Selcuk Dental Journal 11/2 (Ağustos 2024): 192-200

Research / Araştırma Makalesi

A Bibliometric Analysis of the Field of Artificial Intelligence in Cariology

Diş Çürüklerinde Yapay Zeka Kullanımının Bibliyometrik Analizi

İbrahim Tevfik GÜLŞEN[α], **Ruşen ERDEM**[β], **Yavuz Selim GENÇ**[€], **Gülbeddin YALINIZ**[¥]

[α]Alanya Alaaddin Keykubat University, Faculty of Dentistry, Department of Oral and Maxillofacial Radiology, Antalya, Türkiye
[α]Alanya Alaaddin Keykubat Üniversitesi, Diş Hekimliği Fakültesi, Ağız, Diş ve Çene Radyolojisi AD, Antalya, Türkiye
[β]Kafkas University, Faculty of Dentistry, Department of Orthodontics, Kars, Türkiye
[β]Kafkas Üniversitesi, Diş Hekimliği Fakültesi, Ortodonti AD, Kars, Türkiye
[€]Samsun Oral and Dental Health Hospital, Samsun, Türkiye
[€]Samsun Ağız ve Diş Sağlığı Hastanesi, Samsun, Türkiye
[¥]Ataturk University, Faculty of Dentistry, Department of Periodontics, Erzurum, Türkiye
[¥]Atatürk Üniversitesi, Diş Hekimliği Fakültesi, Periodontoloji AD, Erzurum, Türkiye

ABSTRACT

Background: The aim of this study is to examine the development trends and dynamics of research on the use of artificial intelligence in dental caries diagnosis, to identify the strengths and limitations of the existing literature, and to guide future research.

Methods: A literature search was conducted using the Web of Science database, covering articles published before June 3, 2024. Pilot searches were conducted, and 883 studies were reached. After the specified scanning and filtering processes, the study was carried out on 270 publications. In the bibliometric analysis, the Biblioshiny R package as well as the features of Web of Science and VOSviewer software were used for visualizations. Microsoft Excel was utilized to tabulate the data.

Results: There is a general increase in the number of articles published each year. A total of 3081 citations were made to publications on the use of artificial intelligence in cariology. The average number of citations per article was found to be 11.41, and the H index was 29. The most cited country was Germany (581 citations), and the most influential author was Falk Schwendicke. On the basis of institutions, the highest contribution was made by Charite University Medicine Berlin (19 articles, 475 citations).

Conclusion: Since 2008, and particularly since 2018, the utilization of artificial intelligence (AI) in the investigation of dental caries and oral and dental diseases has garnered increasing interest. Artificial intelligence (AI) can be said to be a groundbreaking discovery that will be increasingly applied in various branches of dentistry.

Keywords: Artificial intelligence, Bibliometric, Dental caries

ÖZ

Amaç: Bu çalışmanın amacı, yapay zekânın diş çürüğü teşhisindeki kullanımına yönelik yapılan araştırmaların gelişim trendlerini ve dinamiklerini incelemek, mevcut literatürün güçlü ve zayıf yönlerini belirlemek ve gelecekteki araştırmalara rehberlik etmektir.

Gereç veYöntemler: Web of Science veritabanı kullanılarak 3 Haziran 2024'ten önce yayınlanan makaleleri kapsayan bir literatür taraması yapılmıştır. Pilot aramalar yapılarak 883 çalışmaya ulaşıldı. Belirlenen tarama ve filtreleme işlemlerinin ardından çalışma 270 yayın üzerinde gerçekleştirilmiştir. Bibliyometrik analizde görselleştirmeler için Biblioshiny R paketinin yanı sıra Web of Science'ın özellikleri ve VOSviewer yazılımı kullanıldı. Verilerin tablolanması için Microsoft Excel kullanıldı.

Bulgular: Her yıl yayımlanan makale sayısında genel bir artış görülmektedir. Kariyolojide yapay zekâ kullanımına ilişkin yayınlara toplam 3081 atıf yapılmıştır. Makale başına ortalama atıf sayısı 11,41, H indeksi ise 29 olarak bulunmuştur. En fazla alıntı yapılan ülke Almanya (581 alıntı), en etkili yazar ise Falk Schwendicke olmuştur. Kurumlar bazında ise en yüksek katkıyı Charite University Medicine Berlin (19 makale, 475 alıntı) yapmıştır.

Sonuç: 2008 yılından itibaren ve özellikle 2018'den sonra yapay zekânın (AI), kariyoloji ve ağız ve diş hastalıklarının araştırılmasında kullanımı giderek büyük ilgi görmeye başlamıştır. Yapay Zekânın (AI) diş hekimliğinin çeşitli dallarında giderek daha fazla uygulanacak çığır açıcı bir keşif olduğu söylenebilir.

Anahtar Sözcükler: Yapay zekâ, Bibliyometri, Diş çürüğü

Introduction

Tooth decay is one of the most prevalent oral health issues globally.[1] Dental caries and periodontal diseases are oral diseases that affect individuals of diverse age groups worldwide. These conditions represent a significant public health concern with a substantial impact on global disease burden.[2] Despite the implementation of various strategies to reduce dental caries, only a 4% reduction in cases has been observed over the past few decades. The philosophy of caries management is evolving towards minimal intervention practices. These include the early detection and assessment of dental caries, the remineralization of tooth-hard tissues, and the implementation of preventive treatments over the course of an individual's lifetime.[3] The early detection of dental caries obviates the necessity for invasive procedures and, concomitantly, reduces healthcare costs.[4] Therefore, researchers are developing novel approaches to the prevention, early detection, risk assessment, and treatment of dental caries.[3] It is of significant importance to accurately diagnose dental caries at an early stage, as this enables the most suitable form of treatment to be determined. Dental caries is usually diagnosed clinically by means of a visual-tactile assessment and a radiographic examination.[5] In addition to the aforementioned methods, further devices are employed to identify dental caries. These include digital image processing, fiber-optic transillumination, light-emitting diode (LED) technology, and fluorescence cameras and lasers.[5,6]

