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Artificial intelligence in joint arthroplasty

A bibliometric analysis of global research trends (2001–2025)

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Abstract

Background: Artificial intelligence (AI) has significantly advanced the field of joint arthroplasty by transforming key aspects such as surgical planning, implant design, and postoperative management. Despite their growing importance, research trends and priorities in AI applications for joint arthroplasty remain underexplored. This study employed bibliometric analysis to elucidate the main research focus areas and global trends in AI and arthroplasty from 2001 to 2025.

Methods: Relevant publications were retrieved from the Web of Science Core Collection. Bibliometric and visualization tools, including CiteSpace, VOSviewer, and Scimago Graphica, were used to analyze the data. Key metrics, such as countries, institutions, authors, journals, references, and keywords, were examined to identify influential contributors and emerging research hotspots. This study did not require ethical approval from institutional review board.

Results: A total of 533 publications were identified, demonstrating a steady increase in both publication volume and citations over time, with a peak of 136 publications by 2024. England emerged as the leading country in terms of research output, while Harvard University in the USA was identified as the most productive institution. The influential authors included Kwon Young-Min, Ramkumar Prem, and Mont Michael A. The Journal of Arthroplasty has led to the publication volume. Frequently occurring keywords included "machine learning," "AI," "total knee arthroplasty," "total hip arthroplasty," and "deep learning." Keyword burst analysis has revealed "implant identification" as a prominent recent research focus.

Conclusions: This bibliometric analysis highlighted the rapid growth and evolution of research priorities in AI applications for joint arthroplasty. With the increasing prevalence of advanced techniques, such as machine learning and deep learning, research in this area is expected to further revolutionize clinical practice. Future efforts should focus on optimizing AI-based solutions to address clinical challenges, improve patient outcomes, and foster international collaborations.

Abbreviations: AI = artificial intelligence, IF = impact factor, THA = total hip arthroplasty, TKA = total knee arthroplasty, WoSCC = Web of Science Core Collection.

Keywords: artificial intelligence (AI), deep learning, joint arthroplasty, machine learning, total hip arthroplasty (THA), total knee arthroplasty (TKA)

1. Introduction

Total knee arthroplasty (TKA) and total hip arthroplasty are well-established procedures in orthopedics that offer significant relief from degenerative joint diseases and markedly improve both mobility and quality of life for patients.[1] As the global population continues to age, the prevalence of osteoarthritis is anticipated to rise, driving an increased demand for these surgeries in the coming years.[2]

In recent years, the integration of Artificial Intelligence (AI) with arthroplasty has introduced new opportunities to enhance surgical outcomes, optimize implant designs, and improve postoperative recovery. AI-driven tools, including machine learning algorithms and deep learning methods, show great potential in areas such as preoperative planning, real-time intraoperative decision-making, and personalized postoperative care.[3] However, despite the overall success of these procedures, approximately 20% of patients remain dissatisfied, often due to persistent pain or unmet functional expectations.[4]

In science, bibliometric analyses are often used to evaluate published research and forecast future trends.[5,6] This study

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The datasets generated during and/or analyzed during the current study are publicly available.

The study doesn't need the Ethics Committee of People's Hospital of Chongqing Hechuan approval.

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aimed to identify the key research trends and priorities in the application of AI in arthroplasty from 2001 to 2025 through bibliometric and visual analyses. By analyzing global publications, influential contributors, and emerging research hotspots, this study aimed to shed light on how AI is revolutionizing arthroplasty and shaping its future direction.

2. Material and methods

2.1. Search strategy

The search strategy is illustrated in Figure 1. In this study, we conducted a comprehensive search for relevant publications within the Web of Science Core Collection (WoSCC) database. The search formula used was as follows: TS=("arthroplasty") AND TS=("AI" OR "machine learning" OR "deep learning"); AND Document types: (article OR review) AND Languages: (English), covering the timespan from 2001 to 2025 (Fig. 1).

2.2. Data analysis

The following software tools were employed for bibliometric analysis (BA) and visualization: Vosviewer 1.6.20 (Leiden Universiteit), CiteSpace 6.3. R1 (Chaomei Chen), and Scimago Graphica 1.0.46.0 (SCImago Research Group S.L.). A viewer was used to construct collaborative networks among countries, institutions, and co-occurrence of keywords. CiteSpace was employed to analyze the dual-map overlays of journals, keyword timelines, reference bursts, and keyword bursts. Scimago Graphica was used to generate the geographical visualizations. The H-index, impact factor, and category quartiles were sourced from 2021 Journal Citation Reports.

