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Machine learning and deep learning–based imaging applications in pediatric dentistry: A bibliometric analysis

Mehmet Veysel Kotanlı[1] Nurbanu Şahin[2] Mehmet Sinan Doğan[3]

[1]Mehmet Veysel Kotanlı Harran University, Faculty of Dentistry, Department of Pediatric Dentistry, Sanliurfa, Turkey dtmvkotanli@harran.edu.tr / Orcid: /0000-0001-7032-4367

[2]Nurbanu Şahin Harran University, Faculty of Dentistry, Department of Dentomaxillofacial Radiology, Sanliurfa, Turkey, nurbanuuluisik@harran.edu.tr / Orcid ID: 0000-0003-2936-2833

[3]Mehmet Sinan Doğan Harran University, Faculty of Dentistry, Department of Pediatric Dentistry, Sanliurfa, Turkey dtmvkotanli@harran.edu.tr / Orcid: /0000-0002-3089-1305

Abstract

Background: Deep learning and machine learning techniques have become increasingly prominent in dental research as part of the broader integration of artificial intelligence–based approaches. In pediatric dentistry, these methods offer particular potential due to age-specific diagnostic challenges and the need for early detection strategies. Despite growing interest, the overall development and structure of this research field have not yet been comprehensively evaluated.

Material and Method: A bibliometric analysis was conducted using publications indexed in the Web of Science Core Collection between 2000 and 2026. A topic-based search strategy combining deep learning– and machine learning–related terms with pediatric dentistry–specific keywords was applied. Bibliometric indicators, including annual publication output, leading journals, authors, countries, institutions, and keyword co-occurrence networks, were analyzed using the bibliometrix package in R and the Biblioshiny interface.

Result: A total of 162 publications were included. Scientific output remained limited until 2017, followed by a marked increase after 2020, with the highest number of publications recorded in 2024. China, South Korea, and Saudi Arabia were the most productive countries. The literature was primarily concentrated in dental and interdisciplinary journals. Keyword analysis revealed that research predominantly focused on diagnostic and classification-oriented applications, particularly dental caries.

Conclusion: The findings demonstrate a recent and rapid expansion of deep learning and machine learning research in pediatric dentistry, highlighting a growing emphasis on diagnostic support and preventive care. This bibliometric overview provides a structured perspective on current research trends and may guide future investigations in this evolving field.

Key words: Artificial Intelligence; Deep Learning; Pediatric Dentistry; Bibliometrics

INTRODUCTION

The rapid development of artificial intelligence (AI) has led to a growing integration of data-driven computational approaches into various fields of dentistry (Schwendicke et al., 2020; Wang et al., 2025). Among these approaches, deep learning and machine learning techniques have gained particular attention due to their ability to analyze complex datasets, recognize patterns, and support decision-making processes (Esteva et al., 2019). In recent years, these methods have increasingly been applied to dental research, especially in areas involving diagnostic imaging, classification tasks, and predictive modeling (Ren et al., 2021; Hung et al., 2020a).

Pediatric dentistry represents a distinct domain within dental science, characterized by age-related anatomical and developmental variations, unique disease patterns, and specific diagnostic challenges. The assessment of dental caries, tooth development, growth-related changes, and treatment outcomes in children often relies on accurate interpretation of clinical and imaging data. In this context, deep learning and machine learning techniques offer promising opportunities to enhance diagnostic accuracy, improve classification performance, and support early detection strategies tailored to pediatric populations (Khanagar et al., 2022; Karhade et al., 2021; Ahn et al., 2021; Zaborowicz et al., 2021; You et al., 2020).

Although the application of AI–based methods in dentistry has expanded substantially, the adoption of deep learning and machine learning approaches in pediatric dentistry has followed a different trajectory compared with adult-focused dental research (Schwendicke et al., 2020; Wang et al., 2025). Pediatric applications tend to emphasize developmental processes, age estimation, and early-stage disease detection, reflecting the specific clinical needs of children (Khanagar et al., 2022). As a result, the scientific literature in this area has grown rapidly but remains heterogeneous in terms of research focus, methodological approaches, and publication venues (Schwendicke et al., 2020; Hung et al., 2020b).

Bibliometric analysis provides a systematic framework for evaluating the evolution and structure of a research field by quantitatively examining publication trends, citation patterns, and collaborative networks (Aria & Cuccurullo, 2017; Donthu et al., 2021). By applying bibliometric methods, it is possible to identify leading contributors, influential journals, and emerging thematic areas, as well as to assess how research interests evolve over time (Zupic & Čater, 2015). Despite the increasing number of studies employing deep learning and machine learning techniques in pediatric dentistry, a comprehensive bibliometric overview of this body of literature is still lacking (Khanagar et al., 2022).

Therefore, the present study aims to conduct a bibliometric analysis of scientific publications focusing on deep learning and machine learning applications in pediatric dentistry. Beyond mapping publication output and citation characteristics, this analysis seeks to identify patterns in research focus, methodological orientation, and collaborative structures within the literature (Aria & Cuccurullo, 2017; Donthu et al., 2021). By providing a structured overview of the field, the findings of this study are intended to facilitate a critical discussion of how AI–driven approaches have been adopted in pediatric dentistry, where current research efforts are concentrated, and which areas may warrant further investigation (Zupic & Čater, 2015).

