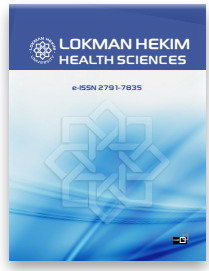
LOKMAN HEKIM HEALTH SCIENCES

DOI: 10.14744/lhhs.2026.32975
Lokman Hekim Health Sci 2026;6(2):272–281



lokmanhekimhs.com

ORIGINAL ARTICLE

A Bibliometric Analysis of Artificial Intelligence and Simulation Technologies in Dental Education

Hafize Gamze Demirbaş

Department of Restorative Dentistry, Aydın Adnan Menderes University, Faculty of Dentistry, Aydın, Türkiye

Abstract

Introduction: Artificial intelligence (AI) and simulation technologies are increasingly used in dental education to improve learning safety, standardization, and skill assessment. This study examines their intersection, including AI-integrated simulations and curricula that apply AI and simulation separately. Despite rapid growth, the intellectual structure and trends of this intersection have not been comprehensively delineated in focused studies. We therefore conducted a bibliometric analysis of the literature.

Methods: Publications indexed in the Web of Science Core Collection from 2010 to 2026 were included. The search captured studies addressing dental education, simulation technologies, and AI applications. Bibliometrix in R was used to analyze publication trends, journals, countries, institutions, authors, and keyword patterns. Collaboration networks and keyword co-occurrence were visualized with VOSviewer. Only English-language articles and reviews were included.

Results: Publications increased markedly after 2019. Early research centered on virtual reality and simulation-based training, whereas recent studies emphasize AI, machine learning, and automated performance assessment. The United States and China were the most productive countries, with limited international collaboration. Keywords indicate a shift from immersive simulation toward AI-driven, adaptive, and data-informed educational systems. Both AI-integrated simulations and standalone AI or simulation applications were represented, reflecting diverse approaches.

Discussion and Conclusion: AI and simulation technologies constitute a growing research domain in dental education. The field is moving from technology-assisted simulation toward AI-enhanced systems, reflecting evolving research priorities rather than established clinical superiority. Future work should use standardized, multicenter, outcome-focused designs to assess educational effectiveness and relevance.

Keywords: Artificial intelligence; Bibliometric analysis; Dental education; Simulation; Virtual reality

Traditional apprenticeship models in dental education are increasingly complemented by safe, repeatable, and measurable technology-supported learning environments, reflecting a shift toward objective evaluation.[1] The COVID-19 pandemic accelerated hybrid and technology-enhanced learning and highlighted the need for digital readiness in dental curricula.[2,3]

Simulation-based education enables translation of theoretical knowledge into clinical skills within controlled, risk-free environments. Immersive technologies such as

Cite this article as: *Demirbaş HG. A Bibliometric Analysis of Artificial Intelligence and Simulation Technologies in Dental Education. Lokman Hekim Health Sci 2026;6(2):272–281.*

Correspondence: Hafize Gamze Demirbaş, M.D. Aydın Adnan Menderes Üniversitesi Diş Hekimliği Fakültesi, Restoratif Diş Hekimliği Anabilim Dalı, Aydın, Türkiye
E-mail: hafize.demirbas@adu.edu.tr; gamzedemirbas91@gmail.com **Submitted:** 05.03.2026 **Revised:** 28.05.2026 **Accepted:** 08.06.2026
Available Online: 00.06.2026

virtual reality (VR), augmented reality (AR), and haptic systems support interactive visualization, standardized practice, and objective performance assessment, strengthening psychomotor skill acquisition.[4–6]

Artificial intelligence (AI) has emerged as a transformative element in health professions education, supporting automated evaluation, adaptive learning pathways, and data-driven feedback. In dental education, AI applications have demonstrated benefits in diagnostic accuracy, learner confidence, and individualized formative assessment, particularly in clinical decision-making and radiographic interpretation.[7,8] Deep learning further augments cognitive and clinical training by identifying complex clinical patterns with high accuracy.[9]

The convergence of AI with simulation technologies advances intelligent learning environments. AI-supported haptic simulators enable objective assessment of manual performance, detection of technical errors, and immediate corrective feedback, supporting competency-based education and targeted remediation.[5,10–12] Implementation remains constrained by high costs, technical complexity, infrastructure requirements, and ethical concerns related to data privacy, algorithmic bias, and preservation of professional judgment.[11,13–15]

Despite the growing volume of studies, the intellectual structure and research dynamics at the intersection of AI and simulation technologies in dental education remain insufficiently specified rather than entirely unexplored. Prior bibliometric analyses show an overall increase in publications related to digital technologies in dental education, particularly following the COVID-19 pandemic.[16,17] While prior bibliometric studies have examined general trends in AI and digital intelligence within dentistry,[18–20] the novelty of this work lies in its integrated framework that maps AI-related approaches and simulation technologies both independently and in their convergence within dental education.

