

Evaluation of the use of artificial intelligence in evidence-based endodontology: Bibliometric and scientometric analysis

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Abstract

Background. Artificial intelligence (AI) systems have the potential to revolutionize the fields of medicine and dentistry by identifying solutions for managing multiple clinical problems. This greatly facilitates the tasks of physicians. Bibliometric studies not only provide insight into the history of a particular topic, but also help to determine how the work evolves over time, and to identify interesting new research.

Objectives. The aim of the present study was to identify and analyze bibliographically recent research articles on the use of AI in endodontics.

Material and methods. The search was conducted in March 2024 in the Web of Science Core Collection (WoS-CC), using the Clarivate™ search engine. The search strategy in all fields included in the database was as follows: “endodontics” was the main keyword, and the other keywords were “artificial intelligence”, “deep learning”, “machine learning”, “artificial neural network”, and “convolutional neural network”. The title, authors, institution, country, impact factor, total number of citations, year of publication, journal name, number of authors, keywords, abstracts, and other topics of interest were recorded. Bibliometric networks were generated and analyzed using the Visualization of Similarities Viewer (VOSviewer).

Results. Of the 54 articles published by the journals indexed in the WoS-CC between 2012 and 2024 that contained the search terms, 40 were included in this study. The article citations ranged from 0 to 168, with an average of 18.97. The number of countries contributing to the research was 29. The country with the highest contribution rate in the field was the USA ranked first (27.5 %), followed by Germany (17.5 %), China (15.0%), and India (15.0%).

Conclusions. Based on this review, it can be concluded that a more significant research interest in AI and endodontics was observed in the USA. The most cited research articles dealt with dental image diagnosis with the use of convolutional neural networks (CNN), the radiologic diagnosis of apical lesions using AI, and the computer-aided diagnosis of periapical lesions using AI in computed tomography (CT) analyses.

Keywords: artificial intelligence, endodontics, citation analysis, bibliometrics

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Highlights

- Artificial intelligence (AI) applications in endodontics have grown rapidly since 2019, addressing key challenges, such as diagnosis, treatment outcome prediction and case difficulty assessment.
- Convolutional neural networks showed particular promise for the radiographic detection of apical and periapical lesions, though further improvement in sensitivity is needed for routine clinical use.
- Bibliometric evidence underscores AI as an emerging transformative approach in endodontics, with the capacity to reshape both the trajectory of research and future clinical applications.

Introduction

Planning a research idea, obtaining study data by successfully applying an appropriate method, and analyzing and comparing the data with other studies in the literature are the stages that must be carefully managed in preparing a scientific publication.¹ Research is deemed worthy of publication in a scientific journal if it will attract the attention of researchers, be frequently cited and make a scientifically meaningful contribution to the field under investigation.² Bibliometrics assesses academic productivity using quantitative measures, with the aim of analyzing and monitoring the development and structure of science.³ Bibliometric studies enable the evaluation of the contribution of particular countries to the scientific literature in certain disciplines and topics, as well as the assessment of journals through comparative studies.⁴ The number of citations an article receives may not reflect its scientific quality or impact on clinical practice, but it is considered an objective indicator for researchers to track new trends and make evidence-based decisions with regard to technological development in the field.^{5,6}

The rationale underlying bibliometric research is that analyzing articles on a specific topic in peer-reviewed journals can provide clinicians and researchers with a historical perspective on the progress of the topic. It can also help to identify where research is most concentrated and how areas of interest have changed over time.³ The first bibliometric analysis in endodontics addressed trends in endodontic research by examining the top 100 most cited articles.⁷

Artificial intelligence (AI) is a field of applied computer science, first defined by John McCarthy. The development of AI is often referred to as the “fourth industrial revolution” due to its ability to simulate critical thinking, intelligent behavior and human-like decision making based on computer technology.^{8,9} Recent interest in AI is due to the development of a new generation of specialized algorithms capable of analyzing and predicting, using large datasets.¹⁰

Artificial intelligence has found its application in areas of medicine and dentistry, as well as in all kinds

of industries.^{11,12} Artificial intelligence systems have the potential to revolutionize the fields of medicine and dentistry by identifying solutions for managing multiple clinical problems. This greatly facilitates the tasks of physicians.⁸ Today, modern medicine is witnessing a revolution with the application of AI in clinical decision making. Artificial intelligence has been shown to improve efficiency and accuracy in a timely manner at a lower cost, with results comparable to those reached by medical professionals.¹³ However, the implementation of AI systems is becoming increasingly complex due to emerging potential risks and ethical challenges that must be considered from a legal standpoint.¹⁴

The application of AI has not become routine in dental clinical practice.¹⁵ However, pathology detection,¹⁶ caries diagnosis,¹⁷ robotic assistance,¹⁸ and electronic record retrieval¹⁹ with the use of AI have been gaining acceptance in dentistry.