The term "artificial intelligence" (AI) is defined as a system that is capable of acquiring, understanding, and applying knowledge and that is also capable of performing adaptive and autonomous actions that are similar to human intelligence.7 The healthcare sector has undergone a digital revolution as a consequence of the widespread adoption of AI innovations in everyday clinical practice.8 In recent years, there has been a notable increase in interest in the potential applications of artificial intelligence (AI) in the field of healthcare. Artificial intelligence is employed in a multitude of applications, including the prediction of disease onset, the facilitation of precision surgery, the personalization of treatment plans, the management of patient care, and the enhancement of nursing capabilities. The application of artificial intelligence (AI) technologies in dentistry could potentially overcome the difficulties associated with traditional methods of dental

Gönderilme Tarihi/Received: 21 Haziran, 2024
Kabul Tarihi/Accepted: 14 Temmuz, 2024
Yayınlanma Tarihi/Published: 19 Ağustos, 2024
Atıf Bilgisi/Cite this article as: Gülşen İT, Erdem R, Genç YS, Yalınız G. A Bibliometric Analysis of the Field of Artificial Intelligence in Cariology. Selcuk Dent J 2024;11(2): 192-200 Doi: 10.15311/ selcukdentj.1503076

Sorumlu yazar/Corresponding Author: Yavuz Selim GENÇ
E-mail: yavuz_selim_genc@hotmail.com
Doi: 10.15311/ selcukdentj.1503076

caries diagnosis. The application of machine learning algorithms to an increasing amount of radiographic data suggests that AI may offer a promising approach to dental caries diagnosis.[9]

Bibliometric analysis is a method of examining and analyzing a wide range of scientific data that has a long history and is characterized by a high degree of rigor. This methodology allows for the examination of the evolutionary nuances of a specific field while simultaneously identifying the emerging areas within that field. Nevertheless, its application in scientific research is relatively recent, and in many instances, it is still underdeveloped.[10] To gain a comprehensive understanding of the publication landscape and citation patterns, it is necessary to conduct a bibliometric study, which will enable the qualitative and quantitative analysis of the publication characteristics of scholarly work focusing on AI in cariology.

The aim of this study was to conduct a comprehensive bibliometric analysis of the research on the use of artificial intelligence in dental caries diagnosis. In this vein, the study sought to analyze the development trends and research dynamics of the field, identify leading studies, authors, and institutions, ascertain the most cited publications, and reveal research networks. The objective of this analysis was threefold: firstly, to identify the strengths and weaknesses of the existing literature; secondly, to provide guidance for future research in the field; and finally, to identify any gaps in the current body of knowledge.

Material and Methods

A literature search of the Web of Science (WoS) database, created by the Institute for Scientific Information (ISI) and then maintained by Clarivate Analytics, was conducted in June 2024. All articles published before June 3, 2024, were screened, and pilot searches were conducted in order to refine the search strategy. During these pilot searches, the scope was broadened, and a total of 883 studies were identified. The electronic search was performed using "all fields," which allows for the search of all searchable fields. To prevent the omission of potentially relevant publications, our search was exhaustive, and manual sifting was conducted in order to achieve greater precision. To identify publications to be included in the study, we searched the search bar ("deep learn*" OR "artificial intelligen*" OR "machine learn*" OR "convolutional neural network*" OR "RNN" OR "CNN*" OR "Recurrent neural network*" OR "FCN*" OR "Fully Convolutional Network*" OR "artificial neural network*") (All Fields) AND ("tooth dec*" OR "dental cari*" OR "teeth dec*" OR "tooth cari*") (All Fields), a total of 883 studies were found. The articles were initially screened by a single author, who opened the title, abstract, and, in cases where no decision could be made, the full text. The selected articles were then collated into a list. A total of 276 publications were selected for further analysis. By filtering the selected articles, the document types "article," "proceeding paper," "review," and "early access" were identified. In the screening process, the publication language was set as English, and only articles published in this language were included in the study. Following the aforementioned screening and filtering processes, the study was conducted on 270 publications. As the research did not involve clinical studies or patient data, no ethical approval was required.

The "analyze result and citation report" options in the Web of Science database were employed to ascertain which authors had the highest number of articles and citations on this subject, in which countries and universities more research was conducted on this subject, and graphical representations of these data. The bibliometric analysis and visualization of the data were conducted using the VOSviewer software (Center for Science and Technology Studies, Leiden University) and the Bibliometrix Biblioshiny R-package software (https://www.bibliometrix.org/home/index.php/layout/biblioshiny) . VOSviewer enables the creation of maps of authors or journals based on co-citation data, as well as maps of keywords based on co-occurrence data. The program provides a viewer that allows a comprehensive examination of the bibliometric maps.[11] VOSviewer version 1.6.20, released on September 31, 2023, was downloaded for free from the official website of the VOSviewer program. The data in the ".txt" format, previously exported, was transferred to the VOSviewer program, processed, and visuals were created.

The Biblioshiny R-pack represents a distinctive open-source tool for the comprehensive analysis of science mapping. The software supports a proposed workflow for the execution of bibliometric analyses. As it is programmed in the R language, the proposed tool is flexible and can be easily upgraded and integrated with other statistical R packages. It is therefore useful in a field that is in a constant state of evolution, such as bibliometrics.[12] The data was exported in the "bib" file format and processed by the program, resulting in the generation of visualizations.

The Microsoft Excel (Microsoft, Inc., Redmond, Washington) software was employed to tabulate the data.