This study did not require ethical approval from an institutional review board or ethics committee for the following reasons:

(1) Nature of study: This paper is a BA based on open literature and does not involve human subjects, animal experiments, or personal patient data.
(2) Source of data: All data were obtained from the open academic literature in the Web of Science Core Collection database and did not contain any personally identifiable data (Non-Identifiable Data).
(3) Noninterventional: No experimental manipulations, clinical interventions, or new data collection were performed; only quantitative analysis of existing literature was performed.
(4) Institutional exemption policy: according to the research ethics review regulations of the first corresponding author's institution (People's Hospital of Chongqing Hechuan), no ethical approval was required for the pure literature analysis type of study.

3. Results

3.1. Literature development trends

Based on data from the WoSCC, 533 publications related to AI in arthroplasty were identified between 2000 and 2025. Among these, 491 (92.12%) were articles and 74 (13.88%) were reviews. Figure 2 illustrates that the number of related articles published increased dramatically from 2018 to 2025, when 136 articles were published throughout the year. From 2001 to 2015, the total number of publications annually remained low. However, since 2016, the number of publications in relevant literature has continued to increase. The number of publications per year has consistently remained above 10, with 2024 having the highest number of publications at 136. In addition, the number of citations has steadily increased annually, exceeding 2600 by 2024 (Fig. 2).

3.2. Countries and institutions analysis

A total of 52 countries and regions, including 929 organizations, contributed to the literature, and their specific percentages are shown in Figure 3A and B, and Table 1. Figure 3A shows the top 10 countries with the highest number of relevant papers, with the United States leading the list (n = 257, 48.22 %), followed by China (n = 86, 16.14 %), and England (n = 37, 6.94 %). In terms of the average citation rate and the number of times cited by others, the United States, China, and England

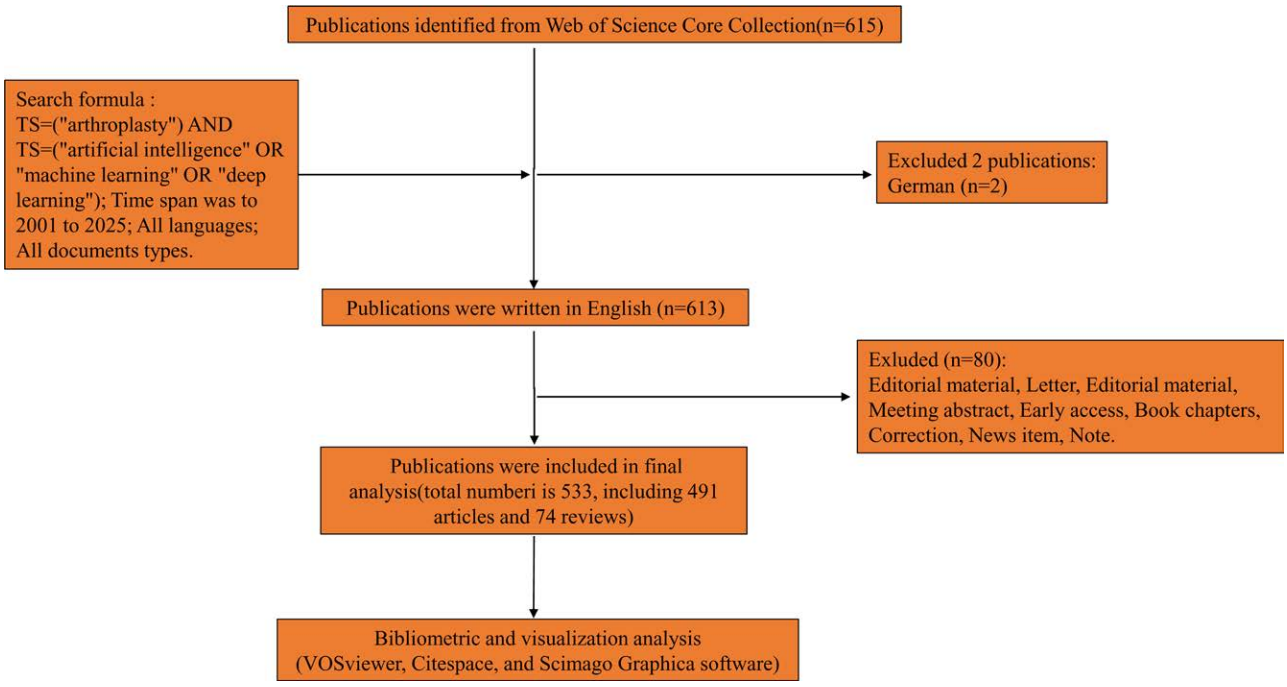


Figure 1. The flowchart of search strategy.