In recent years, there has been a significant increase in the number of papers reporting the application of AI models in endodontics. The determination of root canal working length,²⁰ the detection of vertical root fractures,^{21,22} the success of root canal treatment,²³ the detection of pulp diseases,²⁴ the detection and diagnosis of periapical lesions,²⁵ the detection of unfilled canals,²⁶ the prediction of postoperative pain²⁷ and case difficulty²⁸ are the main focus in some of the studies conducted in this field.

Artificial intelligence research in endodontics has grown alongside other dental specialties.⁸ In recent years, bibliometric research has been conducted in many fields of dentistry.^{7,29,30} As far as we are aware, no bibliometric analysis of AI studies in the field of endodontics has been published. From this perspective, the aim of the present study was to bibliometrically evaluate studies using AI models in the field of endodontics.

Material and methods

A systematic search of the literature was conducted using the Web of Science Core Collection (WoS-CC) online database and the Clarivate™ search engine to identify

relevant research in the field. An electronic search was conducted on March 2024. The search strategy for all fields included in the database applied the main keyword “endodontics” and other keywords: “artificial intelligence”; “deep learning”; “machine learning”; “artificial neural network”; and “convolutional neural network” [(artificial intelligence) OR (deep learning) OR (machine learning) OR (artificial neural network) OR (convolutional neural network)) AND (endodontics)]. A total of 54 studies published between 2012 and March 2024 were identified in the scanning. Articles that were not directly related to the subject, or were related only to disciplines other than endodontics, were excluded. After a thorough review of all articles, 2 investigators excluded 6 proceeding papers, 1 editorial material and 7 irrelevant articles. Thus, a total of 40 articles were included in the study. They were then ranked according to the frequency of citations and were further analyzed.

Each article was thoroughly reviewed, and basic information, including the study design, was recorded. The data was imported into the application using a tab-delimited file tool; this data included the full record and the cited references. The following information was recorded: title; authors; institution; country; impact factor; total number of citations; year of publication; journal name; number of authors; keywords; abstracts; and other topics. The Visualization of Similarities Viewer (VOS Viewer) software, v. 1.6.19 (Centre for Science and Technology Studies, Leiden University, the Netherlands), was used. An algorithm for automatic term data identification was used to map the bibliometric network of the exported data.³¹

With regard to the aim of the present study, the questions to be answered are listed below:

1. What is the distribution of articles written on the topic by years?
2. Which countries are the highest contributors?
3. Which journals publish the highest number of articles in the field?
4. Who are the most cited authors and what are the most cited publications?
5. What is the most common use of AI in endodontics?

Results

A total of 40 articles were included in the study; they were all published in indexed journals (WoS-CC, the Science Citation Index Expanded (SCIE)) between 2012 and 2024. The distribution of the number of publications and citations over the years is shown in Fig. 1.

The countries of all authors (not only first authors) who contributed to the articles are shown in Fig. 2. The highest contribution came from the USA, with 11 articles. The countries of origin of the authors who published the most articles on the topic were the USA (11) ranked first,

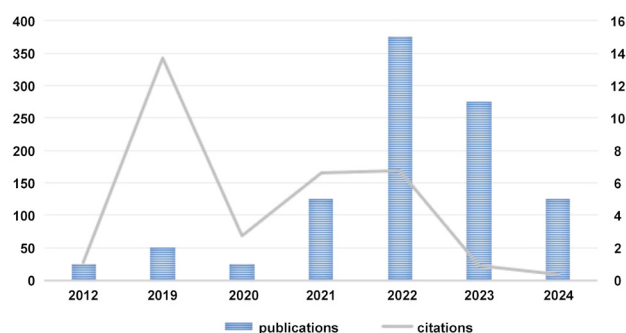


Fig. 1. Distribution of the number of publications and citations over the years 2021–2024



Fig. 2. Contribution to the literature by country of all authors

followed by Germany (7), China (6), and India (6). Other countries with the number of articles published are as follows: Saudi Arabia (4); Iran (4); South Korea (3); Denmark (2); Pakistan (2); and Spain (2); and the UAE, Angola, Austria, Belgium, Brazil, Czech Republic, Colombia, England, Indonesia, Italy, Japan, Mexico, the Netherlands, Romania, Slovakia, Sweden, Thailand, Turkey, and Wales (1). Although a total of 40 articles were included in the study, the number of contributing countries exceeded the number of articles, since some publications had international co-authorship from multiple countries.

A total number of 103 contributing institutions was determined based on the authors' addresses. The analysis of the country of origin using VOSviewer showed that 29 countries contributed to research and publications in the field, both with and without collaboration.

The citation analysis of articles was conducted by selecting countries that had published at least one article and received at least one citation, and 24 countries were observed to have the most connections (Fig. 3). While the countries of origin of the most cited articles were Germany and the USA, the countries of origin of the authors who published the most articles on the topic were the USA, Germany, China, and India. In terms of the total link strength of the countries of origin of the articles on the topic, the USA ranked first, Germany ranked second, followed by China and India. The article citations ranged from 0 to 168, with an average of 18.97. Two articles received over 100 citations.

