Generation
2025	Prinz *et al.* [63]	IEJ	BR	Endodontic education	GPT-4-turbo	Generation
2025	Çakar et *al.* [64]	AEJ	BR	Clinical knowledge	Gemini 1.5 Flash, Gemini 1.5 Pro, ChatGPT-3.5 and ChatGPT-4	Generation

AEJ, Australian Endodontic Journal; IEJ, International Endodontic Journal; IranEJ, Iranian Endodontic Journal; JCDE, Journal of Conservative Dentistry and Endodontics; JOE, Journal of Endodontics; OOO, Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology; BR, basic research; RA, review article; ANN, artificial neural network; AR/VR, augmented reality/virtual reality; CNN, convolutional neural network; DL, deep learning; LLM, large language model; ML, machine learning; NLP, natural language processing; VGG, visual geometry group; YOLO, you only look once.

Table 2. Authors with three or more publications

Author	Number of articles
Mohammad-Rahimi, Hossein	8
Nosrat, Ali	8
Dianat, Omid	6
Setzer, Frank C	6
Aminoshariae, Anita	5
Dummer, Paul Michael Howell	4
Nagendrababu, Venkateshbabu	4
Duncan, Henry F	3
Jacobs, Reinhilde	3
Li, Jing	3
Ourang, Seyed AmirHossein	3
Sohrabniya, Fatemeh	3
Yan, Hao	3

Table 3. Contributing countries to the publications on AI in endodontics

Countries	Number of articles
United States of America	15
Turkey	5
China	4
Belgium	2
Brazil	2
Iran	2
Pakistan	2
South Korea	2
United Kingdom	2
Australia	1
Austria	1
Egypt	1
Germany	1
India	1
Japan	1
Jordan	1
Saudi Arabia	1
Spain	1
Sweden	1
Switzerland	1
Thailand	1

Table 4. Contributing institutions to the publications on AI in endodontics

Institutions	Number of articles
University of Maryland	7
University of Pennsylvania	4
Aga Khan University Hospital	2
Case School of Dental Medicine	2
King's College London	2
Tuiuti University of Paraná	2
University of Leuven	2
Yonsei University	2
Aichi Gakuin University	1
Atatürk University	1
Azad University	1
Charité-Universitätsmedizin Berlin	1
Erciyes University	1
Huazhong University of Science and Technology	1
Kafrelsheikh University	1
Karabük University	1
Karolinska Institute	1
King Saud bin Abdulaziz University for Health Sciences	1
Maharishi Markandeshwar College of Dental Sciences and Research	1
Marquette University	1
Osmangazi University	1
Shahid Beheshti University of Medical Sciences	1
Shanghai Jiao Tong University	1
Sichuan University	1
Thammasat University	1
The Ohio State University	1
Tongji University	1
Trakya University	1
Universidad Europea de Madrid	1
University of Bern	1
University of Graz	1
University of Jordan	1
University of Queensland	1

Table 5. Study field of the articles on AI in endodontics

Study field	Number of articles
Radiology	26
Clinical knowledge	10
General view	6
Endodontic education	4
Endodontic outcome	1
Microscopic imaging	1

Thirty-three institutions contributed to the field. The University of Maryland led with seven publications, followed by the University of Pennsylvania (*n*=4) and several institutions with two each. Most institutions produced a single article, indicating that AI research in endodontics remains concentrated in a small number of well-equipped academic centers that function as global innovation hubs.

Previous bibliometric analyses have reported that the Journal of Endodontics and the International Endodontic Journal are the most influential journals in the field of endodontics [65] [66]; [16, 67]. In line with previous studies, in our study, most papers on AI in endodontics were published in the Journal of Endodontics (*n*=28) and the International Endodontic Journal (*n*=12). This finding reflects these journals' leadership in disseminating emerging technologies within the field of endodontics and emphasizes their commitment to high-quality evidence.

