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TRENDS IN DEEP AND MACHINE LEARNING FOR DENTAL LESION DETECTION: A BIBLIOMETRIC ANALYSIS (1991–2024)

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ABSTRACT

Objective: *This study aims to evaluate the literature on the use of deep learning models in the diagnosis of dental lesions through bibliometric mapping analysis.*

Material and Method: *Studies indexed in the Web of Science Core Collection database using relevant keywords were examined within the scope of bibliometric analysis. Publication year, citation numbers, countries, journals, authors, keywords, and collaboration networks were analyzed using VOSviewer software.*

Results: *The analysis results showed that the number of publications on deep learning applications in the diagnosis of dental lesions increased significantly, especially after 2018. The keywords "deep learning", "artificial intelligence", and "machine learning" were found to have a central position in the literature. South Korea, China, and the United States were among the countries with the highest citations, while clinical and radiology-focused journals were found to be prominent in the field.*

Conclusion: *This bibliometric analysis reveals research trends, prominent areas of study, and existing knowledge gaps regarding deep learning applications in the diagnosis of dental lesions. It is expected that the findings will guide future studies and contribute to the development of artificial intelligence-based diagnostic approaches in dental radiology.*

Keywords: *Dental lesions, deep learning, artificial intelligence, bibliometric analysis, dental radiology*

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DENTAL LEZYONU TESPİTİ İÇİN DERİN ÖĞRENME VE MAKİNE ÖĞRENMESİNDEKİ TRENDLER: BİBLİYOMETRİK BİR ANALİZ (1991–2024)

ÖZET

Amaç: Bu çalışmanın amacı, derin öğrenme modellerinin dental lezyonlarının tanısında kullanımına yönelik literatürün bibliyometrik haritalama analizi ile değerlendirilmesidir.

Materyal ve Metot: Web of Science Core Collection veri tabanında, ilgili anahtar kelimeler kullanılarak indekslenen çalışmalar bibliyometrik analiz kapsamında incelenmiştir. Yayın yılı, atıf sayıları, ülkeler, dergiler, yazarlar, anahtar kelimeler ve iş birliği ağları VOSviewer yazılımı kullanılarak analiz edilmiştir.

Bulgular: Analiz sonuçları, dental lezyonlarının tanısında derin öğrenme uygulamalarına yönelik yayın sayısının özellikle 2018 yılından sonra belirgin şekilde arttığını göstermiştir. "Deep learning", "artificial intelligence" ve "machine learning" anahtar kelimelerinin literatürde merkezi bir konuma sahip olduğu saptanmıştır. Güney Kore, Çin ve Amerika Birleşik Devletleri en yüksek atıf alan ülkeler arasında yer alırken, klinik ve radyoloji odaklı dergilerin alanda ön plana çıktığı görülmüştür.

Sonuçlar: Bu bibliyometrik analiz, dental lezyonlarının tanısında derin öğrenme uygulamalarına yönelik araştırma eğilimlerini, öne çıkan çalışma alanlarını ve mevcut bilgi boşluklarını ortaya koymaktadır. Elde edilen bulguların, gelecekte yapılacak çalışmalara yön vermesi ve dental radyolojide yapay zekâ tabanlı tanı yaklaşımlarının geliştirilmesine katkı sağlaması beklenmektedir.

Anahtar kelimeler: Dental lezyonlar, derin öğrenme, yapay zekâ, bibliyometrik analiz, dental radyoloji.

INTRODUCTION

Dental lesions can arise from cysts, tumors, dysplastic changes in bones, and metabolic diseases, and are classified as radiolucent, radiopaque, or mixed type on radiographs depending on the quality and amount of tissue they contain. These lesions can lead to clinical problems in terms of aesthetics, function, and phonation. In asymptomatic cases, bone pathologies can be incidentally detected in radiographs obtained during routine dental examinations. However, factors such as distortion, magnification, and superposition visible in panoramic radiographs can cause some lesions to be missed or incompletely evaluated. In these cases, advanced imaging methods are used; however, these methods create additional costs, time, and labor requirements and can increase the radiation dose to which the patient is exposed.[1]