Therefore, this study aims to map the research landscape of AI and simulation technologies in dental education by conducting a bibliometric analysis of publications indexed in the Web of Science Core Collection between 2010 and 2026. By identifying publication trends, leading contributors, collaboration patterns, and emerging research themes, the study will clarify the field's developmental trajectory and provide a framework to guide future research, educational strategies, and policy development.

Materials and Methods

Study Design

This study was designed as a descriptive bibliometric analysis to examine the scientific literature on AI and simulation technologies in dental education. Since this analysis used only public bibliographic records, ethical approval was not required.

Data Source and Search Strategy

The Web of Science Core Collection was selected as the primary data source due to its standardized citation indexing and suitability for bibliometric mapping in emerging scientific fields. To ensure methodological consistency and avoid potential duplicate indexing, a single standardized source was used throughout the analysis.

The database search was conducted on February 15, 2026, and covered publications indexed between January 01, 2010, and February 15, 2026. The year 2010 was selected as the starting point because it marks the beginning of a period in which digitalization, virtual simulation, and computer-assisted learning became increasingly visible in dental education, preceding the later acceleration of AI-based applications. Publications were retrieved using the Topic (TS) field, which includes titles, abstracts, author keywords, and Keywords Plus. The search strategy was designed to capture studies addressing dental education in conjunction with simulation technologies and AI–based applications. The following Boolean search query was applied:

TS=(dent*) AND TS=("dental education" OR training OR student* OR preclinical) AND TS=(simulation OR simulator OR "virtual reality" OR "augmented reality" OR haptic* OR "computer-based simulation") AND TS=("artificial intelligence" OR "machine learning" OR "deep learning" OR "intelligent system*" OR "computer-assisted" OR "automated feedback" OR "intelligent tutoring").

The search was restricted to articles and review papers published in English. Conference proceedings, editorial materials, letters, meeting abstracts, and book chapters were excluded to ensure methodological consistency and scientific rigor. To manage broad search terms such as "training" or "automated feedback," retrieved records were screened for topical relevance. Titles, abstracts, and keywords were reviewed to exclude clinical or engineering-focused studies unrelated to dental simulation or AI-supported assessment. During this screening stage, 14 records were excluded based on these criteria, reducing the initial pool of 159 publications to the final dataset of 145 publications. Broader e-learning records were retained

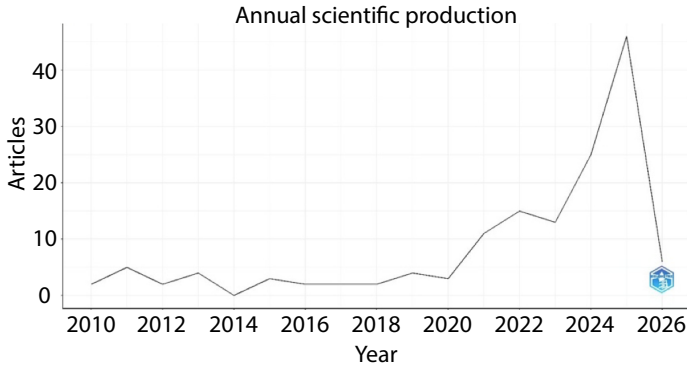


Figure 1. Annual scientific production related to artificial intelligence and simulation technologies in dental education (2010–2026).

only for contextual discussion rather than as direct evidence of effectiveness. All eligible records were exported in plain text format, including full bibliographic information and cited references.

Data Analysis

Bibliometric analyses were conducted using the Bibliometrix package in R(Bibliometrix package version 5.1.1) in RStudio statistical software (version 2025.05.1+513; Posit Software, PBC, Boston, MA, USA) through its web-based interface, Biblioshiny. Descriptive performance indicators were calculated, including annual publication trends, leading authors, countries, institutions, journals, total citation counts, and h-index values.

To explore the intellectual structure and research dynamics of the field, established science mapping techniques were applied. These included analyses of co-authorship networks, keyword co-occurrence patterns, and citation relationships. Network visualizations were generated using VOSviewer software (version 1.6.20; Centre for Science and Technology Studies, Leiden University, Leiden, The Netherlands) to illustrate collaboration structures and thematic relationships. Threshold values for network inclusion were determined based on data distribution to ensure clear, interpretable, and reproducible visual representations. VOSviewer thresholds were selected to optimize readability and preserve the intellectual core by minimizing noise. A 3-occurrence minimum was applied to keyword co-occurrence to retain central themes while excluding idiosyncratic terms. Author-level networks used a 1-document and 1-citation minimum to reflect the field's emerging nature. These thresholds support reproducible construction and analytically meaningful cluster structures. No inferential statistical analyses were performed, as the study relied on bibliometric data derived from published literature.

From a methodological perspective, the bibliometric mapping procedures applied in this study followed established guidelines for conducting bibliometric analyses.[21,22] These approaches enable the identification of structural patterns, thematic evolution, and collaboration dynamics within a research field, providing a macro-level understanding of knowledge production and intellectual organization.