Regarding the year of publication, studies ranged from 2008 to 2025, with a notable rise in the last two years. This recent increase reflects the rapid technological advances in DL, imaging, and computational capacity, as well as a growing interdisciplinary collaboration between dental researchers and computer scientists. This pattern shows that AI in endodontics is changing from an exploratory research topic to a consolidated area of scientific interest.

The finding that 35 of 48 analyzed articles are classified as basic research indicates that AI in endodontics remains at a conceptual level, primarily focused on establishing methodological frameworks and algorithm validation. This heavy concentration on radiological applications, such as periapical imaging and root morphology, reflects a "proof-of-concept" phase aimed at refining image recognition and data processing. However, such reliance on experimental designs may delay the seamless integration of AI into active chairside workflows. To bridge this gap, research must transition from purely diagnostic modeling toward prospective clinical trials that evaluate the impact of AI on procedural outcomes and real-world clinical decision-making within diverse endodontic settings.

In terms of the study field, more than half of the articles belonged to radiology (*n*=26), highlighting the clinical relevance of AI in supporting diagnostic accuracy and efficiency. Most investigations have applied DL architectures, particularly convolutional neural networks (CNNs), to detect periapical lesions and to evaluate root canal morphology by means of CBCT and periapical radiographs. These advances demonstrate AI's potential to assist clinicians in reducing interpretation errors, optimizing treatment planning, and enhancing overall diagnostic performance, although they require standardized data acquisition and rigorous algorithm validation [68]. In second place was "clinical knowledge" (*n*=10), this category included all the articles that evaluated the accuracy of AI-generated answers to questions in the field of endodontics. Interestingly, all the "clinical knowledge" articles have been published in 2024 and 2025, which represents a novel AI research approach in endodontics.

Early efforts to incorporate AI into endodontics relied on artificial neural networks (ANNs) and Bayesian models for diagnostic tasks and clinical outcome prediction [18, 19].
Although these pioneering studies demonstrated the feasibility of AI-assisted dentistry, their dependence on manually engineered features and limited datasets constrained robustness and clinical generalizability. Since 2019, the field has transitioned toward CNNs, enabling automatic feature extraction and substantially improving

Table 6. Number of citations of the top-ten most cited articles (September 2025).

Rank	Title of the article	Number of citations			
		WoS	Scopus	PubMed	Google Scholar
1	Deep learning for the radiographic detection of apical lesions	276	266	185	412
2	Evaluation of artificial intelligence for detecting periapical pathosis on cone-beam computed tomography scans	226	224	166	375
3	Artificial intelligence for the computer-aided detection of periapical lesions in cone-beam computed tomographic images	163	159	107	227
4	Artificial intelligence in endodontics: current applications and future directions	146	131	84	251
5	Artificial intelligence for fast and accurate 3-dimensional tooth segmentation on cone-beam computed tomography	135	138	100	200
6	Unveiling the ChatGPT phenomenon: Evaluating the consistency and accuracy of endodontic question answers	102	87	73	138
7	The reliability of artificial neural network in locating minor apical foramen: A cadaver study	72	70	43	128
8	Critical analysis of artificial intelligence in endodontics: A scoping review	61	57	45	83
9	Deep learning for detection of periapical radiolucent lesions: A systematic review and meta-analysis of diagnostic test accuracy	60	53	45	91
10	Validity and reliability of artificial intelligence chatbots as public sources of information on endodontics	55	58	48	73

the detection of apical and periapical lesions in radiographs and CBCT images, often achieving performance comparable to human experts [20, 21]. In parallel, segmentation-oriented architectures such as U-Net and its variants emerged as key tools for delineating complex dental anatomy.

Subsequent studies introduced advanced and hybrid CNN-based architectures to enhance diagnostic automation. Multilabel U-Net, feature pyramid networks (FPN), and residual U-Net demonstrated improved accuracy, sensitivity, and intersection-over-union (IoU), supporting tasks such as root canal segmentation and endodontic treatment planning [22, 23, 26]. The integration of deeper residual architectures, including ResNet and Xception, further improved model generalizability across heterogeneous datasets and real clinical conditions [25]. CNNs were also extended to classify three-dimensional root canal morphology using two-dimensional radiographs, reinforcing their role as a robust technical foundation for automated image analysis in endodontics [26, 27].