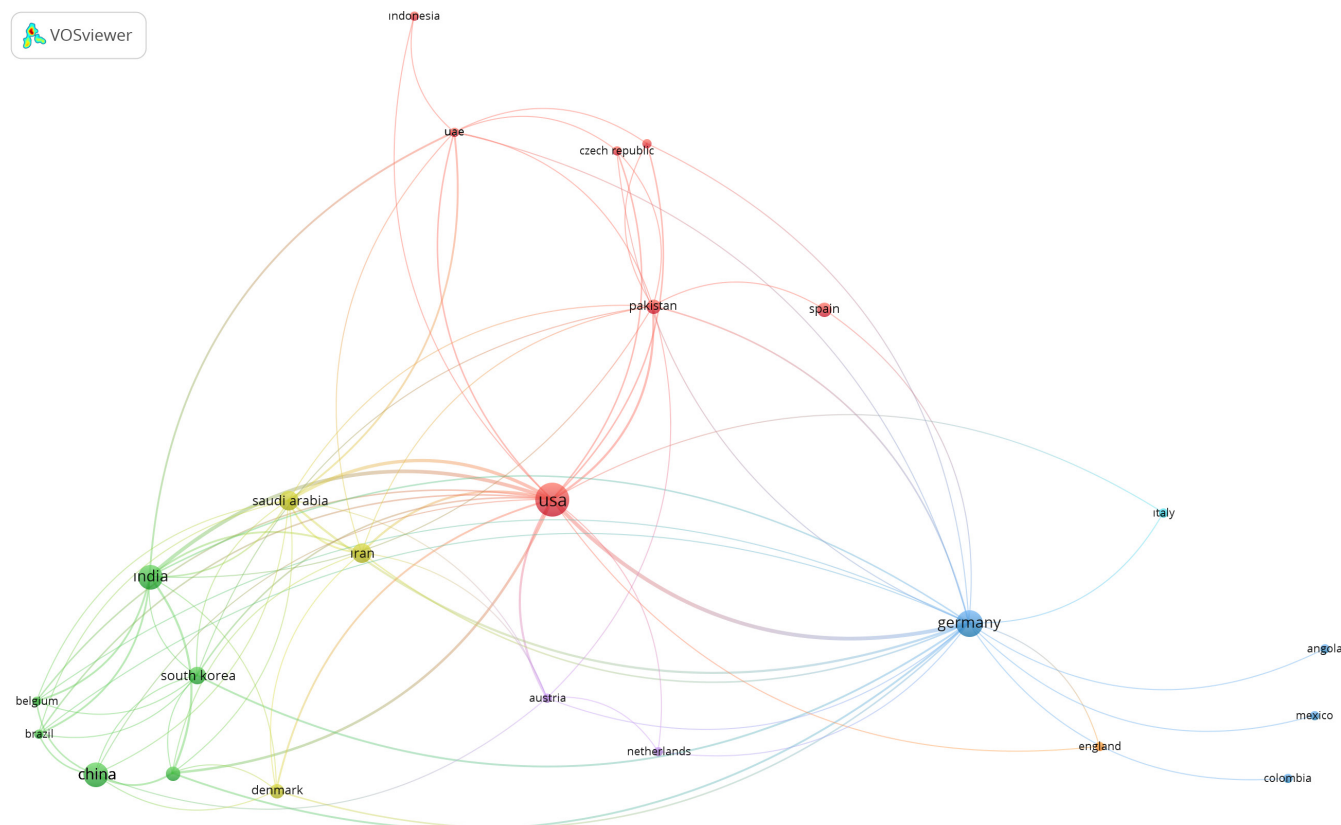


Fig. 3. Citation analysis based on country

The comparison of the total number of citations of the journals related to the subject and the number of publications is shown in Fig. 4. The *Journal of Endodontics* has published the highest number of articles – 14 articles (35%). The *Journal of Dentistry* with 4 articles (10%) followed the *Journal of Endodontics*. The *International Endodontic Journal* took the 3rd place with 3 articles (7.5%).

When examining the first authors of the 3 most cited publications, Schwendicke is ranked first, followed by Ekert in the 2nd place and Setzer in the 3rd place. It was found that 217 authors were involved in articles on the topic of AI in endodontics. Schwendicke was the most cited author with a total of 335 citations in 3 articles. Krois and Golla followed, with a total number of 317 citations, each with 2 articles (Table 1).

Based on the scientometric evaluation, the AI application that received the most focus in endodontics was the detection and segmentation of anatomical structures using AI on dental radiographs, and the diagnosis of periapical lesions in radiographic and tomographic images, followed by the analysis of canal morphology (C-shaped canals and second mesial buccal (MB2) canals).

The 10 most commonly used keywords and their frequency of occurrence in the included articles, as well as their total link strength, are shown in Table 2. The most cited article was published in the *Journal of Dentistry* in 2019, the 2nd most cited article was published in the *Journal of Endodontics* in 2019 and the 3rd most cited ar-

ticle was published in the *Journal of Endodontics* in 2020. The list of publications is presented in Table 1 in order from the most cited to the least cited.