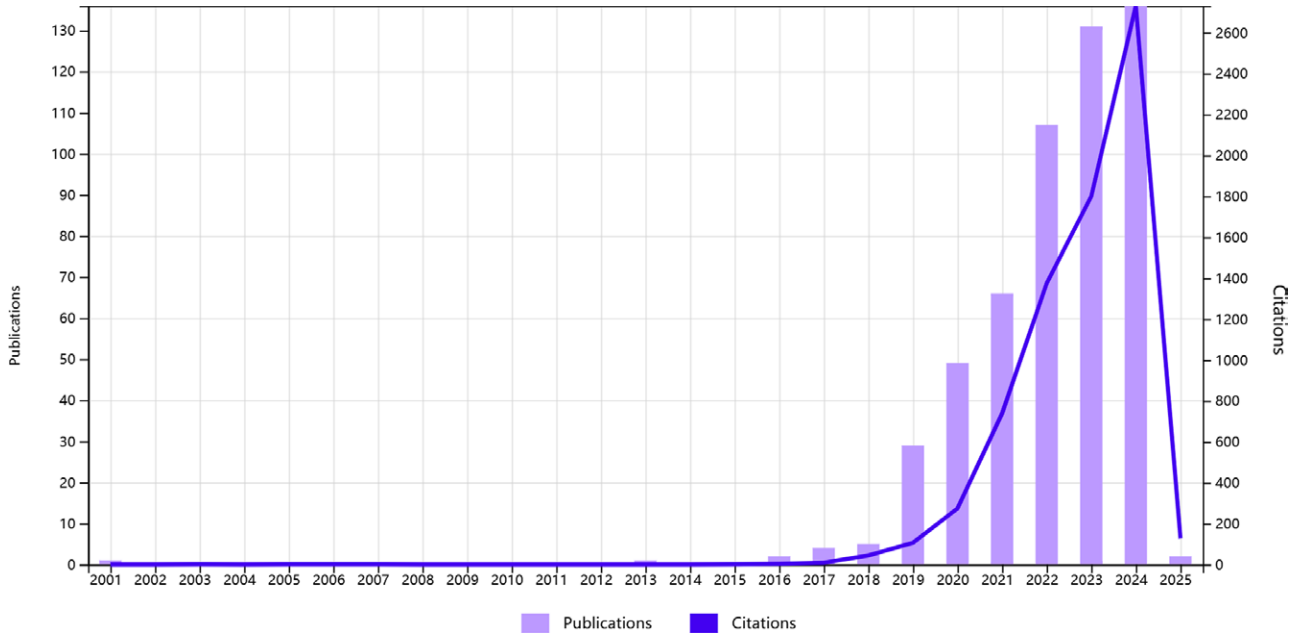


Figure 2. The annual number of publications and citations on AI in total joint arthroplasty between 2001 and 2025. AI = artificial intelligence.