Object detection frameworks such as You Only Look Once (YOLO) and Mask Region-based CNN (Mask R-CNN) expanded AI applications to the identification of canal orifices, fractured instruments, and localized lesions. Hybrid pipelines combining U-Net with YOLO or Faster Region-based Convolutional Neural Network (Faster R-CNN) demonstrated strong performance in detection, segmentation, and regional analysis tasks, highlighting the versatility of DL approaches for comprehensive diagnostic workflows [30, 33].

In 2024, the emergence of generative language models marked a paradigm shift in AI integration within endodontics, particularly in education and decision support. Evaluations of ChatGPT revealed coherent responses to theoretical and clinical questions, while also identifying limitations in contextual reasoning and causal inference [34, 37]. Complementary studies highlighted the potential of generative models as virtual tutors, providing adaptive learning environments that promote autonomy and immediate feedback in endodontic education [36].

From a clinical perspective, DL continued to demonstrate diagnostic utility. Mask R-CNN–based models achieved high accuracy in detecting fractured endodontic instruments in periapical radiographs, offering promising tools to reduce diagnostic errors and treatment delays [39]. A systematic review by Asgary [40] documented a rapid increase in AI-focused endodontic publications, particularly in periapical lesion detection, automated pulp space segmentation, clinical outcome prediction, and educational chatbots, confirming that AI enhances both diagnostic performance and reproducibility of radiographic interpretation.

Advanced segmentation approaches incorporated Bayesian inference within U-Net/V-Net architectures for multilabel lesion detection and scalable CBCT analysis [41]. Other studies proposed multimodal frameworks combining U-Net with Faster R-CNN or Mask R-CNN to segment periapical pathology and associate lesions with causative teeth in panoramic radiographs [42]. Reviews of CBCT-based AI methods identified U-Net derivatives, generative adversarial networks (cGANs), YOLOv5, and specialized frameworks such as PulpNet as dominant architectures between 2020 and 2024, supporting diagnosis, treatment planning, and preclinical education [43].

AI has also enabled advanced three-dimensional analysis of root canal morphology. CNNs trained on combined micro-CT and CBCT data outperformed endodontic residents in identifying canal configurations [45]. Super-resolution techniques based on BasicVSR networks reduced discrepancies in canal volume and length, facilitating MB2 identification in maxillary molars [48]. Transformer-based architectures such as UNETR and Swin-UNETR further advanced CBCT lesion segmentation while reducing training costs and reliance on large pretraining datasets [47].

Recent studies indicate a transition from purely CNN-based models toward generative approaches, including Generative Adversarial Networks (GANs) and transformers, to enhance robustness and data augmentation [49]. Commercial platforms such as Diagnocat demonstrated diagnostic performance comparable to experienced clinicians in detecting periapical radiolucencies, although further validation against CBCT remains necessary [56]. AI-driven educational platforms and object detection models have also improved anatomical identification and clinical training outcomes [59, 63].

In endodontics, AI applications have primarily focused on the detection of periapical lesions, the analysis of root canal morphology, and automated segmentation using periapical radiographs and CBCT, with radiology as the dominant domain of study.

From a methodological perspective, the earliest applications of artificial intelligence in the field relied mainly on Bayesian approaches and artificial neural network (ANN) models, targeting tasks such as predicting endodontic treatment outcomes and detecting the apical foramen. With technological advancements, the field transitioned to more complex deep learning architectures, notably CNNs for automatic lesion detection, as well as specialized variants such as U-Net and residual networks for precise segmentation of anatomical structures. Taken together, these architectures enabled significant advances in detection, classification, and segmentation tasks in clinical imaging, improving diagnostic accuracy.