Results

General Characteristics of the Literature

The Web of Science search covering the period 2010–2026 initially identified a total of 159 publications; following the exclusion of 14 records based on the screening criteria, a final dataset of 145 publications focusing on AI and simulation technologies in dental education met the inclusion criteria and were included in the bibliometric analysis. These publications were distributed across 90 sources and comprised 106 original articles (including early access) and 39 review papers.

The dataset contained 6,037 cited references, with an average of 15.86 citations per document and a mean document age of 3.93 years. The annual publication growth rate was calculated as 7.11%, indicating a steady expansion of research activity in this field. Overall, 742 authors contributed; only 8 were single-authored, reflecting a collaborative structure. The mean number of co-authors per document was 5.34, and the international collaboration rate was 26.21%, suggesting a moderate level of global research cooperation.

In terms of thematic scope, the dataset included 577 author keywords and 303 Keywords Plus, indicating substantial conceptual and methodological diversity within the field.

The annual publication output remained relatively low and stable between 2010 and 2018, followed by a marked increase after 2019. Research productivity accelerated notably after 2021 and reached its highest level in 2025, while early indexing of publications in 2026 suggests continued growth momentum (Fig. 1).

Citation analysis showed that earlier publications achieved higher average citation counts, largely attributable to longer citation windows. The highest average citations per article were observed in 2013, while relatively strong citation performance was also noted for publications from 2021. Lower citation averages in the most recent years likely reflect limited time for citation accumulation rather than diminished scholarly impact.

Table 1. Top 10 most productive sources based on publication output and citation impact

Source	NP	TC	h-Index	First year
Journal of dental education	27	570	15	2010
European journal of dental education	5	43	3	2013
Journal of dentistry	4	44	4	2022
IEEE access	4	101	3	2024
Journal of medical ınternet research	3	112	3	2021
Applied sciences	3	73	3	2022
Cureus	3	47	2	2023
Dentistry journal	3	14	2	2025
Bioengineering	2	4	2	2023
International dental journal	2	7	2025	2

NP: Number of publications; TC: Total citations; h-index: Hirsch Index; First year: Year of the first publication of the source within the dataset.

Overall, research on AI and simulation technologies in dental education is a rapidly expanding domain with growing publications, collaboration, and scientific visibility.

Most Productive Sources and Influential Documents

As noted in Section 3.1, the publications were disseminated across 90 sources. The journals represented in the dataset primarily covered dental education, health professions education, digital health, and computer-assisted learning, reflecting the convergence of educational sciences and emerging digital technologies.

The Journal of Dental Education was the most productive and influential source, publishing 27 articles and receiving 570 total citations (h-index=15). This was followed by the European Journal of Dental Education, which published five articles and accumulated 43 citations (Table 1). The leading sources were mainly journals specializing in dental education and educational technologies, reflecting their central role in shaping research agendas and dissemination patterns. In addition, several interdisciplinary journals, such as those focusing on medical informatics, engineering, and applied sciences, also contributed to the literature, underscoring the integration of AI, VR, and simulation technologies into dental training.

Source impact analysis showed that journals with higher output demonstrated stronger citation performance, reflecting their influence in AI and simulation technologies in dental education. Publication concentration suggests knowledge production is anchored within core dental and interdisciplinary outlets (Table 1). Globally, the most cited studies addressed VR, haptic simulation, AI-based assessment, automated feedback, and adaptive learning environments. These publications reflect an increasing emphasis on objective evaluation, personalized learning, and immersive training in the field.

The most frequently cited document in the dataset was published by Frehywot et al.[23] receiving 338 total citations.[23] Although this article is broader in scope and focuses on e-learning in medical education rather than dental AI-simulation specifically, it appeared in the dataset because the search strategy captured broader digital education literature. It was therefore interpreted as a contextual citation reflecting digital education infrastructure and not as direct evidence for AI-supported dental simulation. Several more recent publications also exhibited high annual citation rates, indicating strong contemporary impact, particularly for studies integrating AI applications with digital and simulation-based learning approaches (Table 2).

Table 2. Top 10 most cited documents in the dataset

First author	Year	Source	Total citations	TC per year
Frehywot	2013	Human resources for health	338	24.14
Li	2021	Journal of medical ınternet research	99	16.50
Sai	2024	IEEE access	82	27.33
Schwendicke	2021	Journal of dental research	81	13.50
Ben Gal	2011	Journal of dental education	70	4.38
Sotgiu	2020	Anatomical sciences education	67	9.57
Monterubbianesi	2022	Applied sciences	58	11.60
Saghiri	2022	Journal of dental education	55	11.00
Collaço	2021	Journal of dental education	52	8.67
Gandedkar	2021	Seminars in orthodontics	42	7.00

TC indicates total global citations received according to the Web of Science database. TC per year represents the average annual citation rate.

These findings may suggest that research in AI and simulation in dental education is concentrated in a few influential journals and guided by highly cited studies on immersive simulation and AI-supported educational systems.

Country and Institutional Contributions

A total of 45 countries contributed to the field, showing broad global engagement. China (n=147) and the United States (n=136) led scientific production, followed by India (n=41), South Korea (n=31), Germany (n=30), and Brazil (n=27). Significant contributions also came from Thailand (n=23), Canada (n=21), Japan (n=19), and Spain (n=18), spanning Asia, North America, and Europe.