In recent years, artificial intelligence in the healthcare field has shown high accuracy rates, potentially reducing the workload of physicians and minimizing diagnostic errors.[2–4] The use of deep learning-based systems in dental radiology is gaining increasing interest in terms of the automatic detection and classification of dental lesions. However, many variables, such as the characteristics of the datasets used in the literature, imaging techniques, lesion types, and preferred deep learning models, cause the obtained results to differ significantly. This situation necessitates a systematic evaluation of the general trends, research densities, and knowledge gaps in the field of studies.[5]

While there are numerous deep learning-based studies on the detection and evaluation of dental lesions in the current literature, research that comprehensively examines these studies from a bibliometric perspective is limited. Bibliometric analyses reveal publication trends, prominent research topics, collaboration networks, and development over time in a particular field, providing guidance for future studies.[6]

The aim of this study is to perform a bibliometric mapping analysis of publications on the use of deep learning models in the diagnosis of dental lesions. In this context, the goal is to determine research trends and potential research gaps in the field by quantitatively evaluating the existing literature. The aim is for these findings to contribute to the development of deep learning applications in dental radiology and to shed light on future studies aimed at reducing the need for advanced imaging methods.

MATERIAL and METHOD

In this section of the study, a bibliometric mapping analysis of studies on dental lesion detection using deep or machine learning methods that were searched in the Web of Science database is presented to provide an overview of the related literature. The keywords 'deep or machine learning method' and 'dental lesion detection' were entered into the Web of Science database as subject options. The following indexes in the Web of Science database were selected as literature sources to access the studies: Science Citation Index

Expanded (SCI-EXPANDED), Conference Proceedings Citation Index- Science (CPCI-S), Emerging Sources Citation Index (ESCI), Social Sciences Citation Index (SSCI), and Arts and Humanities Citation Index (A&HCI).

In this context, a total of 151 studies obtained from the Web of Science database between 1991 and 2024 were included in the analysis (Access date: August 2024). Regarding document types, the dataset consisted of 114 research articles, 22 review articles, 16 proceeding papers, 5 early access publications, and 1 data paper, providing a comprehensive representation of both original research and secondary literature in the field. Within the scope of the research, the data were analyzed in terms of publication language, publication year, most cited publications, keywords, most cited authors, journals, and countries. The VOSviewer software developed by Van Eck and Waltman was used in these analyses.[7] The following research questions were analyzed using bibliometric mapping analysis to guide new research, identify trends in the field, and compare existing studies:

1. What is the publication language of the studies on dental lesion detection with deep or machine learning methods?
2. In which years were the studies on dental lesion detection by deep or machine learning methods published?
3. What is the number of citations of studies on dental lesion detection by deep or machine learning methods according to years?
4. Which are the most cited publications among the studies on dental lesion detection with deep or machine learning methods?
5. What are the most frequently used keywords of the studies on dental lesion detection by deep or machine learning methods?
6. Who are the most cited (citation and co-citation) authors in studies on dental lesion detection by deep or machine learning methods?
7. Which are the most cited (co-citation) journals among the journals in which studies on dental lesion detection by deep or machine learning methods are published?
8. Which countries are the most cited in studies on dental lesion detection with deep or machine learning methods?

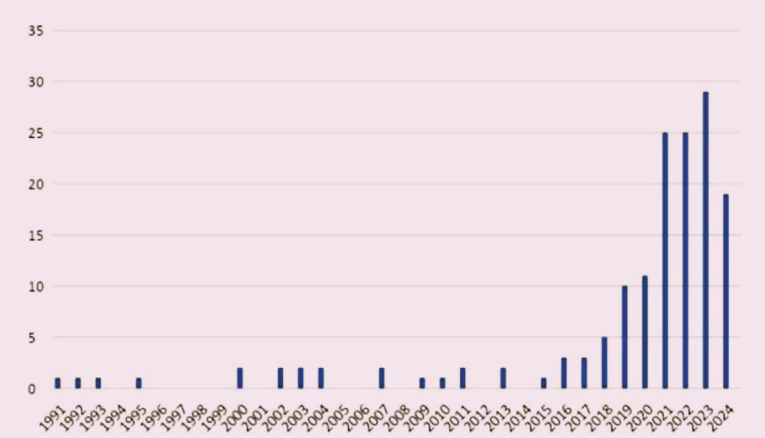

Figure 1. Publication years of studies on dental lesion detection with deep or machine learning methods.