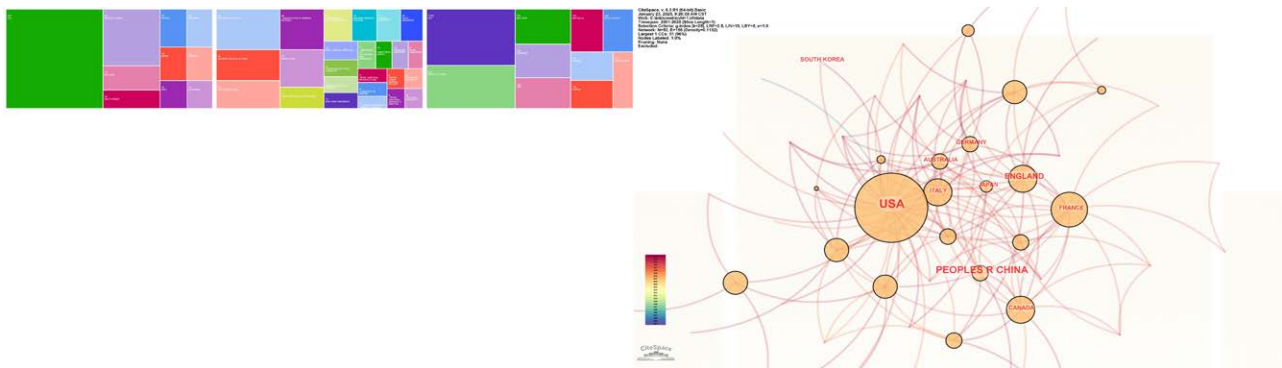


Figure 3. Countries were analyzed for co-authorship of AI in joint arthroplasty. (A) Geographic sitemap chart showing the top countries in terms of the number of articles published by AI in joint arthroplasty, with the size of the square area representing the number of articles published by each country. (B) A Sitemap Chart showing the number of articles published by each institution, with the size of the square representing the number of articles published by each institution. (C) The top countries in terms of cited articles, with the size of the square representing the number of articles cited by others. (D) Cooperation networks across countries. The size of the concentric circle represented the number of articles published by each country and the thickness of the connecting lines indicated the degree of cooperation between countries. AI = artificial intelligence.

Table 1

Presents the top 10 institutions based on the number of academic outputs in this field.

Rank	Institutions	Publications
1	Harvard University	63
2	Hospital Special Surgery	56
3	Harvard Medical School	48
4	Massachusetts General Hospital	43
5	Mayo Clinic	41
6	Cornell University	28
7	Cleveland Clinic Foundation	23
8	University of California System	21
9	Weill Cornell Medicine	21
10	Brigham Women's Hospital	19

Harvard University has the highest number of publications (63 publications), followed by the Hospital for Special Surgery (56 publications) and Harvard Medical School (48 publications).

were among the top 3 (Fig. 3C). Additionally, the National Cooperative Network (Fig. 3D) highlights that the United States has the most active collaborative relationship with China and England. This indicates that the United States dominates the field of AI in joint arthroplasty.

3.3. Authors analysis

A total of 2536 authors were identified as contributors to the literature; the top 10 authors with the most publications are listed in Figure 4A. Kwon Young-Min of Harvard Medical School led the list of 23 publications, Ramkumar PN of the Hospital for Special Surgery was second, with 19 publications, and Wyles CC of Stanford University was third, with 17 publications. Ramkumar PN of Hospital for Special Surgery published 19 papers and ranked second; Wyles CC of Mayo Clinic published 17 papers and ranked third. The top 3 cited authors in Figure 4B were Wright TW, with 26 citations; Li J, with 25 citations; and Kunze KN, Pareek A, and Schoch BS, with 23 citations each.

3.4. Journals analysis

A total of 170 journals published literature related to this topic. The top 10 journals published a total of 206