More recently, the incorporation of large language models (LLMs) introduced a new dimension to the use of artificial intelligence in endodontics, particularly in the processing of textual information and in the generation of knowledge-based clinical responses. In this context, their use has been oriented toward education and clinical knowledge assessment, specifically in question-and-answer (Q&A) tasks and in conversational systems that act as agents, providing feedback and adaptive learning.

The bibliometric analysis demonstrates a growing interaction of artificial intelligence in endodontics, with more than 50% of the included studies published between 2024 and 2025. This growth reflects technological, computational, and methodological advances, particularly in deep learning for medical imaging and in the interdisciplinary collaboration between dentistry and computer science. Despite this increase, the evidence suggests that AI applications in endodontics remain in a pre-clinical phase, as most studies focus on algorithm development, validation, and comparative performance evaluation to establish methodological foundations prior to clinical adoption.

It is appropriate to recognize the limitations of this study. A first limitation is that only endodontic journals indexed in WoS and Scopus were included; relevant articles not indexed in these databases may be excluded. A second limitation is the reduced number of keywords chosen for the search query; other terms like "deep learning" and "machine learning" may allow to retrieve a wider quantity of publications. Third, while using the last corresponding author's affiliation is a conventional bibliometric approach, it represents a deliberate simplification for analysis. This method may inadvertently undervalue the intellectual contribution and leadership of first or co-corresponding authors from other institutions, particularly in international collaborations. Consequently, the resulting geographic and institutional distributions (Figs. 2 & 3, Tables 3 & 4) should be interpreted as highlighting primary hubs of senior supervisory and communicative responsibility, rather than as a complete map of all contributing research nodes.

Future analysis could focus on AI and its application in specific endodontic fields such as education or radiology. Furthermore, studies could include databases such as Google Classroom, PubMed, or the Directory of Open Access Journals to have a broader perspective of the topic. Future AI research in endodontics should adopt guidelines such as CONSORT-AI [69] or TRIPOD-AI [70] to promote methodological standardization, transparency, reproducibility, and objective model evaluation.

Conclusions

This bibliometric study demonstrates the growing adoption of DL techniques in endodontic research, where universities from countries such as the United States of America, Turkey, and China have integrated computational tools into endodontics, primarily focusing on radiology. Mohammad-Rahimi, Hossein, and Nosrat, Ali were the most prolific authors. The University of Maryland had the highest number of publications. The articles were mainly published in the *Journal of Endodontics*. More than half of the articles were published between 2024 and 2025. Basic research was the main study type. The article "Deep Learning for the Radiographic Detection of Apical Lesions", published in 2019, was the most cited paper.

The analysis shows a trend toward clinical decision-support systems and marks a transition from AI as a purely diagnostic tool to a cognitive clinical assistant that accompanies the endodontist throughout diagnosis, planning, treatment, and prognosis. Artificial intelligence literacy will become an essential component of modern endodontic education, aimed at optimizing diagnosis, enhancing therapeutic precision, and strengthening patient safety.

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Conflict of interest

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Authors' contributions

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References

1. Pritchard J. Statistical-Bibliography or Bibliometrics? Journal of Documentation. 1969;25(4):348-9.
2. Montazeri A, Mohammadi S, P MH, Ghaemi M, Riazi H, Sheikhi-Mobarakeh Z. Preliminary guideline for reporting bibliometric reviews of the biomedical literature (BIBLIO): a minimum requirements. Syst Rev. 2023;12(1):239.
3. Fardi A, Kodonas K, Gogos C, Economides N. Top-cited articles in endodontic journals. J Endod. 2011;37(9):1183-90.
4. Ahmad P, Dummer PMH, Chaudhry A, Rashid U, Saif S, Asif JA. A bibliometric study of the top 100 most-cited randomized controlled trials, systematic reviews and meta-analyses published in endodontic journals. Int Endod J. 2019;52(9):1297-316.