Corresponding-author analysis (Table 3) showed that China and the USA each led with 26 publications (17.9%). However, collaboration profiles differed: China had a high single-country publication (SCP=92.3%), rate whereas the USA showed more international engagement (multiple-country publications [MCP]=30.8%). Germany and Thailand exhibited the highest relative international collaboration (MCP=66.7%), while Canada's output was entirely domestic.

At the institutional level, the output was concentrated in a few universities led by Sichuan University (n=28), the University of São Paulo (n=16), and Wuhan University (n=13). Other key contributors included Chulalongkorn, Danube Private, and Peking Universities (n=11 each), alongside Charité – Universitätsmedizin Berlin, the University of Iowa, and the University of Michigan. These findings highlight a landscape dominated by a few highly productive centers with uneven global collaboration.

Author Productivity and Collaboration Network

A total of 742 authors contributed to the 145 publications included in the dataset, indicating a broad but highly dispersed authorship structure. The majority of authors produced only a single publication, suggesting that research activity in this field is distributed across many contributors rather than concentrated among a small group of consistently prolific researchers.

Only a limited number of authors published more than one article during the study period. The most productive contributors authored between two and three publications, with no individual exceeding three articles. Authors with the highest publication counts included Steven P. Engebretson, Peter Haddawy, Nikos Mattheos, Sallaberry, and Alice Urbankova, each contributing three publications. A second group of authors, including Richard Mosch, Siriwan Suebnukarn, A. Chaurasia, Xu Chen, and Yaning Li, each contributed two publications.

Table 3. Top 10 most productive countries based on corresponding author affiliations

Country	Articles	Articles (%)	SCP	MCP	MCP (%)
China	26	17.9	24	2	7.7
USA	26	17.9	18	8	30.8
India	9	6.2	7	2	22.2
Brazil	7	4.8	5	2	28.6
Germany	6	4.1	2	4	66.7
South Korea	6	4.1	4	2	33.3
Spain	6	4.1	4	2	33.3
Thailand	6	4.1	2	4	66.7
Saudi Arabia	5	3.4	3	2	40.0
Canada	4	2.8	4	0	0.0

SCP: Single-country publications; MCP: Multiple-country publications.

When co-authorship was taken into account using fractionalized authorship analysis, the proportional contributions of even the most productive authors remained limited. Fractionalized publication values ranged from approximately 0.24 to 1.17, reflecting substantial collaboration and the absence of sustained individual research dominance within the field.

Author collaboration patterns were further examined through co-authorship network analysis using VOSviewer (Fig. 2). The resulting network revealed several small and weakly connected research clusters, with no evidence of large, densely interconnected collaboration groups. Most of the collaborative relationships were confined to small teams, and cross-cluster interaction was limited, indicating a fragmented collaboration structure at the author level.

To further characterize authorship patterns, Lotka's law was applied to assess the distribution of scientific productivity. The analysis demonstrated that 96.5% of authors contributed only a single publication, whereas only a very small proportion produced two or more papers. This highly skewed distribution is consistent with Lotka's inverse square law and confirms a high degree of author dispersion within the field.

Overall, the findings reveal limited author continuity and fragmented collaboration networks, suggesting that stable and consolidated research groups have not yet emerged in this domain.

Keyword Analysis and Research Trends

A total of several hundred author keywords were identified across the 145 publications, reflecting the broad and multidisciplinary nature of research on AI and simulation