Results

A general increase in the number of articles published each year is observed. While the publications on the use of artificial intelligence in cariology received 3081 citations in total, 1816 of these citations were made by authors other than the authors themselves. The average number of citations per article was 11.41, while the H index was 29. A co-citation network containing the top 10 references was analyzed (**Figure 7**).

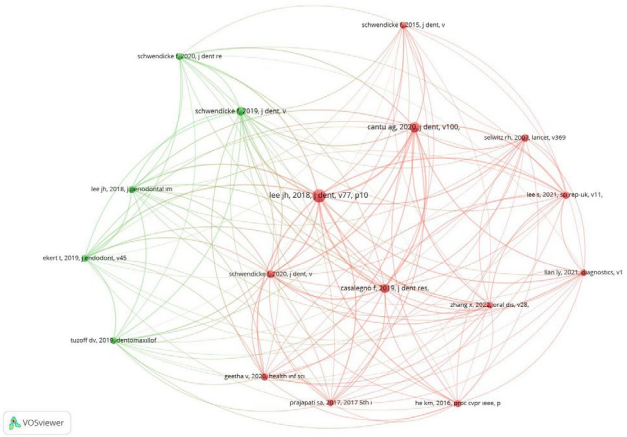

Figure 7. Co-citations source network

In light of the information available in the database, data on specific topics, including titles, authors, journals, publication dates, total citations, and annual averages, was extracted and organized into tables.

The ten most frequently cited articles in the research on the use of artificial intelligence in dental cariology were identified using the search terms and presented in **Table 1**.

Table 1. Most cited 10 articles

Title	Author	Journals	Publication Year	Total Citations	Average per Year	Type of Study
Detection and Diagnosis of Dental Caries Using a Deep Learning-Based Convolutional Neural Network Algorithm	Lee JH, Kim DH, Jeong SN, Choi SH	Journal of Dentistry	2018	346	49.43	Article
Caries Detection with Near-Infrared Transillumination Using Deep Learning	Casalegno F, Newton T, Daher R, Abdelaziz M, Lodi-Rizzini A, Schürmann F, Krejci I, Markram H	Journal of Dental Research	2019	140	23.33	Article
Detecting Caries Lesions of Different Radiographic Extension on Bitewings Using Deep Learning	Cantu AG, Gehrung S, Krois J, Chaurasia A, Rossi JG, Gaudin R, Elhennawy K, Schwendicke F	Journal of Dentistry	2020	114	22.80	Article
Deep Learning for Caries Lesion Detection in Near-Infrared Light Transillumination Images: A Pilot Study	Schwendicke F, Elhennawy K, Paris S, Friebertshäuser P, Krois J	Journal of Dentistry	2020	82	16.40	Article
An Artificial Multilayer Perceptron Neural Network for Diagnosis of Proximal Dental Caries	Devito KL, Barbosa FD, Felippe WN	Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontology	2008	72	45383	Article
Application of Machine Learning for Diagnostic Prediction of Root Caries	Hung M, Voss MW, Rosales MN, Li W, Su WC, Xu J, Bounsanga J, Ruiz-Negron B, Lauren E, Licari FW	Gerodontology	2019	60	10	Article
Dental Caries Diagnosis in Digital Radiographs Using Back-Propagation Neural Network	Geetha V, Aprameya KS, Hinduja DM	Health Information Science and Systems	2020	59	45515	Article
Deep Learning for Caries Detection: A Systematic Review	Mohammad-Rahimi H, Motamedian SR, Rohban MH, Krois J, Uribe SE, Mahmoudinia E, Rokhshad R, Nadimi M, Schwendicke F	Journal of Dentistry	2022	57	19	Review
Caries Detection on Intraoral Images Using Artificial Intelligence	Kühnisch J, Meyer O, Hesenius M, Hickel R, Gruhn V	Journal of Dental Research	2022	54	18	Article
Deep Learning for Caries Detection and Classification	Lian LY, Zhu TE, Zhu FD, Zhu HH	Diagnostics	2021	53	13.25	Article

A graphical representation of the number of articles and citations published per year from 2008 onwards was shown in **Figure 1.**

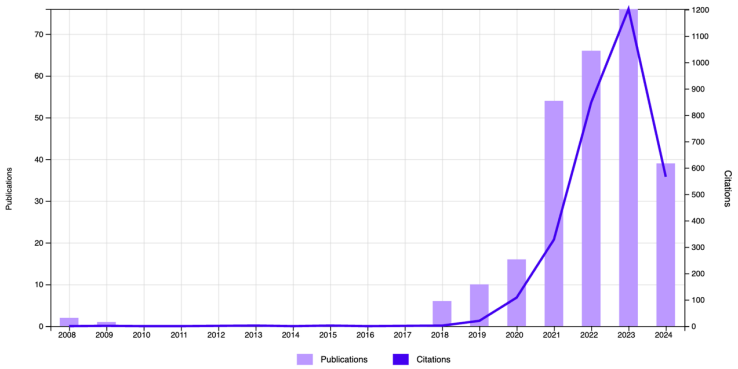

Figure 1. Number of publications and citations published each year from 2008 to 2024

As a consequence of bibliometric analyses, collaboration maps of countries (**Figure 2**), authors (**Figure 3**), and institutions (**Figure 4**) were constructed.