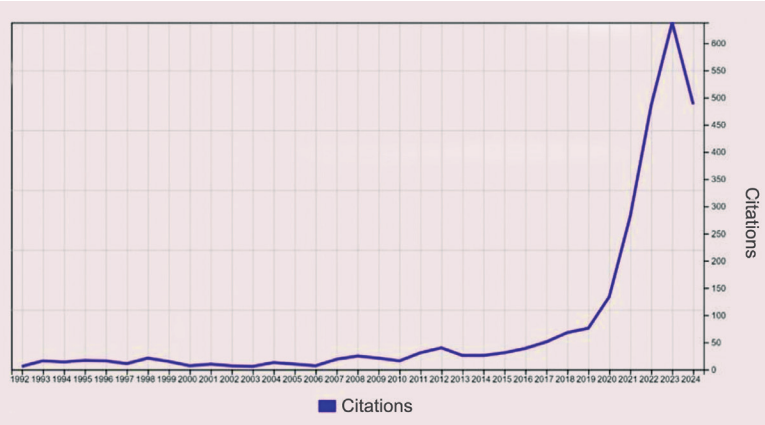

Figure 2. Citation counts of studies on dental lesion detection with deep or machine learning methods.

RESULTS

Publication Language

The language distribution of 151 publications analyzed in this study is as follows: English (150) and Chinese (1). These data show that most of the publications (99%) are in English.

Publication Year

Figure 1 shows the distribution of 151 publications from 1991 to 2024. The annual distribution of publications is as follows: 19 publications were published in 2024, 29 in 2023, 25 in 2022, 25 in 2021, 11 in 2020, 10 in 2019, and 5 in 2018. It is observed that the number of annual publications varied between 1 and 3 in the period until 2018 (between 1991 and 2017). These data reveal that there has been a significant increase in studies on dental lesion detection using deep or machine learning methods since 2018. Although the first study on the subject collected in the Web of Science database was in 1991, it is seen that the majority of the studies (f=29) were published in 2023.

Table 1. Top 10 most cited publications within the scope of the study

Publication Title	Authors	Source Title	Year	(WoS) The Number of Citations	Average Citations per Year
Dental Caries and Its Management	Warreth, Abdulhadi[19]	International Journal of Dentistry	2023	15	7.5
Deep Learning Application in Dental Caries Detection Using Intraoral Photos Taken by Smartphones	Mai Thi Giang Thanh; Ngo Van Toan; Vo Truong Nhu Ngoc; Nguyen Thu Tra; Cu Nguyen Giap; Duc Minh Nguyen[20]	Applied Sciences-Basel	2022	15	5
Deep learning classifier with optical coherence tomography images for early dental caries detection	Karimian, Nima; Salehi, Hassan S.; Mandian, Mina; Alnajjar, Hisham; Tadinada, Aditya[21]	Lasers in Dentistry XXIV	2018	15	2.14
Caries detection with tooth surface segmentation on intraoral photographic images using deep learning	Park, Eun Young; Cho, Hyeonrae; Kang, Sohee; Jeong, Sungmoon; Kim, Eun-Kyong[22]	BMC Oral Health	2022	14	4.67
Clinical and primary evidence of silver diamine fluoride on root caries management	Hiraishi, Noriko; Sayed, Mahmoud; Takahashi, Motoi; Nikaido, Toru; Tagami, Junji[23]	Japanese Dental Science Review	2022	14	3.5
Effectiveness of Resin-Based Sealants with and without Fluoride Placed in a High Caries Risk Population: Multicentric 2-Year Randomized Clinical Trial	Muller-Bolla, Michele; Courson, Frederic; Lupi-Pegurier, Laurence; Tardieu, Corinne; Mohit, Shrisha; Staccini, Ascal; Velly, Ana Miriam[24]	Caries Research	2018	14	2
A Novel Deep Learning-Based Approach for Segmentation of Different Type Caries Lesions on Panoramic Radiographs	Dayi, Burak; Uzen, Huseyin; Cicek, Ipek Balikci; Duman, Suayip Burak [25]	Diagnostics	2023	13	6.5
Deep learning convolutional neural network algorithms for the early detection and diagnosis of dental caries on periapical radiographs: A systematic review	Musri, Nabilla; Christie, Brenda; Ichwan, Solachuddin Jauhari Arief; Cahyanto, Arief [26]	Imaging Science in Dentistry	2021	13	3.25
Monitoring of cariogenic demineralization at the enamel-composite interface using swept-source optical coherence tomography	Horie, Kei; Shimada, Yasushi; Matin, Khairul; Ikeda, Masaomi; Sadr, Alireza; Sumi, Yasunori; Tagami, Junji [27]	Dental Materials	2016	13	1.44
Patients' Perspectives on Artificial Intelligence in Dentistry: A Controlled Study	Kosan, Esra; Krois, Joachim; Wingenfeld, Katja; Deuter, Christian Eric; Gaudin, Robert; Schwendicke, Falk [28]	Journal of Clinical Medicine	2022	12	4