5. Fu D, Yao L, Zhu H, Yan Y, Ji M, Li Y, et al. The landscape of endodontic education research area: A bibliometric analysis. J Dent Educ. 2023;87(5):711-20.
6. Nagendrababu V, Jacimovic J, Jakovljevic A, Rossi-Fedele G, Dummer PMH. A bibliometric analysis of the top 100 most-cited case reports and case series in Endodontic journals. Int Endod J. 2022;55(3):185-218.
7. Silva E, Pinto KP, Ajuz NC, Sassone LM. Ten years of minimally invasive access cavities in Endodontics: a bibliometric analysis of the 25 most-cited studies. Restor Dent Endod. 2021;46(3):e42.
8. Sheikh H, Prins C, Schrijvers E. Artificial Intelligence: Definition and Background. In: Sheikh H, Prins C, Schrijvers E, editors. Mission AI: The New System Technology. Cham: Springer International Publishing; 2023. p. 15-41.
9. Topol EJ. High-performance medicine: the convergence of human and artificial intelligence. Nat Med. 2019;25(1):44-56.
10. Russell S, Norvig P. Artificial Intelligence: A Modern Approach, Global Edition: Pearson Education; 2021.
11. Kishen A, Peters OA, Zehnder M, Diogenes AR, Nair MK. Advances in endodontics: Potential applications in clinical practice. J Conserv Dent. 2016;19(3):199-206.
12. Isufi A, Deriu MA, Shah STH, Pasqualini D. On the Horizon: What's Next for Endodontics. Dent Clin North Am. 2025;69(4):603-16.
13. Mohammad-Rahimi H, Sohrabniya F, Ourang SA, Dianat O, Aminoshariae A, Nagendrababu V, et al. Artificial intelligence in endodontics: Data preparation, clinical applications, ethical considerations, limitations, and future directions. Int Endod J. 2024;57(11):1566-95.
14. Ahmad P, Elgamal HAM. Citation Classics in the Journal of Endodontics and a Comparative Bibliometric Analysis with the Most Downloaded Articles in 2017 and 2018. J Endod. 2020;46(8):1042-51.
15. Dos Reis-Prado AH, Maia CA, Nunes GP, de Arantes LC, Abreu LG, Duncan HF, et al. Top 100 most-cited scientific articles in regenerative endodontics 2019-2023: A bibliometric analysis. Int Endod J. 2024;57(10):1434-52.
16. Deng Y, Zhang J, Wang X, Yang L, He Q, Huang D, et al. A bibliometric analysis of root canal irrigation: From laboratory to clinical practice. Aust Endod J. 2025;51(1):197-208.
17. Ho Y-S. Bibliometric Analysis of the Journal of Orthopaedic Research from 1991 To 2018. Orthopedic Research Online Journal. 2019;6(2).
18. Suebnukarn S, Rungcharoenporn N, Sangsuratham S. A Bayesian decision support model for assessment of endodontic treatment outcome. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2008;106(3):e48-58.
19. Saghiri MA, Garcia-Godoy F, Gutmann JL, Lotfi M, Asgar K. The reliability of artificial neural network in locating minor apical foramen: a cadaver study. J Endod. 2012;38(8):1130-4.
20. Ekert T, Krois J, Meinhold L, Elhennawy K, Emara R, Golla T, et al. Deep Learning for the Radiographic Detection of Apical Lesions. J Endod. 2019;45(7):917-22.e5.
21. Orhan K, Bayrakdar IS, Ezhov M, Kravtsov A, Ozyurek T. Evaluation of artificial intelligence for detecting periapical pathosis on cone-beam computed tomography scans. Int Endod J. 2020;53(5):680-9.
22. 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;46(7):987-93.
23. Lahoud P, EzEldeen M, Beznik T, Willems H, Leite A, Van Gerven A, et al. Artificial Intelligence for Fast and Accurate 3-Dimensional Tooth Segmentation on Cone-beam Computed Tomography. J Endod. 2021;47(5):827-35.