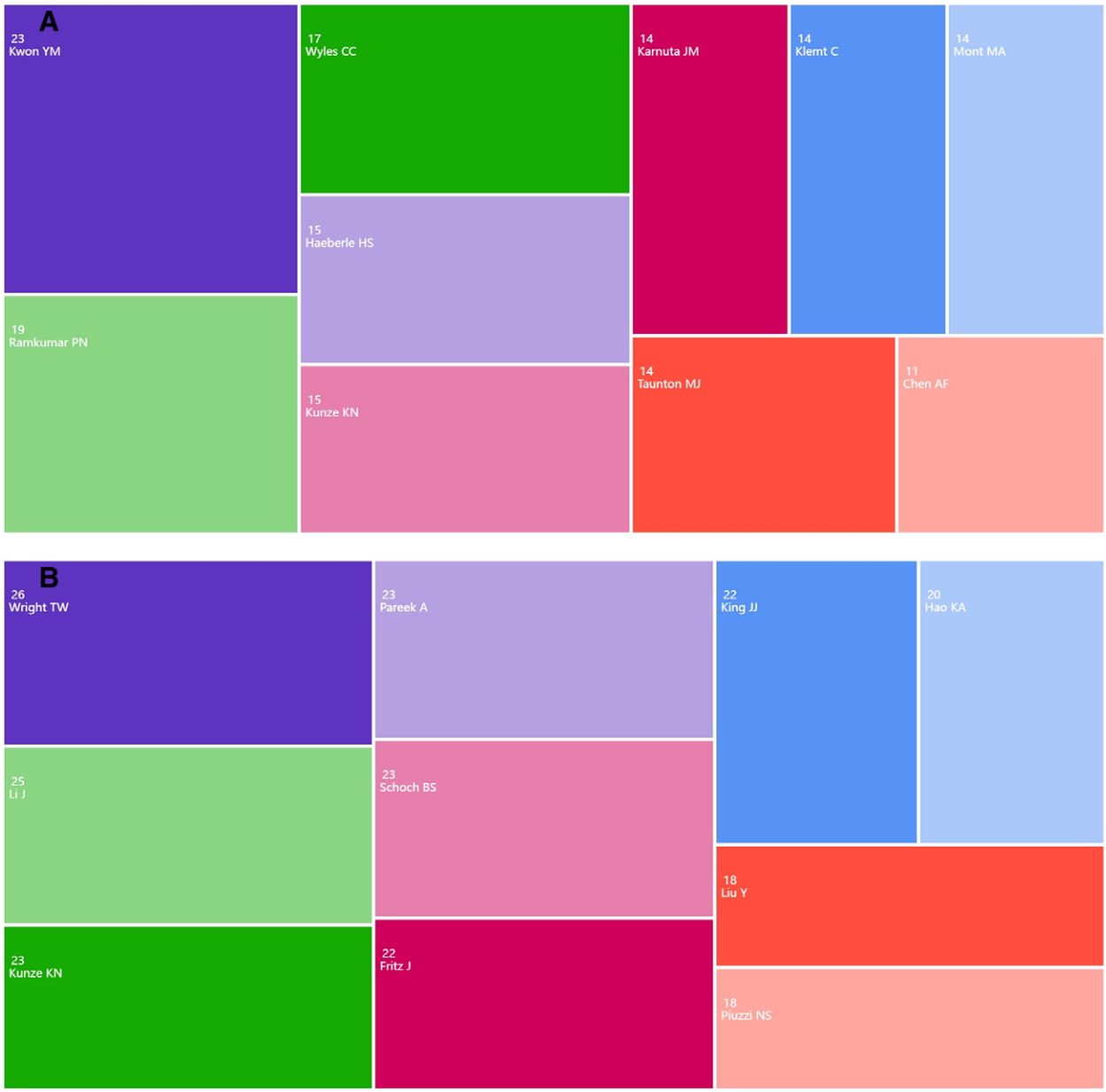


Figure 4. (A) It display the total of 2536 authors were identified as contributors to the literature, and (A) lists the top 10 authors who contributed the most papers. The larger the area of the squares, the greater the number of papers the author has published. (B) lists the top 10 authors in terms of the number of citations of their papers. The larger the area of the square, the more citations the author has received.

articles, with the Journal of Arthroplasty publishing the largest number of articles (81), followed by Knee Surgery Sports Traumatology Arthroscopy (26), and Journal of Shoulder and Elbow Surgery (18) (Fig. 5A). The top 3 most-cited journals were Journal of Arthroplasty with 146 citations, followed by Knee Surgery Sports Traumatology Arthroscopy with 86 citations, and Journal of Clinical Medicine with 76 citations (Fig. 5B). In the Web of Science categories, the top 3 journals were Orthopaedics, surgery, and sports sciences, with corresponding numbers of 1072, 663, and 281, respectively, while Radiology Nuclear Medical Imaging, which deals with medical imaging, was only one of the top 3 journals in terms of impact factor. This indicates that there is room for improvement in the use of deep learning in image processing for joint arthroplasty (Fig. 5C).

3.5. Top citation references analysis

These studies were published after 2017 (Table 2). Among the top 10 studies, the Journal of Arthroplasty published the highest number of papers. In terms of the average number of citations per year, the most-cited literature is "An algorithmic approach to reducing unexplained pain disparities in underserved populations," published in 2021, with an average citation of the top 4 articles all having more than 100 citations overall.

3.6. Keywords analysis

Figure 6A and B show our analyses of 179 keywords with more than 5 occurrences using VOSviewer software. In Figure 6A, Group 1 (red) is mainly concerned with algorithms, Group 2

Figure 5. (A) shows the top 10 journals published on AI in joint arthroplasty. The larger the square, the more relevant is the literature published by the journal. (B) indicates the top 10 journals were cited by others. The larger the square, the more frequently the journal has been cited by others. (C) shows the top 10 Web of Science categories for AI in joint arthroplasty. The larger the square, the more categories that have been published. AI = artificial intelligence.

(green) is mainly related to machine learning, Group 3 (blue) focuses on AI, and Group 4 (yellow) is centered on TKA. The 5 most frequently occurring keywords are machine learning, AI, TKA, total hip arthroplasty, and deep learning, suggesting that research in recent years has focused primarily on the use of machine learning in knee arthroplasty. In addition, Figure 6C lists the top 10 keywords with the most-cited outbreak words, which are system, selection, neural networks, big data, United States, implant identification, satisfaction, risk calculator, association and knee. Each outbreak word is not more than 3 years old, indicating that AI is advancing and changing rapidly in arthroplasty and that the United States still represents the most advanced country for this project.