When a bibliometric analysis was performed according to keyword, it was observed that the most frequently used words in studies on AI in endodontics were “artificial intelligence”, “endodontics” and “deep learning”, followed by “machine learning”. In total, 124 unique keywords were identified in the included studies. In Fig. 5, the size of a node represents the frequency of use of the word in the published articles.

Discussion

Bibliometric studies not only provide insight into the history of a particular topic, but also help to determine how the work evolves over time, and to identify interesting new research.³² Bibliometric studies can evaluate the most cited publications of a journal.³³ Moreover, they can focus on the scientific production of a particular country or field of research.³⁴ Given this background, the aim of our study was to provide a bibliometric evaluation of research on AI in endodontics. This is a current concept in endodontics and dentistry.

The WoS-CC database was searched following the methodology used in another recent endodontic bibliometric review.³⁵ The WoS-CC is a popular and suitable database for bibliometric analysis, as it has a large da-

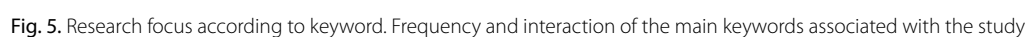
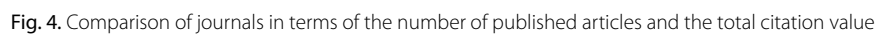


Table 1. List of publications on artificial intelligence (AI) in endodontics

Authors	Research article	Journal	Institution (corresponding author)	Times cited (WoS-CC)	Times cited (all databases)	Year	Main topic	Conclusion
Schwendicke Golla Dreher Krois	Convolutional neural networks for dental image diagnostics: A scoping review	Journal of Dentistry	Charité – Universitätsmedizin Berlin, Freie Universität Berlin, Humboldt-Universität zu Berlin, and Berlin Institute of Health	168	182	2019	review dental diagnosis with AI	Convolutional neural networks are increasingly used for dental image diagnosis in research settings.
Ekert Krois Meinhold Elhennawy Emara Golla Schwendicke	Deep learning for the radiographic detection of apical lesions	Journal of Endodontics	CODE University of Applied Sciences	149	161	2019	the diagnosis of apical lesions	The convolutional neural network has been satisfactory in differentiating periapical lesions on panoramic radiographs.
Setzer Shi Zhang Yan Yoon Mupparapu Li	Artificial intelligence for the computer-aided detection of periapical lesions in cone-beam computed tomographic images	Journal of Endodontics	University of Pennsylvania	64	68	2020	the diagnosis of periapical lesions	The deep learning algorithm trained in a limited CBCT environment showed excellent lesion detection accuracy and voxel matching accuracy.
Lahoud EzEldeen Beznik Willems Leite Van Gerven Jacobs	Artificial intelligence for fast and accurate 3-dimensional tooth segmentation on cone-beam computed tomography	Journal of Endodontics	University of Leuven	55	55	2021	the diagnosis of tooth segmentation	Successfully performed AI-guided automatic tooth segmentation in CBCT imaging.
Li Ye H Ye F Liu Lv Zhang P Zhang X Zhou	The current situation and future prospects of simulators in dental education	Journal of Medical Internet Research	Peking University School and Hospital of Stomatology	37	42	2021	review the use of AI in dental education	The review was to provide an overview of current dental simulators on related technologies, advantages and disadvantages, the methods of evaluating effectiveness, and future directions for development.
Aminoshariae Kulild Nagendrababu	Artificial intelligence in endodontics: Current applications and future directions	Journal of Endodontics	University of Missouri	33	35	2021	review current applications and future directions	AI has demonstrated accuracy and precision in terms of detection, identification and disease prediction in endodontics.
Thurzo Urbanová Novák Czako Siebert Stano Mareková Fountoulaki Kosnáčová Varga	Where is the artificial intelligence applied in dentistry? Systematic review and literature analysis	Healthcare (Basel)	Comenius University in Bratislava	33	33	2022	systematic review AI applied in dentistry	The research confirms that the current use of AI in dentistry is concentrated mainly around the evaluation of digital diagnostic methods, especially radiology, while it is gradually penetrating all parts of the dental profession.
Saghiri Garcia-Godoy Gutmann Lotfi Asgar	The reliability of artificial neural network in locating minor apical foramen: A cadaver study	Journal of Endodontics	Azad University	28	29	2012	the evaluation of working length determination	The artificial neural network is an accurate method for determining the working length.