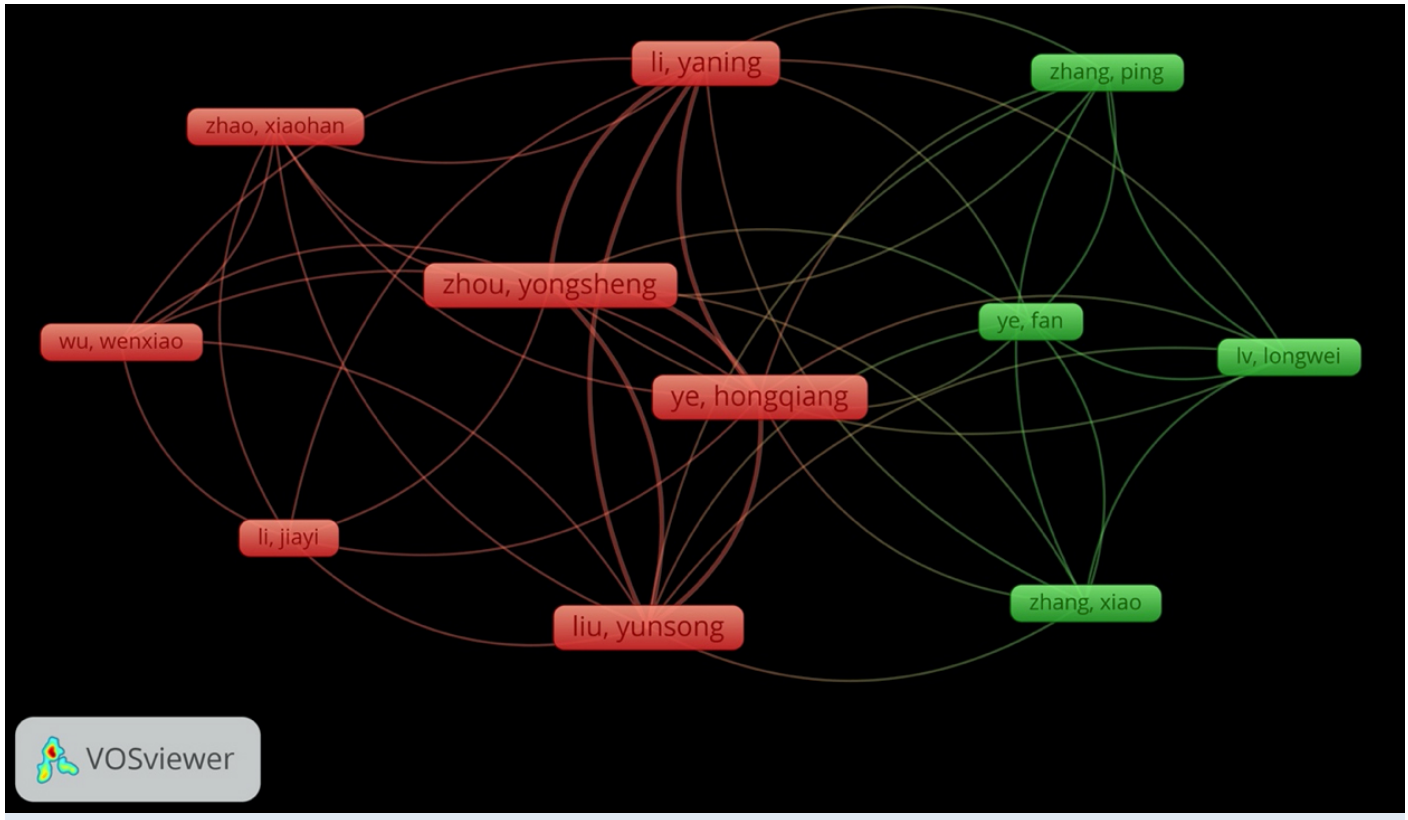


Figure 2. Author-level co-authorship network of publications on artificial intelligence and simulation technologies in dental education.

technologies in dental education. The most frequently occurring keywords were dental education (n=48), AI (n=33), dentistry (n=28), simulation (n=27), and VR (n=25). Other commonly used terms included AR (n=20), computer-assisted instruction (n=16), performance (n=9), students (n=9), deep learning (n=8), feedback (n=8), and machine learning (n=5), indicating a strong emphasis on both immersive technologies and data-driven educational approaches.

Keyword co-occurrence analysis conducted using VOSviewer revealed several major thematic clusters that together define the conceptual structure of the field (Fig. 3a). The largest cluster was centered on simulation-based dental education and included keywords such as simulation, VR, AR, computer simulation, simulator, and haptics. A second prominent cluster focused on AI–related concepts, including AI, machine learning, deep learning, model, and network, highlighting the increasing integration of intelligent systems into simulation-based training environments. A third thematic cluster represented educational processes and learning outcomes, with keywords such as students, learning, teaching, performance, assessment, and psychomotor skills. Smaller clusters reflected more specific clinical and technological applications, including implant planning, digital dentistry, radiology, and computer-assisted surgical procedures.

Overlay visualization analysis demonstrated a clear temporal evolution in research focus (Fig. 3b). Earlier studies predominantly emphasized VR–based simulation systems and computer-assisted training tools. In contrast, more recent publications increasingly incorporated advanced AI concepts, including deep learning–based approaches and emerging discussions related to generative AI, alongside automated performance evaluation. This shift indicates a transition from technology-supported simulation toward intelligent, adaptive, and data-driven educational systems capable of personalized feedback and objective skill assessment.

Discussion

This bibliometric analysis suggests that AI and simulation technologies are gaining increasing research attention in dental education, while also indicating that the field shows emerging but still uneven methodological development according to publication dispersion, collaboration structure, and keyword patterns. The pronounced increase in publication output after 2019 appears to coincide with pedagogical challenges highlighted during the COVID-19