4. Discussion

The results of this BA revealed that the field of AI in joint arthroplasty has experienced significant growth in recent years, particularly from 2018 to 2025. This increase is particularly evident in the increasing number of publications and citations, reflecting growing academic interest in integrating AI technologies into joint arthroplasty procedures. The significant increase

Table 2

shows the top 10 studies with the highest number of citations.

Rank	Publications	First author	Journals	Year	Citations average per year	Citations total
1	An algorithmic approach to reducing unexplained pain disparities in underserved populations	Pierson, E	Nature Medicine	2021	29.6	148
2	Preoperative opioid use is associated with early revision after total knee arthroplasty a study of male patients treated in the veterans affairs system	Ben-Ari	Journal of Bone and Joint Surgery-American Volume	2017	15.11	136
3	Machine learning and primary total knee arthroplasty: patient forecasting for a patient-specific payment model	Navarro, SM	Journal of Arthroplasty	2018	13.38	107
4	Can machine learning methods produce accurate and easy-to-use prediction models of 30-day complications and mortality after knee or hip arthroplasty?	Harris, AHS	Clinical Orthopaedics and Related Research	2019	15.14	106
5	Development and validation of a machine learning algorithm after primary total hip arthroplasty: applications to length of stay and payment models	Ramkumar, PN	Journal of Arthroplasty	2019	14.14	99
6	Remote patient monitoring using mobile health for total knee arthroplasty: validation of a wearable and machine learning-based surveillance platform	Ramkumar, PN	Journal of Arthroplasty	2019	13.43	94
7	Development of machine learning algorithms for prediction of sustained postoperative opioid prescriptions after total hip arthroplasty	Karhade, AV	Journal of Arthroplasty	2019	12.71	89
8	Artificial intelligence and machine learning in lower extremity arthroplasty: a review	Haeberle, HS	Journal of Arthroplasty	2019	12.43	87
9	Comparison of an artificial intelligence-enabled patient decision aid vs educational material on decision quality, shared decision-making, patient experience, and functional outcomes in adults with knee osteoarthritis a randomized clinical trial	Jayakumar, P	JAMA Network Open	2021	16.4	82
10	Assessing ChatGPT responses to common patient questions regarding total hip arthroplasty	Mika, AP	Journal of Bone and Joint Surgery-American volume	2023	25.33	76

in publications, highlighted by 136 articles published in 2024, reflects the rapid growth of AI applications in this field.[7] This trend aligns with broader developments in orthopedics and surgery, where AI is increasingly integral to enhancing the precision of surgical planning and improving the prediction of postoperative outcomes.[8,9]

In terms of global contributions, the United States continues to lead in both publication volume and citation impact, a trend mirrored by the results of this analysis. While China has made considerable strides in increasing the number of publications, its citation impact remains low, reflecting the relative novelty of its contributions in the field. The United States' leadership in AI research for joint arthroplasty is reinforced by its extensive collaboration with countries such as China and the United Kingdom, as exemplified by the national cooperative network.[10] Such partnerships are crucial for advancing AI research and driving innovation. As previous studies have shown, international collaboration can significantly accelerate the development and integration of AI technologies into clinical practice.[11,12]