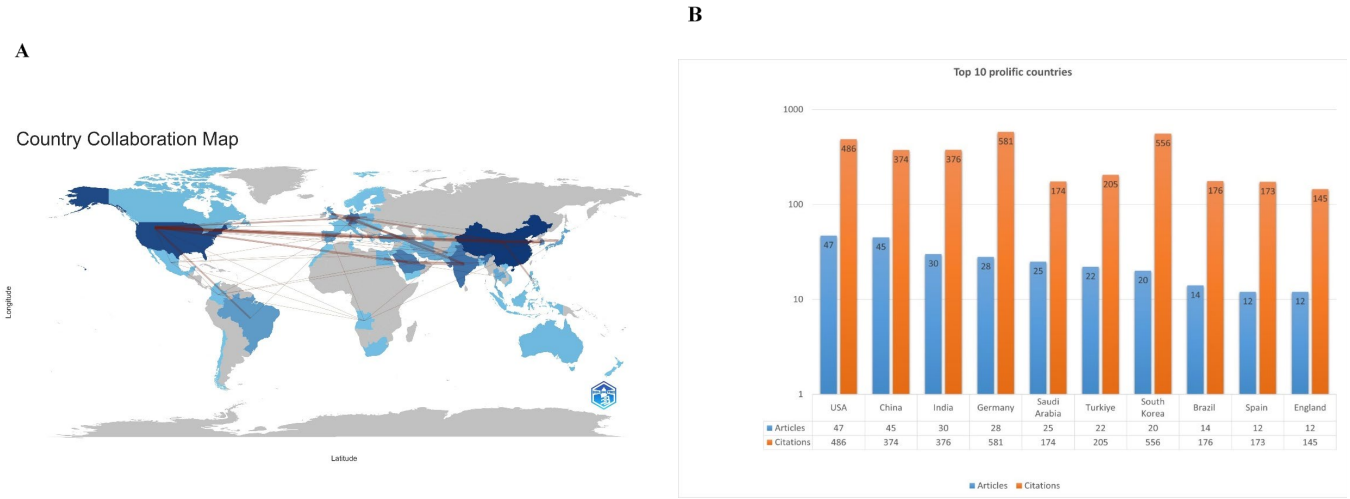

Figure 2. The top 10 countries that have demonstrated the greatest productivity in terms of international collaboration. (A) The degree of collaboration between countries that have published more than 10 articles. It can be observed that the breadth of the connection is positively related to the strength of collaboration. (B) The number of articles and citations of the top 10 most productive countries.

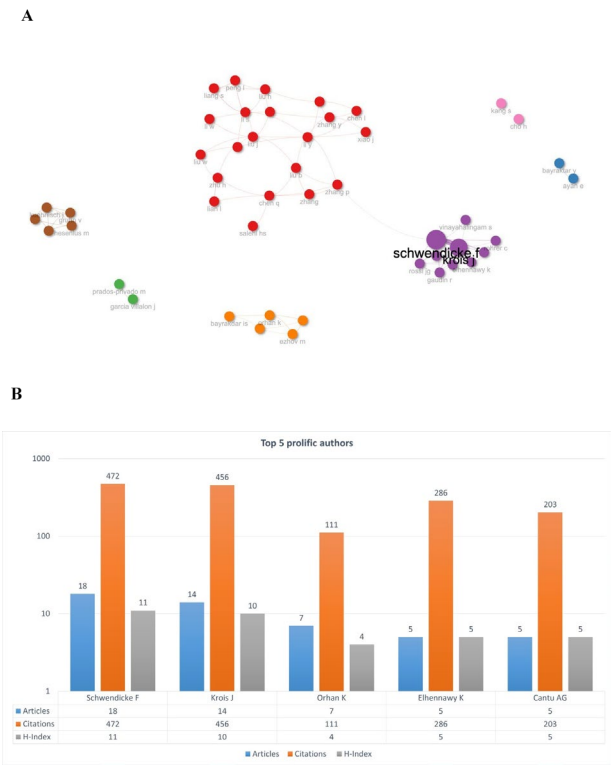

Figure 3. The top 5 most productive authors and their respective collaboration networks are presented here. (A) Co-operation between prolific authors. The number of publications correlates with node size. (B) The number of articles, number of citations and h-index in the top 5 prolific authors.

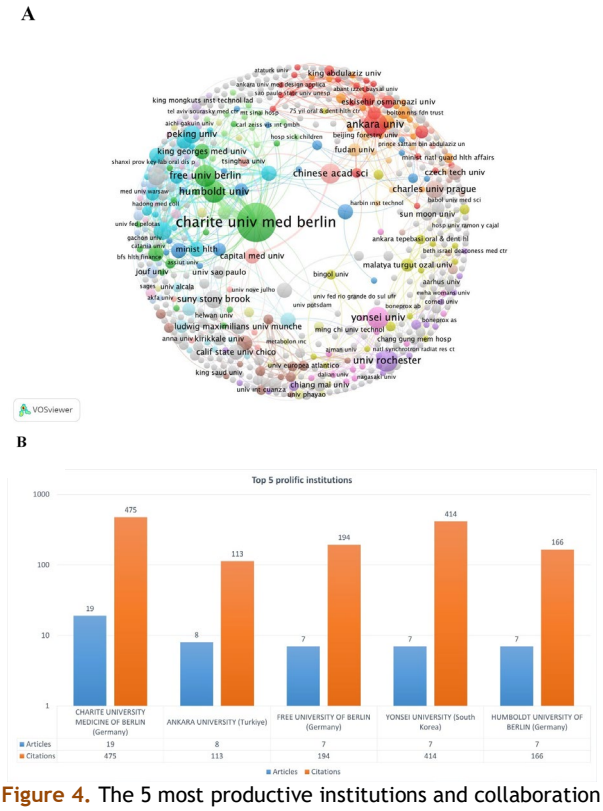

Figure 4. The 5 most productive institutions and collaboration networks (A) Collaboration among affiliations. The size of the nodes is proportional to the number of publications. The width of the links represents the strength of the cooperative relationship. (B) The number of publications, total citations (TC), and total articles (TA) in the top 5 most prolific institutions.