24. Aminoshariae A, Kulild J, Nagendrababu V. Artificial Intelligence in Endodontics: Current Applications and Future Directions. J Endod. 2021;47(9):1352-7.
25. Sherwood AA, Sherwood AI, Setzer FC, K SD, Shamili JV, John C, et al. A Deep Learning Approach to Segment and Classify C-Shaped Canal Morphologies in Mandibular Second Molars Using Cone-beam Computed Tomography. J Endod. 2021;47(12):1907-16.
26. Lin X, Fu Y, Ren G, Yang X, Duan W, Chen Y, et al. Micro-Computed Tomography-Guided Artificial Intelligence for Pulp Cavity and Tooth Segmentation on Cone-beam Computed Tomography. J Endod. 2021;47(12):1933-41.
27. Umer F, Habib S. Critical Analysis of Artificial Intelligence in Endodontics: A Scoping Review. J Endod. 2022;48(2):152-60.
28. Kirnbauer B, Hadzic A, Jakse N, Bischof H, Stern D. Automatic Detection of Periapical Osteolytic Lesions on Cone-beam Computed Tomography Using Deep Convolutional Neuronal Networks. J Endod. 2022;48(11):1434-40.
29. Yang S, Lee H, Jang B, Kim KD, Kim J, Kim H, et al. Development and Validation of a Visually Explainable Deep Learning Model for Classification of C-shaped Canals of the Mandibular Second Molars in Periapical and Panoramic Dental Radiographs. J Endod. 2022;48(7):914-21.
30. Sadr S, Mohammad-Rahimi H, Motamedian SR, Zahedrozegar S, Motie P, Vinayahalingam S, et al. Deep Learning for Detection of Periapical Radiolucent Lesions: A Systematic Review and Meta-analysis of Diagnostic Test Accuracy. J Endod. 2023;49(3):248-61 e3.
31. Lee J, Seo H, Choi YJ, Lee C, Kim S, Lee YS, et al. An Endodontic Forecasting Model Based on the Analysis of Preoperative Dental Radiographs: A Pilot Study on an Endodontic Predictive Deep Neural Network. J Endod. 2023;49(6):710-9.
32. Marwaha J. Artificial intelligence in conservative dentistry and endodontics: A game-changer. J Conserv Dent Endod. 2023;26(5):514-8.
33. Farajollahi M, Safarian MS, Hatami M, Esmaeil Nejad A, Peters OA. Applying artificial intelligence to detect and analyse oral and maxillofacial bone loss-A scoping review. Aust Endod J. 2023;49(3):720-34.
34. Suarez A, Diaz-Flores Garcia V, Algar J, Sanchez MG, de Pedro ML, Freire Y. Unveiling the ChatGPT phenomenon: Evaluating the consistency and accuracy of endodontic question answers. Int Endod J. 2024;57(3):371-2.
35. Mohammad-Rahimi H, Ourang SA, Pourhoseingholi MA, Dianat O, Dummer PMH, Nosrat A. Validity and reliability of artificial intelligence chatbots as public sources of information on endodontics. Int Endod J. 2024;57(3):305-14.
36. Aminoshariae A, Nosrat A, Nagendrababu V, Dianat O, Mohammad-Rahimi H, O'Keefe AW, et al. Artificial Intelligence in Endodontic Education. J Endod. 2024;50(5):562-78.
37. Ourang SA, Sohrabniya F, Mohammad-Rahimi H, Dianat O, Aminoshariae A, Nagendrababu V, et al. Artificial intelligence in endodontics: Fundamental principles, workflow, and tasks. Int Endod J. 2024;57(11):1546-65.
38. Mohammad-Rahimi H, Dianat O, Abbasi R, Zahedrozegar S, Ashkan A, Motamedian SR, et al. Artificial Intelligence for Detection of External Cervical Resorption Using Label-Efficient Self-Supervised Learning Method. J Endod. 2024;50(2):144-53 e2.
39. Ozbay Y, Kazangirler BY, Ozcan C, Pekince A. Detection of the separated endodontic instrument on periapical radiographs using a deep learning-based convolutional neural network algorithm. Aust Endod J. 2024;50(1):131-9.