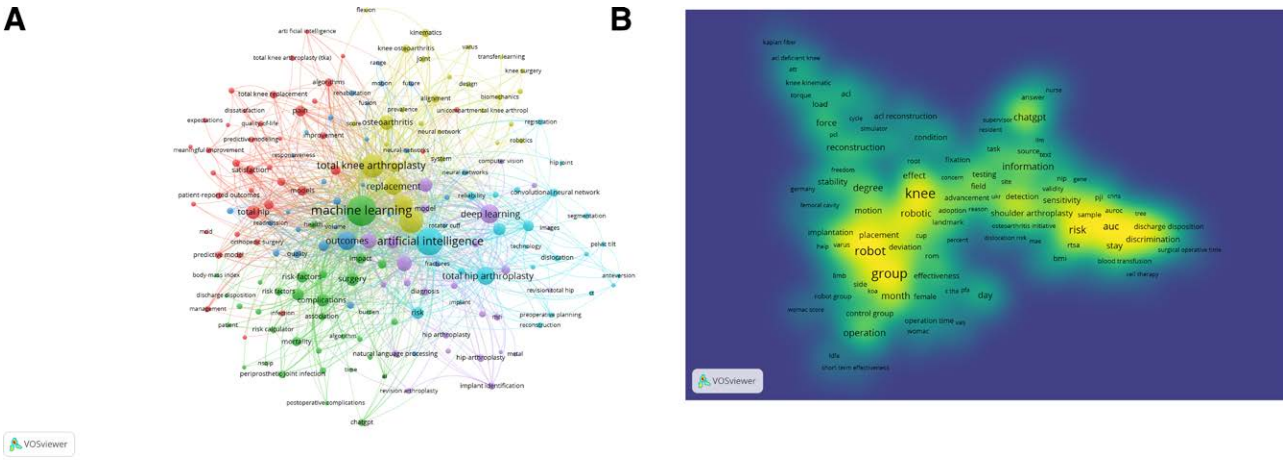
Leading institutions such as Harvard University and the Hospital for Special Surgery play a crucial role in driving AI-related research in arthroplasty. These institutions are not only the most productive in terms of publications but also produce high-impact research that shapes the direction of the field. The concentration of research within a limited number of institutions suggests that while the field is advancing, there remains considerable potential for broader participation from other research centers. Additionally, the prominent presence of these institutions in high-impact journals such as The Journal of Arthroplasty underscores the growing academic recognition of AI's role in joint arthroplasty.[13,14]

The author's analysis revealed significant contributions of individuals such as Kwon Young-Min, Ramkumar Prem N, and Mont Michael A, whose work has been instrumental in advancing the understanding and application of AI in joint arthroplasty. Their research focused on areas such as machine learning algorithms for preoperative planning, deep learning for image analysis, and AI-driven models for improving postoperative recovery, all of which have garnered substantial attention from the academic community. The citation burst of their work illustrates the growing influence of AI in shaping clinical outcomes and optimizing surgical decision-making.[15,16]

In terms of journals, The Journal of Arthroplasty remains the most prolific journal in publishing research on AI in joint arthroplasty. Its prominence is reflected not only in the volume of publications, but also in the journal's citation count, making it a critical platform for disseminating key findings. The top journals in this field, such as Knee Surgery, Sports Traumatology, Arthroscopy, and the Journal of Clinical Medicine, reflect the cross-disciplinary nature of this research. AI is being increasingly integrated into orthopedics, pain management, and postsurgical rehabilitation strategies.[17,18] The diverse range of journals publishing AI-related arthroplasty research highlights the breadth of this field and its relevance in multiple medical specialties.

The keyword analysis in this study highlights the increasing focus on machine learning, deep learning, and implant recognition in arthroplasty-related AI research. Notably, the rising prominence of implant recognition signals a shift towards AI applications aimed at enhancing the surgical precision. This trend aligns with the growing use of AI to assist surgeons in selecting the most suitable implants based on individual patient characteristics, potentially improving clinical outcomes and reducing complications.[19,20] Additionally, the increasing interest in AI-driven personalized medicine underscores the shift towards tailored treatment plans for patients undergoing joint arthroplasty.[21,22]

Moreover, keyword burst analysis revealed a surge of interest in terms such as neural networks, big data, and implant identification, with the United States leading the way in these areas. This aligns with the broader trend of integrating big data and AI in healthcare, where large-scale datasets are leveraged to develop predictive models for surgical outcomes. The ongoing exploration of these emerging keywords indicates that AI is being applied not only to enhance clinical decision-making, but also to develop more efficient systems for managing patient data and optimizing healthcare delivery.[23,24]



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Top 10 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	2001 - 2025
system	2017	2.7	2017	2020	
selection	2017	2.7	2017	2020	
neural networks	2017	2.08	2017	2020	
big data	2018	3.8	2018	2019	
united states	2020	3.29	2020	2022	
implant identification	2020	3.13	2020	2021	
satisfaction	2021	3.08	2021	2022	
risk calculator	2021	3.01	2021	2022	
association	2022	2.46	2022	2023	
knee	2023	2.16	2023	2025	

Figure 6. (A) shows the connection between high-frequency keywords analyzed by the VOSviewer software, with a larger circle area indicating a higher frequency of occurrence; (B) shows the respective weights of the high-frequency keywords analyzed by the VOSviewer software, with a higher brightness implying greater weights. (C) indicates the top 10 keywords with the highest citation burst AI on TJA from 2001 to 2025. AI = artificial intelligence. TJA = total joint arthroplasty.