Authors	Research article	Journal	Institution (corresponding author)	Times cited (WoS-CC)	Times cited (all databases)	Year	Main topic	Conclusion
Li S Liu Zhou Zirui Zhou Zilin Wu Li Y Wang Liao Ying Zhao	Artificial intelligence for caries and periapical periodontitis detection	Journal of Dentistry	Sichuan University	25	25	2022	the diagnosis of periapical periodontitis and caries	Deep learning can improve accuracy and consistency in the assessment of dental caries and periapical periodontitis on periapical radiographs.
Umer Habib	Critical analysis of artificial intelligence in endodontics: A scoping review	Journal of Endodontics	Aga Khan University Hospital	24	25	2022	scoping review the analysis of AI	AI models had acceptable performance, i.e., more than 90% accuracy, in various diagnostic tasks.
Agrawal Nikhade	Artificial intelligence in dentistry: Past, present, and future	Cureus Journal of Medical Science	Datta Meghe Institute of Medical Sciences University	21	23	2022	review the past, present and future of AI	AI can help advance endodontic diagnosis and treatment, which in turn can improve endodontic treatment outcomes.
Sherwood AA Sherwood AI Setzer Sheela Devi K Shamili John Schwendicke	A deep learning approach to segment and classify C-shaped canal morphologies in mandibular second molars using cone-beam computed tomography	Journal of Endodontics	University of Pennsylvania	18	19	2021	the diagnosis and classification of C-shaped canal morphology in mandibular second molars	Deep learning can help detect and classify C-shaped canal anatomy.
Lin Fu Ren Yang Duan Chen Zhang	Micro-computed tomography-guided artificial intelligence for pulp cavity and tooth segmentation on cone-beam computed tomography	Journal of Endodontics	Tongji University	12	14	2021	guided AI for pulp cavity and tooth segmentation	AI has been shown to provide an accurate and automated approach for tooth and pulp cavity segmentation on CBCT images, applicable in research and clinical tasks.
Fatima Shafi Afzal Díez Lourdes Breñosa Martínez Espinosa Ashraf	Advancements in dentistry with artificial intelligence: Current clinical applications and future perspectives	Healthcare (Basel)	Yeungnam University	11	11	2022	systematic review the current clinical applications of AI	AI has the potential to improve dental care, disease diagnosis and prognosis, treatment planning, and risk assessment.
Sadr Mohammad-Rahimi Motamedian Zahedrozegar Motie Vinayahalingam Dianat Nosrat	Deep learning for detection of periapical radiolucent lesions: A systematic review and meta-analysis of diagnostic test accuracy	Journal of Endodontics	University of Maryland	11	11	2023	systematic review deep learning models in detecting periapical lesions	Deep learning showed highly accurate results in detecting periapical radiolucent lesions on dental radiographs.
Cotti Schirru	Present status and future directions: Imaging techniques for the detection of periapical lesions	International Endodontic Journal	University of Cagliari	10	11	2022	review the detection of periapical lesions	All imaging techniques should be associated with a thorough clinical examination and good calibration of the operator.

Authors	Research article	Journal	Institution (corresponding author)	Times cited (WoS-CC)	Times cited (all databases)	Year	Main topic	Conclusion
Kirnbauer Hadzic Jakse Bischof Stern	Automatic detection of periapical osteolytic lesions on cone-beam computed tomography using deep convolutional neuronal networks	Journal of Endodontics	Medical University of Graz	10	10	2022	the diagnosis of periapical osteolytic lesions	Although periapical lesions vary in appearance, size and shape in the CBCT dataset, and there is a high imbalance between teeth with and without periapical lesions, the proposed fully automated method provided excellent results as compared to the relevant literature.
Yang Lee Jang Kim K Kim J Kim H Park	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	Journal of Endodontics	Yonsei University	10	10	2022	the diagnosis of C-shaped canals	A deep learning system may be expected to effectively diagnose C-shaped canals and aid clinicians in practice and education.
Asiri Altuwalah	The role of neural artificial intelligence for diagnosis and treatment planning in endodontics: A qualitative review	Saudi Dental Journal	Majmaah University	8	8	2022	qualitative review endodontic treatment planning and diagnosis with AI	AI with different models or frameworks and algorithms can help dentists diagnose and manage endodontic problems more accurately.
Suárez Díaz-Flores García Algar Sanchez de Pedro Freire	Unveiling the ChatGPT phenomenon: Evaluating the consistency and accuracy of endodontic question answers	International Endodontic Journal	Universidad of Europea de Madrid	7	7	2024	the evaluation of the accuracy and consistency of ChatGPT in endodontic clinical questions	ChatGPT is not capable of replacing dentists in clinical decision making.
Albitar Zhao Huang Mahdian	Artificial intelligence (AI) for detection and localization of unobturated second mesial buccal (MB2) canals in cone-beam computed tomography (CBCT)	Diagnostics (Basel)	Stony Brook University	6	6	2022	the detection and localization of unobturated second mesial buccal (MB2) canals	The current AI algorithm has the potential to identify obturated and unobturated canals in endodontically treated teeth.
Vannaprathip Haddawy Schultheis Suebnuakarn	Intelligent tutoring for surgical decision making: A planning-based approach	International Journal of Artificial Intelligence in Education	Mahidol University	4	4	2022	intelligent tutoring for surgical decision making	The experts evaluating the results of AI in surgical intervention decision making (SDMentor) show that it can only predict which interventions come from SDMentor with 15% accuracy, as compared to a randomized initial accuracy of 9%.
Khanagar Alfadley Alfouzan Awawdeh Alaqla Jamleh	Developments and performance of artificial intelligence models designed for application in endodontics: A systematic review	Diagnostics (Basel)	King Saud Bin Abdulaziz University for Helath Sciences	4	4	2023	the design of AI models for endodontics	The models can be used as supplementary tools in clinical practice to expedite the clinical decision-making process.
Ramezanzade Laurentiu Bakhshandah Ibragimov Kvist Bjørndal	The efficiency of artificial intelligence methods for finding radiographic features in different endodontic treatments – a systematic review	Acta Odontologica Scandinavica	University of Copenhagen	4	4	2023	systematic review finding radiographic features in different kinds of endodontic treatment	AI-based models have shown effectiveness in finding radiographic features in different kinds of endodontic treatment.