Table 2. The most used 14 keywords in the studies

Keywords	Frequency (f)
Deep learning	23
Machine learning	14
Artificial intelligence	11
Dental caries	9
Dentistry	7
Caries detection	6
Convolutional neural networks	5
Image processing	4
Optical coherence tomography	4
Neural networks	4
Digital imaging	3
Classification	3
Object detection	3
Radiography	3

The number of citations by years is shown in Figure 2. The linear increase in the number of citations between 2019 and 2023 is remarkable.

The Most Cited Publications

The 10 most cited publications are presented in Table 1. It was determined that the majority of the studies examined within the scope of the research (n=114) were articles.

As seen from Table 1, the article with the highest citation and average citation value among the studies examined within the scope of bibliometric analysis is the article titled "Dental Care and Its Management" by Warreth and Abdulhadi in 2023.[8]

The Most Cited Keywords

The most frequently used keywords in the studies examined within the scope of the study were identified, and the created map is presented in Figure 3.

As shown in Figure 3, there are four clusters, and the first cluster (blue) is seen to have a high density. The most frequently used keywords are "deep learning" (f=23) and "machine learning" (f=14), followed by "artificial intelligence" (f=11), "dental caries" (f=9),

"dentistry" (f=7), and "caries detection" (f=6). The 16 most frequently used keywords in the studies are presented in Table 2.

The map of the most used keywords by years is presented in Figure 4. It can be inferred that the keywords shown in yellow and frequently used in recent studies are object detection, segmentation, decision support systems, and artificial intelligence. Therefore, it can be concluded that the focus of the studies conducted in the relevant field in recent years is these topics.

The Most Cited Countries

The map of the most cited countries is shown in Figure 5. According to the analysis results, the top 10 countries cited most by authors were South Korea (Documents=6, Citations=277), China (Documents=9, Citations=165), Switzerland (Documents=1, Citations=145), United States of America (Documents=8, Citations=115), Iran (Documents=4, Citations=86), Germany (Documents=3, Citations=82), Chile (Documents=1, Citations=69), Latvia (Documents=1, Citations=69), Turkey (Documents=4, Citations=77), and Canada (Documents=3, Citations=47).

The Most Cited Journals

The map showing the most cited journals (co-citation analysis) is presented in Figure 6. As a result of the analysis, the most cited journals were Journal of Dentistry (87 co-citations), Scientific Reports (56 co-citations), Dentomaxillofacial Radiology (53 co-citations), Journal of Dental Research (41 co-citations), Journal of Biomedical Optics (37 co-citations), Caries Research (34 co-citations), Journal of Endodontics (30 co-citations), Oral Surgery, Oral Medicine, Oral Pathology, and Oral Radiology (26 co-citations). It was also determined that the majority of the evaluated publications (f=120) were scanned in SCI-Expanded.

The Most Cited Authors

A citation analysis was conducted for the most cited authors, and the resulting map is presented in Figure 7. Here, each node represents an author. Node sizes indicate the number of publications or citations of the relevant authors, while the connecting lines between nodes indicate the relationships and interactions between the authors. According to the results, the documents and citation information of the 20 most cited authors are presented in Table 3.