The country with the greatest number of citations was Germany (581 citations), while the most influential author was Falk Schwendicke (18 articles, 475 citations). In terms of institutions, Charite University Medicine Berlin (19 articles, 475 citations) made the highest contribution. The 10 most productive journals are presented in **Figure 5.** A word cloud is a visual representation of the frequency of words in a text, where the font size of each word is proportional to the number of times it occurs in the text.[13] The most frequently used keyword by the authors was "deep learning." **Figure 6** illustrates the frequency of use of keywords according to years.

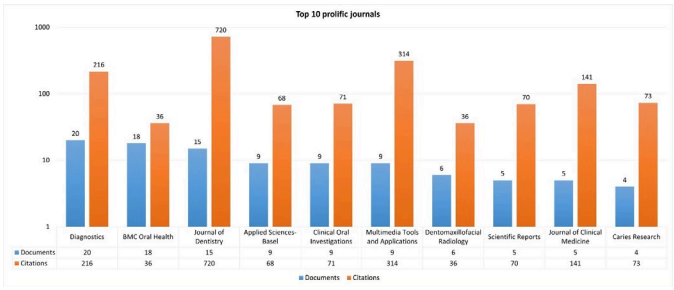

Figure 5. Total publications (TP) and total citations (TC) in the top 10 most prolific journals

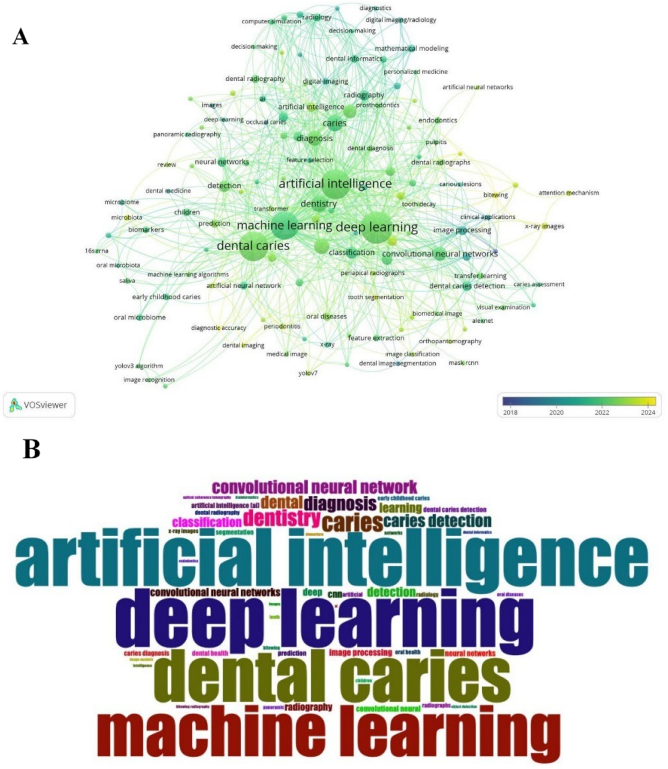

Figure 6. The co-occurrence networks of author keywords (A) Word cloud of keywords (B)

Discussion

This investigation identifies and analyzes articles pertaining to AI in cariology. The objective is to assist future researchers in identifying emerging trends and areas requiring further research.

Bibliometric analysis has indicated a notable increase in the utilization of AI in the field of cariology since 2008. In particular, since 2018, there has been a notable increase in the number of publications and citations related to the use of artificial intelligence in karyology. Although the search was conducted on articles published before June 3, 2024, the number of articles published up to June 2024 was almost four times that of 2019, while the number of citations was almost twice that of 2021. A total of 76 articles were published in 2023. By

June 3, 2024, 39 articles had been published. This suggests that the number of articles to be published by the end of 2024 may exceed the number of articles published in 2023. The results of this study indicate that the field in question has recently attracted significant interest from researchers, as evidenced by the annual publication volume trend. In terms of global trends and research hotspots for the utilization of artificial intelligence in the field of cariology, it is evident that the majority of research activities are concentrated in the USA, China, and India in terms of the number of articles. Germany, South Korea, and the USA are considered in terms of the number of citations, with figures of 581, 556, and 486, respectively.

In terms of authorship, the co-authorship map analysis reveals seven clusters of authors where the co-operation network is evident. The largest cluster comprises authors such as Schwendicke F, Krois J, Chaurasia A, Rohrer C, and Elhennawy K, who frequently collaborate with each other. The number of articles published the total number of citations, and the H-indexes of the five most productive authors are presented. Among the researchers in this field, Schwendicke and Krois J. F. were the most prolific, with 18 and 14 publications, 472 and 456 citations, and an H-index score of 11 and 10, respectively. They were also in the same cluster, indicating that they had closely cooperated. Schwendicke and Krois J. published 14 manuscripts on artificial intelligence in cariology together (**Table 2**).