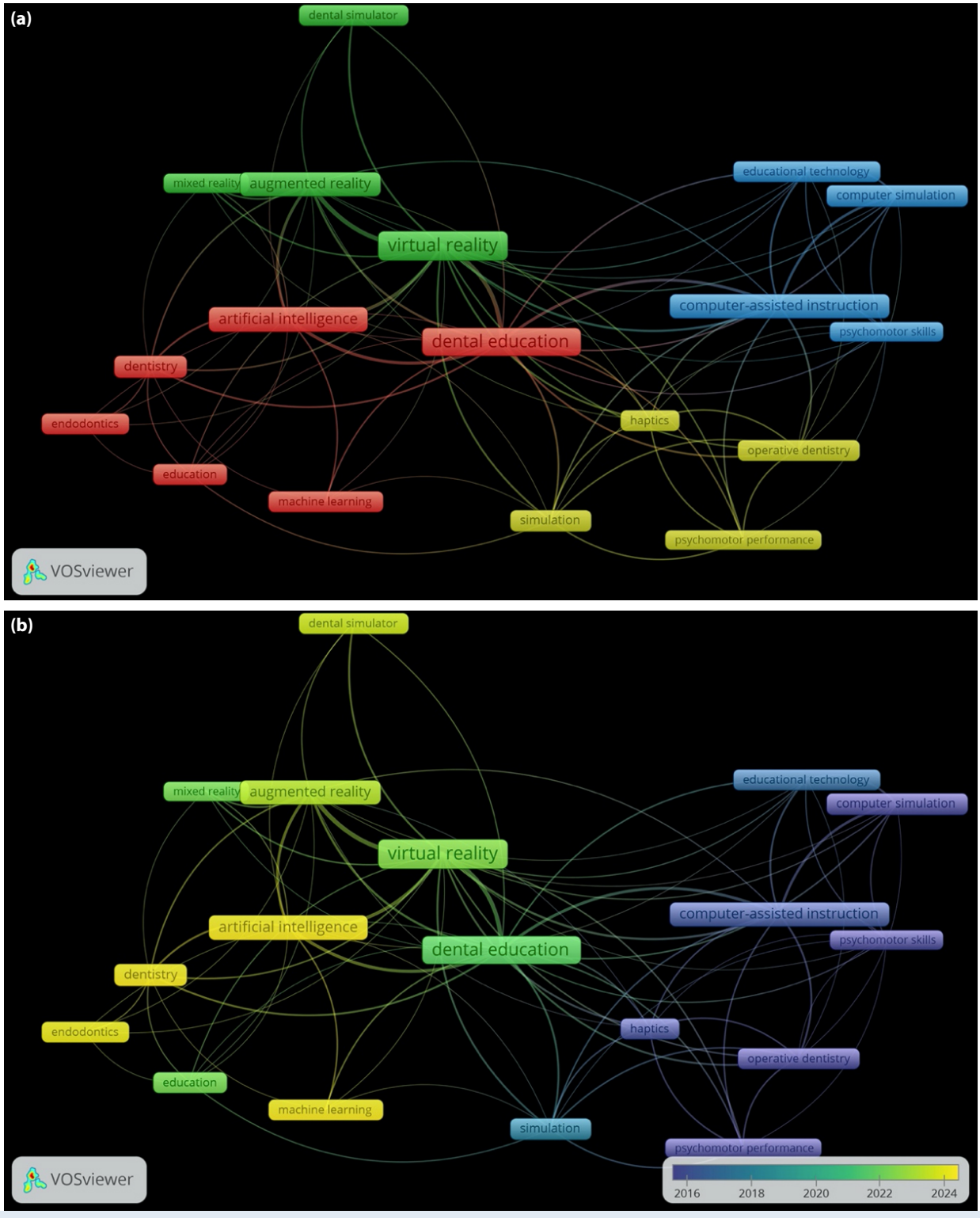


Figure 3. Keyword co-occurrence network and temporal evolution of research topics in artificial intelligence and simulation technologies in dental education: **(a)** network visualization of author keyword relationships; **(b)** overlay visualization showing the temporal evolution of research topics.

pandemic and may reflect a broader transition in which digital technologies are increasingly discussed as integral components of dental education systems rather than temporary crisis-driven solutions.[2,16] These findings align with systematic reviews indicating that recent literature increasingly frames digitalization not merely as an auxiliary enhancement but as a central component supporting standardization, measurability, and educational safety in

dental training.[1] These findings extend prior bibliometric studies on digital technologies and AI trends in dental education.[16–20] While earlier research mapped broader digitalization, this analysis provides a specific perspective by examining AI and simulation technologies within a shared dental education framework. By illustrating evolving thematic patterns and the interaction between these approaches, our study complements existing evidence and establishes a bibliometric foundation for future research in the field.

Bibliometric Structure and Global Research Dynamics

Country- and institution-level analyses revealed a geographically concentrated research landscape, with China and the United States leading in overall publication output. However, corresponding-author–based indicators showed that countries such as the United States, Germany, and Thailand exhibit higher proportions of MCP, may suggest a more central role in shaping international research networks. In contrast, China's predominance of SCP appears to suggest strong domestic research capacity while indicating comparatively lower levels of international co-authorship within this dataset. This distinction appears consistent with prior bibliometric evidence that international collaboration enhances research visibility and knowledge diffusion.[16,17]

Author-level findings further support the interpretation that this research domain is still consolidating. The highly dispersed authorship structure, characterized by a large proportion of single-publication contributors, conforms to Lotka's law and may suggest that sustained, institutionally anchored research groups may still be in an early stage of development. Rather than indicating a lack of scientific interest, this pattern appears to reflect the interdisciplinary and exploratory nature of research on AI and simulation technologies, which often develops through short-term, technology-driven collaborations.[17]