Authors	Research article	Journal	Institution (corresponding author)	Times cited (WoS-CC)	Times cited (all databases)	Year	Main topic	Conclusion
Thakur Kankar Parey Jain A Jain P	Prediction of apical extent using ensemble machine learning technique in the root canal through biomechanical preparation: In-vitro study	Indian Journal of Pure and Applied Physics	Indian Institute of Technology Indore	2	2	2022	the prediction of the apical extent, using a machine learning model	Machine learning approaches can improve the treatment practice and root canal treatment results, and provide a suitable decision support system.
Kumar Ravindranath Srilatha Alobaoid Kulkarni Mathew Tiwari	Analysis of advances in research trends in robotic and digital dentistry: An original research	Journal of Pharmacy and Bioallied Sciences	Gitam Dental Collage and Hospital	1	1	2022	questionnaire study the evaluation of the awareness and application of these technologies by clinicians	The awareness of these advanced technologies and routine practices is low. These technologies show higher sensitivity and accuracy.
Ahlat Aydin Kaya Baysallar	Identification of root canal microbiota profiles of periapical tissue diseases using matrix-assisted laser desorption/ionization time-of-flight mass spectrometer	Anaerobe	University of Health Sciences	1	1	2023	the classification of periapical tissue microorganisms by machine learning models	MALDI-TOF MS can be considered a fast and high-throughput screening technique for microbial species identification in endodontics.
Alzaid Ghulam Albani Alharbi Othman Taher Albaradie Ahmed	Revolutionizing dental care: A comprehensive review of artificial intelligence applications among various dental specialties	Cureus Journal of Medical Science	Riyadh Elm University	1	1	2023	the use of AI in various specialties of modern dentistry	Dental practice also involves administering treatment to patients. While AI cannot replace dentists, a comprehensive understanding of AI concepts and techniques will be advantageous in the future.
Li Inamochi Wang Fueki	Clinical application of robots in dentistry: A scoping review	Journal of Prosthodontic Research	Tokyo Medical and Dental University (TMDU)	1	1	2024	scoping review robots in dentistry	It was revealed that there are still limitations and gaps between research and the application of dental robots.
Huang Farpour Yang Mupparapu Lure Li Yan Setzer	Uncertainty-based active learning by Bayesian U-Net for multi-label cone-beam CT segmentation	Journal of Endodontics	University of Pennsylvania	1	1	2024	the efficacy of active learning strategies while training AI models, using a limited dataset	Active learning may contribute to reducing extensive labeling needs for training AI algorithms for biomedical image analysis in dentistry.
Peeters Silitonga Zuhail	Application of artificial intelligence in a visual-based fluid motion estimator surrounding a vibrating EDDY® tip	Giornale Italiano Di Endodonzia	Laser Research Center in Dentistry	0	0	2022	the AI visualization of sonic activation (Eddy)	The proposed motion estimation program supported by LiteFlowNet can perform detailed flow estimation of a non-PIV experiment.
Kawale Choudhari Sedani	Artificial intelligence: A boon to conservative dentistry	Journal of Research in Medical and Dental Science	Datta Meghe Institute of Medical Sciences (Deemed to be University)	0	0	2022	review AI in endodontics and conservative dentistry	AI is being studied for a range of applications, including the detection of normal and different structures, disease diagnosis and treatment prediction.
Lee J Seo Choi Lee C Kim S Lee Y Lee S Kim E	An endodontic forecasting model based on the analysis of preoperative dental radiographs: A pilot study on an endodontic predictive deep neural network	Journal of Endodontics	Yonsei University	0	0	2023	the prediction of the endodontic outcome with AI	Deep convolutional neural networks can accurately detect various clinical features on periapical radiographs.