Despite these advances, the integration of AI into clinical practice is hampered by several challenges. These include issues related to data quality, standardization, and interpretability. As AI systems become more complex, ensuring that they are transparent and can be reliably integrated into clinical workflows is critical to their successful adoption. Studies indicate that clinician confidence in AI-driven tools is crucial for their integration into decision-making, and addressing concerns related to transparency and explainability is key to overcoming these challenges.[25,26] Furthermore, successful AI adoption requires substantial investment in training healthcare professionals, ensuring they are well equipped to utilize AI systems effectively in clinical settings.[27,28]

It is clear that AI has the potential to significantly improve joint arthroplasty in the future. However, the continued development of AI technologies must be accompanied by rigorous validation studies and collaborative efforts among researchers, clinicians, and healthcare systems. These efforts are essential for overcoming barriers to AI adoption and ensuring that these technologies contribute to improved patient outcomes and more efficient clinical practices.[29,30] Future research should focus on optimizing AI models for clinical use, refining their integration into existing surgical workflows, and addressing practical challenges related to data standardization and system interoperability.[31,32]

This BA provides a comprehensive overview of the trends, contributions, and challenges of AI in arthroplasty. A growing body of literature suggests that AI is expected to revolutionize the field and make significant advances in the coming years. By addressing challenges related to data integration, transparency, and clinician training, AI can be successfully integrated into clinical practice to enhance arthroplasty outcomes.[33,34]

5. Limitations

Although this BA provides valuable insights into the current trends and research priorities regarding AI in joint arthroplasty, several limitations should be noted. First, the study was based on publications retrieved from the WoSCC, which, although comprehensive, may not capture all relevant literature, especially publications from non-English language sources or those indexed in other databases, such as Scopus or Google Scholar. Consequently, the findings may not fully capture the global scope of AI applications in arthroplasty.[35]

Second, this study focuses on research published between 2000 and 2025, which may not include the most recent developments in AI technology. Although the analysis covers data up to 2025, ongoing studies or recently published works not yet indexed in the WoSCC database may limit the representation of the latest research breakthroughs. Future analyses could benefit from incorporating preprints and conference proceedings to offer a more comprehensive view of the rapidly evolving field of AI in joint arthroplasty.[36]

Third, the study primarily relied on bibliometric and visualization tools, such as CiteSpace, VOSviewer, and Scimago Graphica, to quantify and visualize trends in the literature. Although these tools offer valuable insights into the distribution of publications, authorship, and citation impact, they may not fully capture the quality or clinical significance of the studies

included in the analysis. While BA offers a quantitative overview, it may not fully assess the methodological rigor, clinical relevance, or real-world applicability of the AI models discussed in the literature.[37,38]

Another limitation lies in the focus on research articles and reviews, which may overlook other important forms of knowledge dissemination such as clinical guidelines, expert opinions, or case reports that contribute to the application of AI in joint arthroplasty. Given that AI research is an interdisciplinary field, incorporating clinical practice-based sources and insights from outside traditional academic publications could offer a more comprehensive understanding of AI's impact in this area.[39,40]

Finally, although the analysis identified several research hotspots, such as implant identification and predictive modeling, it did not delve into specific challenges related to the implementation and clinical adoption of AI technologies. Issues, such as data privacy, algorithmic transparency, model validation, and clinician training, were not addressed in detail. As AI in joint arthroplasty remains an emerging field, further investigation into these practical challenges is crucial to fully realizing the potential of AI technologies in clinical settings.[41,42]

6. Conclusion

This BA highlights 3 critical insights into AI applications for joint arthroplasty:

(1) Rapid growth: Publication output surged dramatically from 2018 to 2023, with the United States leading contributions (48.2% of studies), followed by China and England. Institutions like Harvard University and the Hospital for Special Surgery drove high-impact advancements.
(2) Technological focus: Machine learning and deep learning emerged as dominant tools, particularly in optimizing implant selection and predicting postoperative outcomes. Recent keyword trends, such as "implant identification," underscore innovations in surgical precision.
(3) Persistent challenges: Barriers to clinical adoption – including fragmented data integration, limited model interpretability, and validation gaps – require urgent attention to unlock AI's full potential.

Future research should prioritize collaborative frameworks to standardize datasets, enhance AI transparency, and validate algorithms in real-world clinical workflows. Addressing these challenges will accelerate AI's transformative role in personalized joint arthroplasty care.

Author contributions

Conceptualization: Xu Peng.
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Software: Yang Hu, Haibo Pu.
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Visualization: Wen Zou, Chaoyang Qu.
Writing – original draft: Xu Peng.
Writing – review & editing: Chaoyang Qu.

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