MATERIAL AND METHODS

This study was conducted as a bibliometric analysis to examine the scientific literature focusing on deep learning and machine learning applications in pediatric dentistry, which represent key methodological components of contemporary AI-based approaches. The aim was to

characterize publication trends, citation patterns, leading journals, authors, countries, institutions, and the conceptual structure of data-driven research in pediatric dental science.

The literature search was performed using the Web of Science Core Collection (WoSCC) database. Publications indexed between 2000 and 2026 were retrieved through a topic-based search strategy that combined terms related to machine learning methodologies (such as deep learning, machine learning, convolutional neural networks, and neural networks) with pediatric dentistry–specific terms, using Boolean operators. To ensure thematic relevance, generic pediatric descriptors (e.g., children) were deliberately excluded to avoid the inclusion of non-dental pediatric literature.

The search strategy did not impose any restrictions based on document type, allowing all publication categories indexed in the Web of Science Core Collection to be considered and subsequently analyzed descriptively. The analysis was limited to publications written in English and to studies conducted within the field of dentistry. Records such as letters, meeting abstracts, and publications unrelated to dental research were excluded.

This study was based exclusively on the analysis of previously published bibliographic records and did not involve any human or animal subjects; therefore, ethical committee approval was not required.

Bibliometric analyses were carried out using the bibliometrix package (version 5.2.1) implemented in R (version 4.5.2), together with its web-based interface, Biblioshiny (Aria & Cuccurullo, 2017). Descriptive bibliometric indicators included annual scientific production, citation metrics, and the identification of the most relevant journals, authors, countries, and institutions contributing to AI–related (deep learning and machine learning–based) research in pediatric dentistry.

The conceptual structure of the literature was explored through keyword co-occurrence analysis based on author-provided keywords (Zupic & Čater, 2015). Network-based clustering techniques were applied to identify dominant thematic patterns, where node size represented keyword frequency, edge thickness reflected the strength of co-occurrence, and colors denoted distinct thematic clusters. Country-level and institutional productivity analyses were conducted using a full counting approach, whereby each country or institution represented in a publication was counted once per article.

RESULTS

A total of 162 publications indexed in the Web of Science Core Collection between 2000 and 2026 and addressing deep learning and machine learning applications in pediatric dentistry were included in this bibliometric analysis.

An examination of annual scientific output revealed that research activity in this area remained limited for an extended period. Publication numbers were particularly low during the early 2010s (2011: 1; 2012–2016: 0). The first noticeable increase was observed in 2017 with two publications, followed by a gradual rise in subsequent years (2018: 5; 2019: 7). A substantial acceleration in research output occurred after 2020. Ten publications were recorded in 2020, increasing to 22 in 2021 and 23 in 2022. This upward trend continued in 2023 with 21 publications and reached its highest level in 2024 with 41 publications. Although a modest decline was observed in 2025 (28 publications), productivity remained markedly higher than in earlier years. Publications from 2026 (2 records) were considered preliminary, as the year had not yet concluded (Figure 1). With regard to document types, the dataset was dominated by

original research articles and review papers, while a smaller proportion of publications consisted of early access articles, proceedings papers, and editorial materials.

Analysis of author productivity identified Gonzalez, J. M. and Temur, Kâtibe Tuğçe as the most prolific contributors to the literature, each with three publications. These authors were followed by Orhan, Kaan; Mishra, Lora; Marocho, Susana Maria Salazar; Hollender, Lars G.; Jodha, Kartikeya Singh; Mishra, Sukanya; Soğukpınar Önsüren, Aslı; Kumar, Manoj; Griggs, Jason A.; Lapińska, Barbara; Panda, Saurav; Rabelo, Gustavo Davi; and Landini, Giulia, each of whom contributed two publications. The majority of authors were represented by a single publication, indicating that research on deep learning and machine learning in pediatric dentistry is characterized by a broad and multi-centered authorship structure rather than concentration within a limited group of researchers (Figure 2).

At the country level, China emerged as the leading contributor in terms of publication volume, followed by South Korea and Saudi Arabia. India also ranked among the countries with substantial research output in this field. In addition, contributions from European and South American countries indicate that research on deep learning and machine learning applications in pediatric dentistry is characterized by a geographically diverse distribution (Figure 3).

Analysis of publication sources indicated that the scientific output was concentrated within a relatively limited number of journals. Among the most productive outlets were Journal of Dentistry, BMC Oral Health, Clinical Oral Investigations, Dental Materials, and Scientific Reports. In addition, interdisciplinary journals such as IEEE Access and Computers in Biology and Medicine contributed a notable number of publications to the literature (Figure 4). This distribution demonstrates that research on deep learning and machine learning in pediatric dentistry is disseminated through both specialized dental journals and platforms oriented toward computational and biomedical sciences.