Table 2. Schwendicke and Krois J's collaborative articles

Publication	Keywords	Keywords Plus	Source	Citation	References
Patients' perspectives on the use of artificial intelligence in dentistry: a regional survey	Artificial Intelligence, Machine Learning, Qualitative Research, Patient Survey, Perception	Proximal Caries, Future, Knowledge, Radiology	Head & Face Medicine	2	Ayad et al.
Artificial Intelligence for Caries Detection: Value of Data and Information	AI, Caries Detection, Diagnosis, Prevention, Computer Simulation, Dental Informatics, Economic Evaluation, Radiology	Cost-Effectiveness, Lesions	Journal of Dental Research	8	Schwendicke et al.
Towards Trustworthy AI in Dentistry	Computer Vision, CNN, AI, Deep Learning, Machine Learning, Dental Informatics, Bioinformatics, Mathematical Modeling, Standardization	-	Journal of Dental Research	16	Ma et al.
Deep learning for caries detection: A systematic review	Artificial Intelligence, Machine Learning, Neural Networks, Dental Caries, Dentistry, Systematic Review	Diagnostic-Test, Accuracy, Artificial-Intelligence, Optimization, Meta Analysis, Management	Journal of Dentistry	57	Mohammad-Rahimi et al.
Self-Supervised Learning Methods for Label-Efficient Dental Caries Classification	Unsupervised Methods, Self-Supervised Learning, Representation Learning, Dental Caries Classification, Data Driven Approaches, Annotation Efficient Deep Learning	Artificial-Intelligence	Diagnostics	5	Taleb et al.
Patients' Perspectives on Artificial Intelligence in Dentistry: A Controlled Study	Artificial Intelligence, Communication, Dental Diagnosis, Machine Learning, Patients, Trust	Trust, Care, Technology, Prevalence, Validation Anxiety, People, Scale	Journal of Clinical Medicine	11	Kosan et al.
Cost-effectiveness of Artificial Intelligence as a Decision-Support System Applied to the Detection and Grading of Melanoma, Dental Caries, and Diabetic Retinopathy	-	Root-Canal Treatment, Surveillance, Strategies, Services, Outcomes, England, Lesions, Crowns, Field	Jama Network Open	28	Rossi et al.
Cost-effectiveness of AI for caries detection: randomized trial	Artificial Intelligence, Caries Detection, Diagnosis, Prevention, Computer Simulation, Dental Decision-Making, Economic Evaluation, Radiology	General Dental Services, Root-Canal Treatment, Outcomes, England, Crowns	Journal of Dentistry	6	Schwendicke et al.
Artificial intelligence for caries detection: Randomized trial	Artificial Intelligence, Clinical Studies, Trials, Computer Vision, Decision-Making, Deep Learning, Personalized Medicine	-	Journal of Dentistry	38	Mertens et al.
Cost-effectiveness of Artificial Intelligence for Proximal Caries Detection	Caries Diagnosis, Prevention, Computer Simulation, Dental, Decision Making, Economic Evaluation, Radiology	General Dental Services, Root-Canal Treatment, Lesions, Outcomes, England, Crowns	Journal of Dental Research	38	Schwendicke et al.
Generalizability of Deep Learning Models for Caries Detection in Near-Infrared Light Transillumination Images	Artificial Intelligence, Caries, Diagnostics, Digital Imaging, Radiology, Mathematical Modeling	-	Journal of Clinical Medicine	16	Holtkamp et al.
Detecting white spot lesions on dental photography using deep learning: A pilot study	Artificial Intelligence, Caries, Digital imaging, Radiology, Mathematical Modeling, Photography, White	Teeth	Journal of Dentistry	36	Askar et al.
Detecting caries lesions of different radiographic extension on bitewings using deep learning	Artificial Intelligence, Caries, Digital imaging, Radiology, Mathematical Modeling, Radiography	Diagnosis	Journal of Dentistry	114	Cantu et al.
Deep learning for caries lesion detection in near-infrared light transillumination images: A pilot study	Artificial Intelligence, Caries, Diagnostics, Digital imaging, Radiology, Mathematical Modeling	Periodontitis, Restorations, Validation, Accuracy, Teeth, Decay	Journal of Dentistry	82	Schwendicke et al.

These include the detection of dental caries in near-infrared light transillumination images, the detection of white spot lesions in dental photographs, and the detection of dental caries in bitewing radiographs. The most frequently cited papers investigate the use of deep learning methods for the detection of dental caries lesions in near-infrared light transillumination images and deep learning approaches for the detection of dental caries lesions in bitewing radiographs. These have been cited 114 and 82 times, respectively (**Table 1**). In Turkiye, Orhan K, from Ankara University, published 7 papers, with a total citation count of 111 times and an H-index of 4. All of the authors in the top five have been highly active in recent years, making significant contributions to the application of artificial intelligence in cariology.

It is crucial to present a co-authorship map analysis of the institutions involved in the published articles in order to comprehend the extent of collaboration between them. Our analyses have revealed the existence of a network of collaborative relationships between institutions, including Humboldt University of Berlin, Charite University Medicine Berlin, and Free University of Berlin in Germany, as well as Ankara University and Eskişehir Osmangazi University in Turkey. These institutions demonstrate a high level of cooperation. A quantitative analysis of published articles reveals that the institutions with the greatest contributions to this field are Charite University Medicine Berlin in Germany and Ankara University in Turkey, with 19 and 8 articles, respectively. However, a qualitative analysis of the citations received indicates that the institutions with the greatest impact are Charite University Medicine Berlin and Yonsei University in South Korea, with 475 and 414 citations, respectively. In this context, it can be argued that the joint research articles they have published in recent years have had a significant impact on shaping the newest and most advanced research directions in this field. The contributions of these authors to the field of cariology represent a significant advance in the application of artificial intelligence.

When the existing literature was examined, it was stated that the most frequently cited article on the use of artificial intelligence in the detection and diagnosis of dental caries belongs to Lee et al.[14] The purpose of this article is to evaluate the effectiveness of deep convolutional neural network algorithms for diagnosing dental caries on periapical x-rays. Two research articles were presented that demonstrated the effectiveness of caries detection using near-infrared transillumination with the aid of a deep learning technique.[15,16] A research paper sought to apply deep learning to the detection of caries lesions in bitewing radiographs, hypothesizing that this approach would be significantly more accurate than that of individual dentists.[17] The oldest of the studies was published in 2008 and aimed to evaluate the impact of an artificial intelligence model on the radiographic diagnosis of proximal caries.[18] A research paper was published in which machine learning methods were

applied for the purpose of diagnostic prediction of root caries.[19] One research article proposed that the back-propagation neural network could be employed to more accurately predict dental caries. Furthermore, the article asserted that there was a need to enhance the system for classifying caries depth.[20] One research article was a systemic review on detecting caries via deep learning.[21] The objective of one research article was to present a method for the detection and classification of caries using convolutional neural networks (CNNs). In order to achieve this objective, 2417 anonymized photographs of permanent teeth were used.[22] The aim of a research paper was to utilize deep learning methodologies to categorize distinct radiographic expansions observed in panoramic radiographs, identify carious lesions, and evaluate the accuracy of the detected results in comparison to those obtained by expert dentists. For the purposes of this research, 1160 dental panoramic films were evaluated.[23]