40. Asgary S. Artificial Intelligence in Endodontics: A Scoping Review. Iran Endod J. 2024;19(2):85-98.
41. Huang J, Farpour N, Yang BJ, Mupparapu M, Lure F, Li J, et al. Uncertainty-based Active Learning by Bayesian U-Net for Multi-label Cone-beam CT Segmentation. J Endod. 2024;50(2):220-8.
42. Adnan N, Umer F, Malik S, Hussain OA. Multi-model deep learning approach for segmentation of teeth and periapical lesions on pantomographs. Oral Surg Oral Med Oral Pathol Oral Radiol. 2024;138(1):196-204.
43. Alfadley A, Shujaat S, Jamleh A, Riaz M, Aboalela AA, Ma H, et al. Progress of Artificial Intelligence-Driven Solutions for Automated Segmentation of Dental Pulp Space on Cone-Beam Computed Tomography Images. A Systematic Review. J Endod. 2024;50(9):1221-32.
44. de Araujo BMM, de Jesus Freitas PF, Deliga Schroder AG, Kuchler EC, Baratto-Filho F, Ditzel Westphalen VP, et al. PAINe: An Artificial Intelligence-based Virtual Assistant to Aid in the Differentiation of Pain of Odontogenic versus Temporomandibular Origin. J Endod. 2024;50(12):1761-5 e2.
45. Wu W, Chen S, Chen P, Chen M, Yang Y, Gao Y, et al. Identification of Root Canal Morphology in Fused-rooted Mandibular Second Molars From X-ray Images Based on Deep Learning. J Endod. 2024;50(9):1289-97 e1.
46. Yang S, Kim KD, Kise Y, Nozawa M, Mori M, Takata N, et al. External Validation of the Effect of the Combined Use of Object Detection for the Classification of the C-Shaped Canal Configuration of the Mandibular Second Molar in Panoramic Radiographs: A Multicenter Study. J Endod. 2024;50(5):627-36.
47. Chen RQ, Lee Y, Yan H, Mupparapu M, Lure F, Li J, et al. Leveraging Pretrained Transformers for Efficient Segmentation and Lesion Detection in Cone-Beam Computed Tomography Scans. J Endod. 2024;50(10):1505-14 e1.
48. Ji Y, Chen Y, Liu G, Long Z, Gao Y, Huang D, et al. Construction and Evaluation of an AI-based CBCT Resolution Optimization Technique for Extracted Teeth. J Endod. 2024;50(9):1298-306.
49. Fontenele RC, Jacobs R. Unveiling the power of artificial intelligence for image-based diagnosis and treatment in endodontics: An ally or adversary? Int Endod J. 2025;58(2):155-70.
50. Santos-Junior AO, Fontenele RC, Neves FS, Tanomaru-Filho M, Jacobs R. A novel artificial intelligence-powered tool for automated root canal segmentation in single-rooted teeth on cone-beam computed tomography. Int Endod J. 2025;58(4):658-71.
51. Abdulrab S, Abada H, Mashyakhy M, Mostafa N, Alhadainy H, Halboub E. Performance of 4 Artificial Intelligence Chatbots in Answering Endodontic Questions. J Endod. 2025;51(5):602-8.
52. Reader A, Drum M. A review of ChatGPT as a reliable source of scientific information regarding endodontic local anesthesia. Journal of Endodontics. 2025;51(5):571-6.
53. Arılı Öztürk E, Turan Gökduman C, Çanakçi BC. Evaluation of the performance of ChatGPT-4 and ChatGPT-4o as a learning tool in endodontics. Int Endod J. 2025.
54. Mohammad-Rahimi H, Setzer FC, Aminoshariae A, Dummer PMH, Duncan HF, Nosrat A. Artificial intelligence chatbots in endodontic education-Concepts and potential applications. Int Endod J. 2025.
55. Allihaibi 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. Journal of Endodontics. 2025;51(7):898-908. e8.