Authors	Research article	Journal	Institution (corresponding author)	Times cited (WoS-CC)	Times cited (all databases)	Year	Main topic	Conclusion
Qu Wen Chen Guo Huang Gu	Predicting case difficulty in endodontic microsurgery using machine learning algorithms	Journal of Dentistry	Sun Yat-sen University	0	0	2023	the prediction of case difficulty in endodontic microsurgery	The relative feature importance provides a reference for developing a scoring system for case difficulty assessment in endodontic microsurgery.
Ramezanzade Dascalu Ibragimov Bakhshandeh Bjørndal	Prediction of pulp exposure before caries excavation using artificial intelligence: Deep learning-based image data versus standard dental radiographs	Journal of Dentistry	University of Copenhagen	0	0	2023	the investigation of the impact of providing dental students with AI-based radiographic information on their ability to predict pulp exposure	Although the AI model outperformed all groups, the participants only benefited 'slightly' from the AI predictions. While AI technology shows promise, it is important to provide more explainable AI predictions and a learning curve.
Pop Choudhary Porumb Avram Badea I Picos Badea A Jiman Muntean	The future of endodontics. A systematic review	Romanian Journal of Oral Rehabilitation	Iuliu Hatieganu University of Medicine and Pharmacy	0	0	2023	review current trends in endodontics based on the latest scientific literature	Overall, endodontic treatment is becoming more precise, leading to a reduction in complications. In conclusion, the field of endodontics is expected to experience numerous exciting advances in the coming years, some of which will be incremental, while others will be paradigm-shifting.
Sudeep Gehlot Murali Mariswamy	Artificial intelligence in endodontics: A narrative review	Journal of International Oral Health	JSS Dental College and Hospital JSS Academy of Higher Education and Research (JSSAHER)	0	0	2023	review AI in endodontics	Being a potential game changer and the beginning of something dubbed the "fourth industrial revolution", AI has what it takes to revolutionize endodontics over time.
Mohammad-Rahimi Ourang Pourhoseingholi Dianat Howell Dummer Nosrat	Validity and reliability of artificial intelligence chatbots as public sources of information on endodontics	International Endodontic Journal	University of Maryland	0	0	2024	the comparison of the validity of responses between chatbots	In comparison with Google Bard and Bing, GPT-3.5 provided more credible information on topics related to endodontics.
Mohammad-Rahimi Dianat Abbasi Zahedrozeigar Ashkan Motamedian Rohban Nosrat	Artificial intelligence for detection of external cervical resorption using label-efficient self-supervised learning method	Journal of Endodontics	University of Maryland	0	0	2024	the evaluation of radiographic images by endodontists or 7 basic deep learning models as well as 9 contrast-enhanced self-supervised learning models	AI can aid clinicians in detecting early caries lesions and distinguishing them from other lesions. Furthermore, self-supervised learning has been introduced as a means of detecting early caries lesions.
Fu Zhu Li Wang Deng Chen Shen Meng Bian	Clinically oriented CBCT periapical lesion evaluation via 3D CNN algorithm	Journal of Dental Research	Wuhan University	0	0	2024	the detection and segmentation of periapical lesions associated with apical periodontitis on CBCT images, called PAL-Net	PAL-Net can enhance dentists' diagnostic performance and speed when working with CBCT images, provide clinically relevant volume information, and potentially be used in dental clinics without the need for expert-level dentists or radiologists.

WoS-CC – Web of Science Core Collection; AI – artificial intelligence; CBCT – cone-beam computed tomography; MALDI-TOF MS – matrix-assisted laser desorption/ionization time-of-flight mass spectrometer; PIV – particle image velocimetry.

Table 2. Article keywords with the frequency of occurrence and their total link strength

Serial No.	Keyword	Frequency	Total link strength
1	artificial intelligence	22	103
2	endodontics	19	84
3	deep learning	14	74
4	machine learning	11	50
5	dentistry	5	25
6	artificial neural network	4	23
7	diagnosis	3	18
8	root canal treatment	3	17
9	periapical lesion	3	16
10	convolutional neural network	3	15

tabase of publications dating back to 1945.³⁶ However, other similar scientometric or bibliometric studies in the field have used other databases, such as Scopus or MEDLINE/PubMed®, to obtain data.^{34,37} After comparing the available evidence in this area, it was decided to conduct an individual search in a single database (WoS-CC) for the current study. Although the use of more than one database for search may have made more studies available, at this stage, there could have been duplicate publications needing to be removed manually. The presence of duplicate records would alter all the quantitative bibliometric parameters, potentially leading to the misinterpretation of the relationships between different research components. Thus, only one database was included.

Although it has been claimed that bibliometric analysis should be carried out on topics that have been studied for many years, it is confirmed that the articles published and cited in journals tend to be current topics.^{33,38} Artificial intelligence in endodontics is a hot topic. Therefore, in this study, the authors do not consider the fact that the research was conducted on a current issue as a limitation.

The combined data analysis with the use of the bibliometric and network tools of WoS-CC provided many results referring to endodontics and AI. Publications on AI in endodontics continued to increase from 2021 to 2022, peaking in 2022, and decreasing slightly in 2023. This could be an indication that AI is becoming more popular as technology advances, while the topic is becoming more interesting and worthy of discussion through research publication.

The analysis of country of origin and the research institution was conducted using VOSviewer; it showed that 29 countries contributed to research and publications in this field, either collaboratively or non-collaboratively. The country that contributed the most in the field of AI and endodontics was the USA, which can be attributed to the fact that this country has experienced an increase in the number of researchers and working groups in the field of endodontics, and it has followed the technological development.