A co-citation network is a graphical representation of the relationships between academic papers based on their citation patterns. In a co-citation network, nodes represent individual papers, and links between nodes indicate that those papers have been cited together in other works. The strength of the link can be determined by the frequency of co-citations between the two papers in question. Papers that are frequently co-cited are likely to be related conceptually or thematically. By analyzing the structure of the network, researchers can identify key papers, influential authors, and emerging trends within a research domain.[24] A co-citation network comprising the top 10 references was subjected to analysis. Among them, the research paper titled 'Detection and Diagnosis of Dental Caries Using a Deep Learning-Based Convolutional Neural Network Algorithm' received 113 citations and had the highest total link strength.[14] Conversely, when a review entitled 'Dental Caries' was considered, the lowest total link strength was observed.[25] Research hotspots and emerging themes were identified using keyword co-occurrence clustering analysis and a keyword cloud. In particular, since 2018, there has been a noticeable increase in the number of articles devoted to the subject of artificial intelligence in karyology. One author put forth a proposal for the development of an automated system for the identification of dental caries in periapical images.[26] A paper published in 2018 presented a novel methodology that integrates an optical coherence tomography (OCT) imaging approach with deep convolutional neural networks (CNN) for the classification of human oral tissues to detect early dental caries.[27] Gavinho and colleagues sought to develop a method for the segmentation of laser speckle images of tooth surfaces with the goal of facilitating the early diagnosis of caries.[28] In a study conducted by Lee et al., the effectiveness of deep CNN algorithms for the detection and diagnosis of dental caries on periapical radiographs was evaluated. This study has shown that deep convolutional neural network (CNN) algorithms stand out as one of the most effective and efficient methods for diagnosing dental caries.[14]

In 2019, automatic dental decay treatment prediction[29], caries lesion detection using near infrared image[30], fuzzy logic framework for the assessment of the risk of dental caries and erosion[31] were performed.

In 2020, papers such as the realization of post-Streptococcus mutans prediction in dental caries using artificial intelligence (AI) were published.[32] When 16 articles were published in the same year, the number of articles published increased dramatically, reaching 54 in 2021.

In 2021, Ezhov et al. introduced a novel AI system based on deep learning methodologies.[33] A paper was published in which the authors used deep learning to classify cavities in third molars.[34] One research project aimed to analyze metagenomic data from the oral microbiome of Korean children in order to ascertain the bacteria most closely associated with dental caries. This was achieved by utilizing machine learning models.[35] Zheng et al. introduced a new tool, ResNet18, which demonstrated satisfactory performance in the diagnosis of deep caries and pulpitis for CNN, as evidenced by its precision, accuracy, specificity, sensitivity, and area under the curve (AUC).[36] In their study, Heimisdottir et al. employed metabolomics to ascertain the biochemical characteristics of supragingival biofilm in relation to the prevalence and severity of early childhood caries (ECC). A tree-based pipeline optimization tool (TPOT) was employed in this study to identify the optimal classification metabolite model for early childhood caries (ECC) using a machine learning process.[37] The objective of one study was to develop a novel model for caries risk prediction in teenagers, integrating environmental and genetic factors, through the application of a machine learning algorithm.[38] In a particular study, researchers utilized oral microbiome data from both healthy and caries-active mother-child pairs, integrating this information with demographic and environmental factors as well as pertinent fungal data. This comprehensive dataset was then employed to develop a multifactorial machine learning model using LASSO-penalized logistic regression. Machine learning can have a significant impact on the prevention and diagnosis of dental caries, the proof-of-concept study showed.[39] In another study, artificial intelligence (AI) was utilized to automate the process of sex assessment for individual adult tooth X-ray images.[40] The utilization of color photography on smartphones[38], oral photographs captured by mobile phones in accordance with the YOLOv3 algorithm[39], and the deployment of smartphone apps[40] in disparate investigations during the same year were observed.

In 2022, Zhu et al. proposed a novel deep learning architecture, designated CariesNet, with the objective of delineating different degrees of caries from panoramic radiographs.[41] Various advanced methodologies related to artificial intelligence have been used in the literature in the field of cariology.[42-44] Jaiswal et al. employed transfer learning and XGBoost to classify multi-oral diseases from panoramic radiographs.[45] Another study devised an Attention U-Net model for the segmentation of images with caries. This model was created by combining the U-Net model with the convolution block attention module. Furthermore, the initial assessment of this technology, which is pivotal in the detection of dental caries, was conducted.[46] Qu et al. attempted to develop a caries risk prediction model (CRPM) for children using a machine learning algorithm. The study involved a group of children aged between 12 and 60 months, recruited from three kindergartens in China.[47]

In 2023, a study was conducted to ascertain which of three pre-trained models, namely EfficientNet-B0, DenseNet-121, and ResNet-50, was most effective for the purpose of caries detection.[48] The objective of the Dayi et al. study was to assess the diagnostic accuracy of an artificial intelligence system utilizing deep learning for the identification of carious lesions in panoramic radiographs. They proposed the Dental Caries Detection Network (DCDNet) architecture, specifically designed for the detection of dental caries.[49] In a study by Haghanifar et al., an accuracy of 86.05% was achieved on the test set using a dataset of 470 panoramic images for tooth segmentation and dental caries detection with the assistance of PaXNet.[50] The aim of the other study was to investigate the association between body mass index (BMI) and dental caries using innovative statistical and machine learning (ML) models, taking into account cardiovascular risk factors, metabolic syndrome (MetS) components, outcomes, and related conditions.[51] Amasya et al. conducted a comparative study investigating the efficacy of an artificial intelligence (AI) software, namely Diagnocat, in the detection of caries. The study involved comparing cone-beam computed tomography (CBCT) evaluation outcomes with and without the software.[52] In another study, the effectiveness of dental caries detection with quantitative light-induced fluorescence (QLF) images was evaluated using a convolutional neural network (CNN) model by Park et al.[53] A model of artificial intelligence developed by Velusamy et al. demonstrated an effective result with an accuracy of 97.183% in detecting caries lesions.[54] Jiang et al. introduced a detailed RGB image classification model, CariesFG, incorporating an attention mechanism specifically for dental caries. They highlighted that CariesFG successfully captures distinctive features and discriminative components.[55]