Simulation Technologies: Educational Value Over Outcome Superiority

Thematic and keyword analyses showed that early research predominantly focused on VR, haptic systems, and computer-assisted simulation platforms, whereas more recent studies increasingly emphasize AI–based assessment and feedback mechanisms. The literature has not reached a consensus on whether simulation technologies, with or without AI integration, produce superior clinical outcomes compared to conventional training. Instead, their primary contribution may lie in enhancing educational legitimacy through standardization, repeatability, and process efficiency rather than demonstrable outcome dominance.[17]

In addition, some studies within the literature may suggest that highly interactive three-dimensional learning environments may increase cognitive load for certain learner profiles, particularly among students with lower spatial ability.[5,11,17] This observation appears to indicate that technological sophistication alone does not guarantee improved learning outcomes and that pedagogical alignment with learner characteristics remains critical.

AI and Automated Performance Assessment

Bibliometric patterns appear to indicate that AI applications in dental education are most prominently concentrated in objective performance assessment and feedback systems. Machine learning- and deep learning-based approaches appear to be increasingly positioned as tools to reduce instructor dependency and enhance assessment consistency, functioning primarily as complementary mechanisms supporting formative assessment and competency-based education.

Beyond assessment, emerging work may suggest a gradual expansion of AI toward more integrative instructional roles, including intelligent tutoring and decision-support functions within simulation environments. This evolution can be interpreted in light of the concept of human–AI complementarity, although this interpretation should be treated as conceptual and linked cautiously to the observed emergence of keywords and studies related to intelligent tutoring, automated feedback, and decision-support functions.[24]

Ethical Considerations, Integration Challenges, and Future Directions

Research on AI and simulation technologies in dental education appears to reflect ongoing technical and organizational challenges, including infrastructure demands and faculty preparedness, which may influence implementation and publication patterns.[11,15,25] Ethical considerations, such as data governance and algorithmic bias, have become more prominent in recent publications, as reflected by ethics-related keywords and thematic clusters, which may indicate an increasing emphasis on responsible innovation.[14] From a scholarly perspective, the observed fragmentation and thematic dispersion may suggest that future research may benefit from greater methodological rigor, multi-center collaboration, and outcome-oriented designs to strengthen the empirical foundation of AI and simulation technologies in dental education.

Limitations and Drawbacks

This bibliometric analysis has several limitations. The study relied on a single bibliographic database, which may have excluded relevant publications indexed elsewhere. While this choice was made to improve the internal consistency of citation-based indicators, excluding databases such as Scopus, PubMed, and IEEE Xplore may limit coverage of interdisciplinary or conference-based studies not indexed in Web of Science. Variations in author names, institutional affiliations, or keywords could have influenced the results. Citation-based indicators reflect research productivity and visibility but do not directly assess methodological quality or educational effectiveness. Recent publications may appear less impactful due to time-dependent citation accrual, and early-access 2026 records may have incomplete citations. Finally, the interpretation of visualization maps and thematic clusters involves some subjectivity, so the findings should be considered indicative rather than definitive.

Conclusion

This bibliometric analysis mapped the intersection of AI and simulation in dental education, identifying rapid growth since 2019. Research shows a shift toward AI-based automated assessment and intelligent tutoring within an increasingly connected international network. While integrated AI simulations are the primary focus, the bibliometric literature reviewed here does not yet reveal a consensus on whether AI-supported simulation produces superior clinical outcomes. Future research should adopt standardized, outcome-oriented designs to better evaluate educational effectiveness and clinical relevance.

Ethics Committee Approval: Ethics committee approval was not required for this study as it is a bibliometric analysis based on previously published literature and does not involve human participants or animal subjects.

Informed Consent: Informed consent was not required for this study as it is a bibliometric analysis based on previously published data and does not involve human participants.

Conflict of Interest: None declared.

Financial Disclosure: The author declared that this study has received no financial support.

Use of AI for Writing Assistance: Generative AI tools were used solely to assist with language editing and the improvement of readability of the manuscript. No AI-assisted technologies were used in the study design, data collection, data analysis, or interpretation of results. All scientific content, analyses, and conclusions were generated, reviewed, and verified by the author, who takes full responsibility for the accuracy and integrity of the work.

Peer-review: Double blind peer-reviewed.