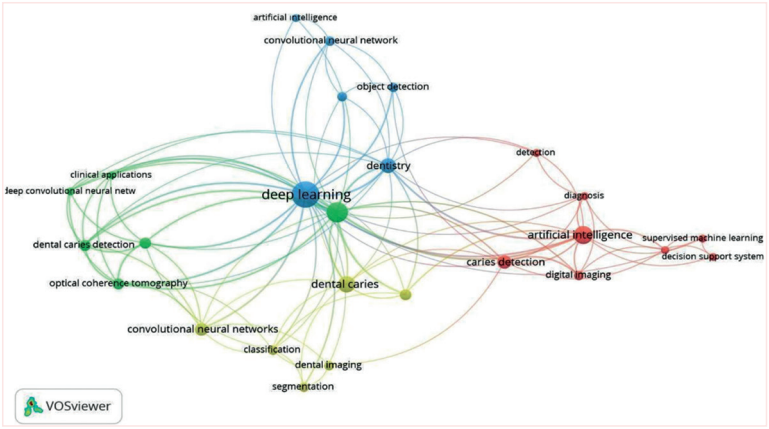

Figure 3. The most used keywords in the studies related to dental lesion detection with deep or machine learning methods..

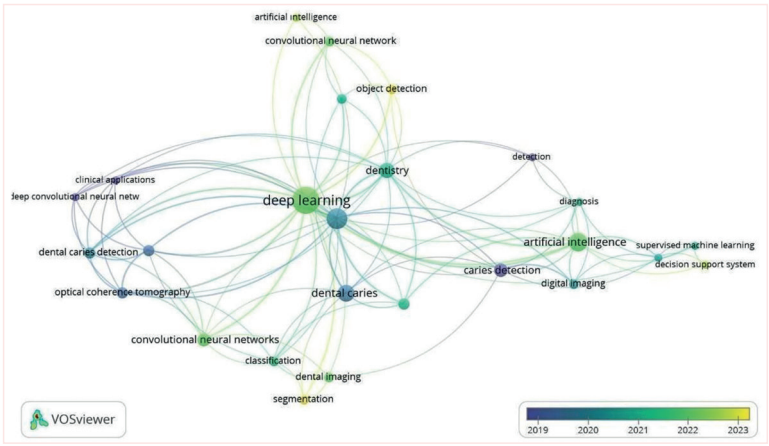

Figure 4. Distribution of most frequently used keywords based on years.

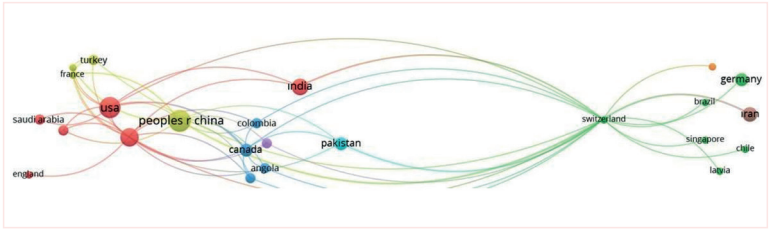

Figure 5. The most cited countries

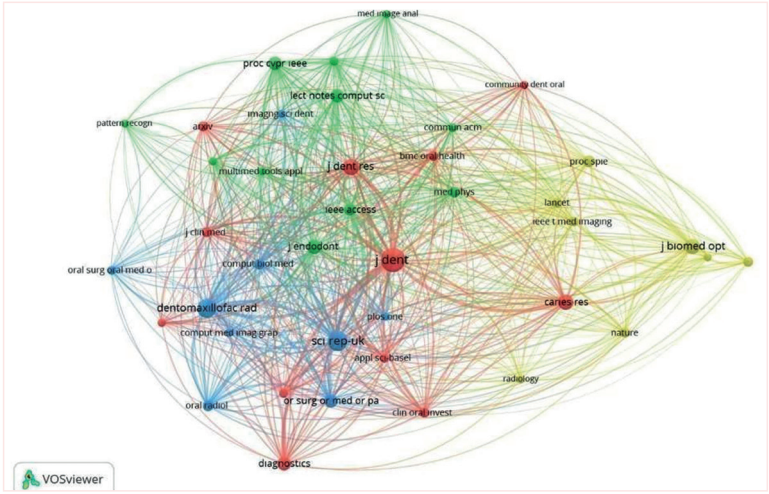

Figure 6. The most cited journals (co-citation analysis)