In 2024, Karakuş et al. employed artificial intelligence (AI) for the automated identification and localization of various forms of dental caries in bitewing radiographs. The researchers employed the YOLOv8 algorithm, which they assert has the potential to enhance precision and reliability while circumventing diagnostic errors and alleviating the workload on dentists.[56] A deep learning-assisted caries segmentation and classification model was developed in a study conducted by Priya et al. with the objective of treating the caries at an early stage in order to avoid tooth loss. Caries segmentation was conducted using the Adaptive Trans-Dense Unet++ (ATDUnet++) method. The classification of dental caries was performed using a

ViT-MRDGRU-based multiscale residual DenseNet and Vision Transformers. The developed model exhibited an accuracy rate of 96.59% and a precision rate of 96.55%.[57] The purpose of another study was to ascertain the value of ChatGPT and Google Bard (now known as Gemini) as resources for educators of dental caries in the generation of multiple-choice questions.[58] Ayhan and colleagues demonstrated that convolutional neural networks (CNNs) can be effectively utilized for the purposes of tooth numbering and caries detection.[59] The objective of another study conducted by Kawazu et al. was to ascertain the feasibility of attaining a certain degree of diagnostic proficiency with a limited dataset through the utilization of domain-specific transfer learning in the context of dental caries detection. The researchers indicated that domain-specific transfer learning methods could be beneficial in terms of reducing the size of datasets and the time required for training.[60]

It must be acknowledged that one limitation of this study is the relatively recent emergence of research on the application of AI in cariology. This may result in a lower number of citations compared to more established dental topics with a longer research history. Furthermore, while the authors' profiles were analyzed to explore international collaboration, the specific level of contribution from each author could not be determined, which may have resulted in an overestimation of collaboration. Furthermore, the quality of the included studies was not sufficiently evaluated, and the level of evidence may be variable. Lastly, the use of only the Web of Science database may have resulted in the exclusion of influential manuscripts listed in other databases, including Scopus and PubMed.

Another limitation is that there are some difficulties in detecting caries in radiographs with artificial intelligence due to gray scale values and confusion with other conditions or small areas. A distinction according to the types of caries was not made and could not be evaluated because there were not enough studies on this subject. Further studies can be conducted in the future to evaluate the success and citationability of research on this topic.

In conclusion, the utilization of artificial intelligence in the field of cariology offers a multitude of promising avenues for the advancement of knowledge and practice in a variety of areas, including the diagnosis, detection, and segmentation of dental caries.

Conclusion

Since 2008, the application of artificial intelligence (AI) in cariology, or the study of dental and oral diseases, has gradually garnered significant attention. The most prolific authors were Schwendicke and Krois JF. Our analyses have revealed the existence of a network of collaborative relationships between institutions, including Charite University Medicine Berlin, Humboldt University of Berlin, and Free University of Berlin in Germany, as well as Ankara University and Eskişehir Osmangazi University in Turkey.

A content analysis of the top 10 publications most frequently cited by others in their work revealed that the most cited paper in diagnosing dental caries using artificial intelligence was that of Lee et al. The research paper titled 'Detection and Diagnosis of Dental Caries Using a Deep Learning-Based Convolutional Neural Network Algorithm' received 113 citations and had the highest total link strength. In the period following 2018, there has been a notable increase in the number of studies on artificial intelligence in the karyological literature, as well as the number of citations to these studies.

In light of the aforesaid, it is clear that artificial intelligence (AI) is a breakthrough exploration that will be increasingly applied to various branches of dentistry.

Değerlendirme / Peer-Review

İki Dış Hakem / Çift Taraflı Körleme

Etik Beyan / Ethical statement

Bu çalışmanın hazırlanma sürecinde bilimsel ve etik ilkelere uyulduğu ve yararlanılan tüm çalışmaların kaynakçada belirtildiği beyan olunur.

It is declared that during the preparation process of this study, scientific and ethical principles were followed and all the studies benefited are stated in the bibliography.

Benzerlik Taraması / Similarity scan

Yapıldı – ithenticate

Etik Bildirim / Ethical statement

ethic.selcukdentaljournal@hotmail.com

Finansman / Grant Support

Yazarlar bu çalışma için finansal destek almadığını beyan etmiştir. | The authors declared that this study has received no financial support.

Çıkar Çatışması / Conflict of Interest

Yazarlar çıkar çatışması bildirmemiştir. | The authors have no conflict of interest to declare.

Yazar Katkıları / Author Contributions

Çalışmanın Tasarlanması | Design of Study: İTG (%40), RE (%25), YSG (%20), GY (%15)
Veri Toplanması | Data Acquisition: İTG (%40), RE (%25), YSG (%20), GY (%15)
Veri Analizi | Data Analysis: İTG (%40), RE (%25), YSG (%20), GY (%15)
Makalenin Yazımı | Writing up: İTG (%40), RE (%25), YSG (%20), GY (%15)
Makale Gönderimi ve Revizyonu | Submission and Revision: İTG (%40), RE (%25), YSG (%20), GY (%15)

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