References

1. Erdilek D, Gümüstas B, Efes BG. Digitalization era of dental education: A systematic review. Dent Med Probl 2023;60(3):513-525. [CrossRef]
2. Tadinada A, Gul G, Godwin L, Al Sakka Y, Crain G, Stanford CM, et al. Utilizing an organizational development framework as a road map for creating a technology-driven agile curriculum in predoctoral dental education. J Dent Educ 2023;87(3):394-400. [CrossRef]
3. Bashary NZ, Levine MH. Teaching strategy adaptations in undergraduate dental education during the COVID-19 pandemic. J Dent Educ 2024;88(6):865-71. [CrossRef]
4. Li Y, Ye H, Ye F, Liu Y, Lv L, Zhang P, et al. The current situation and future prospects of simulators in dental education. J Med Internet Res 2021;23(4):e23635. [CrossRef]
5. Huang S, Qu Y, Sun Y, Chen S, Gu L. Application and development of artificial intelligence and immersive technologies in dental education: a scoping review. BMC Med Educ 2025;26(1):89. [CrossRef]
6. Elhag HHM, Rao GKL, MohdNoor SNFB, Bin Zakaria MN, Mokhtar NB. Augmented reality in dental implants: A systematic review. J Clin Diagn Res 2024;18(1):20-5. [CrossRef]
7. Aminoshariae A, Nosrat A, Nagendrababu V, Dianat O, Mohammad-Rahimi H, O'Keefe AW, et al. Artificial intelligence in endodontic education. J Endod 2024;50(5):562-78. [CrossRef]
8. El-Hakim M, Anthonappa R, Fawzy A. Artificial intelligence in dental education: A scoping review of applications, challenges, and gaps. Dent J 2025;13(9):384. [CrossRef]
9. Cai J, Deng Y, Min Z, Zhang Y, Zhao Z, Jing D. Revealing the representative facial traits of different sagittal skeletal types: decipher what artificial intelligence can see by Grad-CAM. J Dent 2023;138:104701. [CrossRef]
10. Sallaberry LH, Tori R, Nunes FL. Automatic performance assessment in Virtual Reality medical simulators: A model based on procedure trajectories and machine learning. Expert Syst Appl 2024;238:122201. [CrossRef]
11. Lu B, Wei Z, Li X, Yin Y, Linghu J, Wang Y, et al. Progress of a novel dentistry teaching model based on the combination of virtual reality and artificial intelligence technologies in optimizing cognitive load: A systematic review. J Dent Educ 2025;0:1-18.
12. Vannaprathip N, Haddawy P, Schultheis H, Suebnukarn S. SDMentor: A virtual reality-based intelligent tutoring system for surgical decision making in dentistry. Artif Intell Med 2025;162:103092. [CrossRef]
13. Pimkhaokham A, Chow J, Pozzi A, Arunjaroensuk S, Subbalehka K, Mattheos N. Computer-assisted and robotic implant surgery: Assessing the outcome measures of accuracy and educational implications. Clin Oral Implants Res 2024;35(8):939-53. [CrossRef]
14. Lin GSS, Foo JY, Goh SM, Alam MK. Exploring the ethical dimensions of artificial intelligence and robotics in dental education. Bangladesh J Med Sci 2024;23(4):999-1007. [CrossRef]

15. DaSilva AF, Robinson MA, Shi W, McCauley LK. The forefront of dentistry-promising tech-innovations and new treatments. JDR Clin Trans Res 2022;7(1_suppl):16S-24S. [CrossRef]
16. Zou Z, Guo L. Insights into history and trends of teaching and learning in stomatology education: Bibliometric analysis. JMIR Med Educ 2025;11:e66322. [CrossRef]
17. Li Q, Li S, Fu D, Liao G, Zhou X, Gong T, et al. The role of emerging digital technologies in revolutionizing dental education: A bibliometric analysis. J Dent Educ 2025;90(5):753-63. [CrossRef]
18. Iniesta M, Pérez-Higueras JJ. Global trends in the use of artificial intelligence in dental education: A bibliometric analysis. Eur J Dent Educ 2026;30(2):427-38. [CrossRef]
19. Guo R, Zhang Y, Li W, Liu D, Hu W. Digital intelligence in dental education: A bibliometric analysis. Int Dent J 2026;76(3):109495. [CrossRef]
20. Long J, Yang L, Dou J, Zhang L, Tan X. Artificial intelligence in dentistry: A bibliometric analysis. Br Dent J 2025;1-7. [CrossRef]
21. Donthu N, Kumar S, Mukherjee D, Pandey N, Lim WM. How to conduct a bibliometric analysis: An overview and guidelines. J Bus Res 2021;133:285-96. [CrossRef]
22. Kumar R. Bibliometric analysis: comprehensive insights into tools, techniques, applications, and solutions for research excellence. Spectr Eng Manag Sci 2025;3(1):45-62. [CrossRef]
23. Frehywot S, Vovides Y, Talib Z, Mikhail N, Ross H, Wohltjen H, et al. E-learning in medical education in resource constrained low-and middle-income countries. Healthc Hum Resour Health 2013;11(1):4. [CrossRef]
24. Krumsvik RJ, Klock K, Bratteberg MH. Symbiotic intelligence in dental trauma diagnostics-an exploratory case study. Front Oral Health 2025;6:1687841. [CrossRef]
25. Uei LJ, Yeo XH, Leung YY, Pelekos G, Nawas BA, Mattheos N. Computer-Assisted Implant Surgery: Implications for teaching, learning, and educational strategies. Clin Exp Dent Res 2025;11(4):e70197. [CrossRef]