56. Allihaibi M, Koller G, Mannocci F. The detection of apical radiolucencies in periapical radiographs: A comparison between an artificial intelligence platform and expert endodontists with CBCT serving as the diagnostic benchmark. Int Endod J. 2025;58(8):1146-57.
57. Aljamani S, Hassona Y, Fansa HA, H MS, Dafi Jamani K. Evaluating Large Language Models in Addressing Patient Questions on Endodontic Pain: A Comparative Analysis of Accessible Chatbots. J Endod. 2025;51(11):1617-24.
58. Ran S, Wang Q, Wang J, Huang J, Zhou W, Zhang P, et al. Diagnosis of In Vivo Vertical Root Fracture in Endodontically Treated Teeth Using Machine Learning Techniques. J Endod. 2025;51(10):1393-404.
59. Karatas E, Unal O, Celik O, Bayrakdar IS. Artificial Intelligence for Root Canal Orifice Identification Using Dental Operating Microscope Images: A Preliminary Evaluation. Aust Endod J. 2025;51(2):407-14.
60. Bubna DP, de Jesus Freitas PF, Ferraz AX, Abuabara A, Baratto-Filho F, de Araujo BMdM, et al. Dental trauma evo–development of an artificial intelligence-powered chatbot to support professional management of dental trauma. Journal of Endodontics. 2025.
61. Ibrahim M, Omidi M, Guentsch A, Gaffney J, Talley J. Ensuring integrity in dental education: Developing a novel AI model for consistent and traceable image analysis in preclinical endodontic procedures. Int Endod J. 2025.
62. Jalali P, Mohammad-Rahimi H, Wang FM, Sohrabniya F, AmirHossein Ourang S, Tian Y, et al. Performance of 7 Artificial Intelligence Chatbots on Board-style Endodontic Questions. J Endod. 2025;51(10):1413-9.
63. Prinz M, Schafer E, Burklein S, Donnermeyer D. Endodontic diagnostics training in undergraduate dental education: An observational pilot study on AI-driven virtual patient e-learning. Int Endod J. 2025.
64. Cakar M, Avci ATE, Duzgun S, Aslan T, Hekimoglu KN. Assessment of the Accuracy of Modern Artificial Intelligence Chatbots in Responding to Endodontic Queries. Aust Endod J. 2025;51(3):732-9.
65. Mishra L, Kim HC, Singh NR, Rath PP. The top 10 most-cited articles on the management of fractured instruments: a bibliometric analysis. Restor Dent Endod. 2019;44(1):e2.
66. Usta SN, Betancourt P, Ceylan A, Keskin C. The cutting-edge roles of lasers in endodontics: A bibliometric and scientometric analysis of the 100 most-cited articles. Lasers Med Sci. 2024;39(1):219.
67. Yilmaz B, Dincol ME, Yalcin TY. A bibliometric analysis of the 103 top-cited articles in endodontics. Acta Odontol Scand. 2019;77(8):574-83.
68. Schwendicke F, Golla T, Dreher M, Krois J. Convolutional neural networks for dental image diagnostics: A scoping review. J Dent. 2019;91:103226.
69. Liu X, Cruz Rivera S, Moher D, Calvert MJ, Denniston AK, Spirit AI, et al. Reporting guidelines for clinical trial reports for interventions involving artificial intelligence: the CONSORT-AI extension. Lancet Digit Health. 2020;2(10):e537-e48.
70. Collins GS, Moons KGM, Dhiman P, Riley RD, Beam AL, Van Calster B, et al. TRIPOD+AI statement: updated guidance for reporting clinical prediction models that use regression or machine learning methods. bmj. 2024;385:e078378.

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