Institutional productivity analysis demonstrated that research in this field has been conducted predominantly by universities and academic research centers. The most productive institutions included Saveetha Institute of Medical and Technical Sciences and Saveetha Dental College and Hospitals. These were followed by established academic centers such as Sichuan University, Ankara University, Istanbul University, University of São Paulo, Medical University of Warsaw, Jagiellonian University, University of Michigan, and King Saud University (Figure 5). The institutional distribution further indicates that highly productive research centers are primarily concentrated in India, China, Turkey, Brazil, and Poland.

Analysis of author keywords revealed that the most frequently occurring terms included “deep learning,” “machine learning,” “classification,” “pediatric dentistry,” and “dental caries.” The keyword co-occurrence network demonstrated strong associations between methodological terms and concepts related to clinical applications. Network metrics further indicated that deep learning– and machine learning–based approaches occupy a central position within the conceptual structure of the literature, underscoring their integrative role in linking computational methods with pediatric dental research themes (Figure 6).

DISCUSSION

This bibliometric analysis examined the literature on deep learning and machine learning applications in pediatric dentistry and identified a clear temporal pattern characterized by limited early activity followed by a pronounced increase after 2020. Rather than reflecting a

gradual expansion over several decades, the results indicate a rapid growth phase concentrated in recent years. This pattern suggests that the adoption of data-driven computational methods in pediatric dental research has accelerated in parallel with the wider availability of digital dental data and machine learning tools (Schwendicke et al., 2020; Hung et al., 2020a).

An examination of research content shows that applications of deep learning and machine learning in pediatric dentistry have largely focused on a restricted set of clinically relevant tasks. The predominance of keywords related to dental caries, classification, and pediatric dentistry indicates that these methods are primarily used to support diagnostic and categorization processes. This emphasis aligns with the preventive and early-intervention–oriented nature of pediatric dental care and suggests that current applications are driven by immediate clinical needs rather than by complex treatment planning objectives (Khanagar et al., 2022; Jones et al., 2025; Lee et al., 2018).

Although the present bibliometric analysis specifically focused on studies employing deep learning and machine learning techniques, these methods represent core components of contemporary AI frameworks. Accordingly, the observed publication patterns can be interpreted as indicators of the broader adoption of AI–driven approaches within pediatric dentistry. Unlike adult-oriented dental AI research, pediatric studies appear to be primarily oriented toward growth-related, developmental, and early diagnostic tasks, reflecting age-specific clinical priorities (Schwendicke et al., 2020; Vishwanathaiah et al., 2023).

Patterns of authorship and institutional contribution further indicate that research activity in this field is distributed across a wide range of contributors, with relatively few highly prolific authors or centers. This dispersed structure suggests that deep learning and machine learning research in pediatric dentistry has not yet consolidated around a limited number of specialized groups. While this broad participation reflects growing interest, it may also contribute to methodological variability and highlights the potential value of shared datasets and more standardized research designs (Donthu et al., 2021; Zupic & Čater, 2015; Chen et al., 2020; Topol, 2019).

The dissemination of research across both dental journals and interdisciplinary computational science journals reflects the hybrid methodological nature of the field (Aria & Cuccurullo, 2017; Donthu et al., 2021). While dental journals provide clinically grounded contexts for these studies, interdisciplinary platforms facilitate the exchange of methodological approaches between dentistry and data science (Schwendicke et al., 2020; Chen et al., 2020). This dual publication pattern underscores the importance of effective collaboration between clinical researchers and computational specialists in shaping future research directions (Topol, 2019; Kelly et al., 2019).

Several limitations should be acknowledged. This analysis was restricted to publications indexed in the Web of Science Core Collection and limited to English-language documents, which may have resulted in the exclusion of relevant studies published elsewhere. Moreover, as a bibliometric study, the present analysis does not evaluate the technical performance, clinical accuracy, or external validity of individual deep learning or machine learning models.

Accordingly, the findings should be interpreted as reflecting research activity, publication patterns, and thematic orientation rather than direct clinical effectiveness (Donthu et al., 2021).

CONCLUSION

This bibliometric analysis outlines publication trends related to deep learning and machine learning applications in pediatric dentistry between 2000 and 2026. The results indicate a recent and rapid increase in research output, with a primary focus on diagnostic and classification-oriented applications aligned with preventive pediatric dental care. Overall, these findings highlight the expanding role of AI–related methodologies in pediatric dentistry research.

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FIGURE LEGENDS

Figure 1. Annual scientific production of publications related to deep learning and machine learning applications in pediatric dentistry between 2000 and 2026.

Figure 2. Most productive authors in the field of deep learning and machine learning–based research in pediatric dentistry.

Figure 3. Country-level scientific production of publications focusing on deep learning and machine learning applications in pediatric dentistry.

Figure 4. Most productive journals publishing research on deep learning and machine learning applications in pediatric dentistry.

Figure 5. Most productive institutions contributing to deep learning and machine learning research in pediatric dentistry.

Figure 6. Keyword co-occurrence network of deep learning and machine learning research in pediatric dentistry.