It is also important to identify the most influential journals for the publication and dissemination of AI and endodontics research. This can help researchers to follow specific journals and aim to publish their research in sources that show specificity in a scientific field.³⁷ Comparing the number of articles on AI published in scientific journals, the *Journal of Endodontics* had the highest number of publications in the categories of “Dentistry” and “Endodontics”, with 14 articles. As a result of the analysis, the *Journal of Endodontics* was also found to be the journal with the highest total number of citations of articles related to AI in the field of endodontics. One of the reasons for this may be that this journal has published the highest number of articles on the topic and that the journal closely follows current topics in the field of endodontics, and finds them worthy of publication. Additionally, as the journal is in the Q1 quartile of the “Dentistry, Medicine and Oral Surgery” category, its citation rate is high and very popular. The fact that the journal follows all advances in endodontics and that it is indexed in SCIE may be attractive factors for researchers when choosing a journal. The *Journal of Dentistry* followed the *Journal of Endodontics*, with 4 articles. The journal *International Endodontic Journal* took the 3rd place, with 3 articles. An important observation about journals is that, although AI is mostly about diagnostics and radiology, diagnostic and radiological reviews in endodontics are more likely to be published in endodontic journals rather than in general dentistry or radiology journals.

The most cited articles on AI in endodontics play a crucial role in the field. Their knowledge draws public attention to researchers who have influenced the growth and development of the work.⁷ According to the analysis conducted in our study, Schwendicke was the most cited author on the topic. In a 2019 review, Schwendicke et al. reported studies on the detection and segmentation of anatomical structures in different areas of dentistry using AI on dental radiographs.³⁹ The 2nd most cited article was that of Ekert et al., who detected apical lesions on radiographs using AI, and found that AI gave satisfactory results in diagnosing apical lesions on panoramic radiographs.⁴⁰ In the 3rd most cited article, Setzer et al. used AI to detect apical lesions on cone-beam computed tomography (CBCT) images and reported that, in the long term, the addition of automated image analysis based on three-dimensional (3D) imaging could assist clinicians in lesion detection and the differential diagnosis of periapical lesions (pathological and/or non-odontogenic lesions) in combination with previous examinations.⁴¹ In this context, it can be concluded that the most cited articles have paved the way for dental diagnosis, the detection of dental pathology, and even differential diagnosis using AI in endodontics. Dental diagnosis using AI may also help to reduce the time spent by clinicians on making a diagnosis.

Although the most cited article on AI is a review article analyzing general dentistry fields, including endodontics,

the 2nd and 3rd most cited articles are about the use of AI in the diagnosis of apical lesions in panoramic radiography and on CBCT images, published in a journal in the field of endodontics. We can say that the number of citations of publications on AI in the field of endodontics competes with publications on the use of AI in dentistry.

The keyword co-occurrence analysis can be an insight into the development patterns of a particular area of scientific research.³⁵ As shown in Table 2, the first 10 keywords were often repeated, and the most often repeated keyword among them was “artificial intelligence”. This was followed by the keywords “endodontics” and “deep learning”. However, it was also observed that keywords such as “machine learning”, “artificial neural network” and “convolutional neural network” were used as well. Artificial intelligence is a general term that comprises more specific topics, including deep learning, machine learning and artificial neural networks. The results of our keyword analysis show that studies using the concept of AI have begun to specialize in the branches of AI, leaving the general concept behind over time.

One limitation could be a small number of articles included in our study. This was due to the fact that the concept of AI is a current topic, and studies using AI have recently been undertaken in the field of endodontics, as in almost all fields.

Conclusions

The use of AI in dental research has steadily increased since the first applications were reported in 2012, but the “explosion” of research occurred in 2019.³⁹ Indeed, the number of papers reporting on AI models applied in endodontics has raised significantly in recent years. The determination of root canal working length,²⁰ the detection of vertical root fractures,^{21,22} the success of root canal treatment,²³ the detection of pulp diseases,²⁴ the detection and diagnosis of periapical lesions,²⁵ the detection of unfilled canals,²⁶ the prediction of postoperative pain²⁷ and case difficulty²⁸ are some of the issues covered by the studies conducted in this field. In the years that followed, the use of AI in endodontics expanded. Studies were conducted on its use in preclinical education.⁴² To date, AI in endodontics has had many applications, which we have analyzed bibliometrically. For example, the use of a conventional neural network to detect apical lesions based on panoramic radiographs can help dentists in their diagnostic efforts. However, for such approaches to be widely used in clinical settings, their sensitivity needs to be improved via further studies.

The present bibliometric analysis reviewed current trends, as well as leading countries and journals in terms of research focusing on the use of AI applications in endodontics. Our study considered publications related to AI in endodontics to highlight the bibliometric

characteristics of a specific topic. Further research could focus on AI in endodontics in a broader context.

Ethics approval and consent to participate

Not applicable.

Data availability

The datasets supporting the findings of the current study are available from the corresponding author on reasonable request.

Consent for publication

Not applicable.

Use of AI and AI-assisted technologies

Not applicable.

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