Table 3. The most cited authors (citation analysis)

Author	Documents	Citations
Abdelaziz M	1	145
Casalegno F	1	145
Daher R	1	145
Krejci I	1	145
Lodi-Rizzini A	1	145
Markram H	1	145
Newton T	1	145
Schuermann F	1	145
Jeong SN	1	111
Kim DH	1	111
Lee JH	1	111
Jung KH	1	101
Kim J	1	101
Lee HS	1	101
Song IS	1	101
Krois J	2	81
Schwendicke F	2	81
Mahmoudinia E	1	69
Mohammad-Rahimi H	1	69
Motamedian SR	1	69

Table 4. Most cited authors (co-citation analysis)

Cited Author	Citations
Lee JH	39
Schwendicke F	34
Salehi HS	18
Casalegno F	12
Krizhevsky A	10
Masychev V	10
Patil S	9
Geetha V	9
Vinayahalingam S	9
Ekert T	9
Hinton GE	9
Selwitz RH	9
Chen HL	8
Prados-Privado M	8
Prajapati SA	8

A co-citation analysis was then performed, and according to the results, it was determined that the authors were gathered into four clusters. The map is presented in Figure 8.

In addition, the 18 most cited authors according to the co-citation analysis are listed in Table 4. This shows that Lee JH (Citations=39), Schwendicke F (Citations=34), and Salehi HS.(Citations=18) are the most cited (co-citation) authors in this field.

DISCUSSION

Recent bibliometric and review studies consistently demonstrate a significant increase in artificial intelligence research across disciplines. Multidisciplinary and domain-specific analyses show that AI-related publications have expanded sharply in recent years, particularly after 2018, with accelerated growth in fields such as dentistry, healthcare, and scientometric applications. For example, bibliometric reviews in dentistry reveal a substantial rise in AI studies between 2018 and 2023, and broader analyses confirm that AI adoption has grown across scientific fields over multiple decades.[9–11]

In this study, publications on the use of deep and machine learning methods in the detection of dental lesions in the Web of Science database were evaluated using bibliometric mapping analysis. The findings reveal a significant increase in scientific output in this field over time, and a shift in research focus towards AI-based diagnostic approaches, particularly in recent years.[5]

When examining the publication year distribution, it is noteworthy that although the first study on the subject was published in 1991, the vast majority of publications are concentrated in 2023. This situation can be attributed to the increased accessibility of deep learning and machine learning methods in the healthcare field in recent years, the development of computational infrastructures, and the increase in dental imaging data. In addition, the increasing emphasis on the clinical importance of early diagnosis of dental lesions may have contributed to the increased academic interest in this field.[12]

Citation analyses show that certain studies in the literature have a high impact factor. Among the publications examined, it is noteworthy that the study titled “Dental Caries and Its Management” published by Warreth and Abdulhadi in 2023 has both the highest total number of citations and the highest average citation value. This suggests that the study has a broad impact not only from a technical perspective but also in terms of clinical applications.[8] It can be said that such highly cited studies play an important role in making deep learning-based approaches more visible in clinical contexts.

According to language analysis, the vast majority of publications within the scope of bibliometric analysis were published in English, with only one study in Chinese. This finding shows that scientific communication in the fields of dentistry and artificial intelligence is largely conducted through English, and that this language is decisive in terms of international visibility.

Keyword analysis demonstrated that the most frequently used terms in the literature were "deep learning", "machine learning", and "artificial intelligence", highlighting the dominant role of data-driven approaches in current dental imaging research. In addition, clinically oriented keywords such as "dental caries", "caries detection", and "dentistry" were commonly observed, indicating that the primary application focus of these methods is the automated detection and classification of carious lesions. The frequent occurrence of architecture- and technique-related terms, including "convolutional neural networks", "neural networks", "classification", and "object detection", suggests that most studies concentrate on developing and optimizing algorithmic models for diagnostic tasks rather than on comprehensive decision support systems. Furthermore, the presence of imaging-related keywords such as "radiography", "digital imaging", and "optical coherence tomography" reflects the diversity of imaging modalities employed in artificial intelligence–based dental research.[13]

According to journal co-citation analysis, the Journal of Dentistry being the most cited journal shows that studies on artificial intelligence applications in the diagnosis of dental lesions are concentrated in clinically focused journals. Furthermore, the fact that a large portion of the publications examined are indexed within the SCI-Expanded database suggests that the scientific quality and impact level of studies in this field are high.

In country-based citation analyses, South Korea's prominence as the most cited country demonstrates the strong integration of dentistry, medical imaging, and artificial intelligence in that country. The high rankings of countries like China and the United States reflect the global research competition in this field. In the author co-citation analysis, Abdelaziz M was identified as the most cited author, while Lee JH's central position in the co-citation networks suggests that these researchers have a guiding role in knowledge production in the field. The main contribution of this study is to quantitatively reveal the general structure, development trends, and prominent research focuses of the literature on deep and machine learning

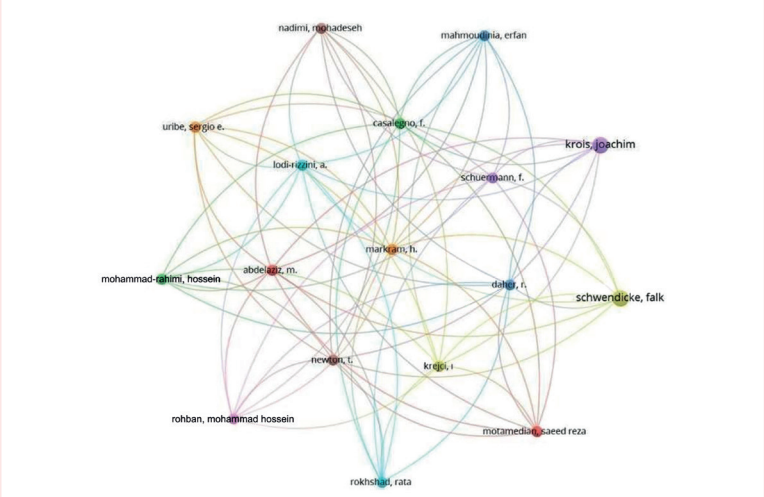

Figure 7. The most cited authors (citation analysis)

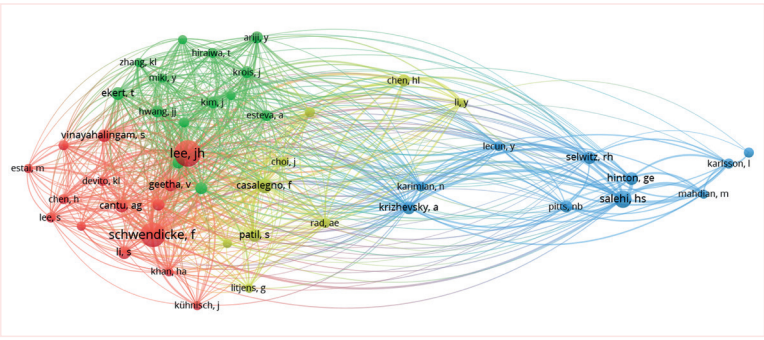

Figure 8. The most cited authors (co-citation analysis)

methods in dental lesion detection. However, the study's limitation to only the Web of Science database and the lack of methodological quality assessment in the bibliometric analyses are its main limitations. Future studies supported by comparative bibliometric analyses and systematic reviews covering different databases will contribute to a more comprehensive evaluation of the field.

CONCLUSION

This study comprehensively evaluates the literature on the use of deep learning and machine learning methods in the diagnosis of dental lesions using bibliometric mapping analysis. The findings indicate a significant increase in academic interest in this field in recent years, with a shift in research focus towards automated detection and decision support systems.

Keyword and citation analyses reveal that deep learning-based approaches hold significant potential for the early diagnosis of dental lesions. However, it was found that existing studies are largely concentrated around specific countries and research groups, exhibiting heterogeneity in terms of datasets and methodological approaches.

This study is significant because it quantitatively presents the overall structure and development direction of the literature, rather than focusing solely on technical performance comparisons. Future research focusing on more standardized datasets, multicenter studies, and clinical integration in light of bibliometric findings will accelerate scientific progress in this field.

Authors' Contributions

All authors contributed to the design of the study, interpretation of the results, writing, and validation.

*The authors declare that there are no conflicts of interest.

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