VOLUME 12 NOMOR 2 DECEMBER 2025 ISSN 2548 – 611X

JURNAL
BIOTEKNOLOGI & BIOSAINS INDONESIA

Homepage Jurnal: http://ejournal.brin.go.id/JBBI/index



BIBLIOMETRIC ANALYSIS OF PATIENT OUTCOMES AND SATISFACTION IN ROBOTIC-ASSISTED HIP AND KNEE JOINT REPLACEMENT SURGERY

Analisis Bibliometrik Hasil dan Kepuasan Pasien pada Bedah Penggantian Sendi Pinggul dan Lutut Robotik

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ABSTRACT

Robotic-assisted hip and knee arthroplasty has gained popularity in orthopedic surgery due to its precision, faster recovery, and improved alignment, potentially enhancing patient outcomes. Despite mixed and heterogeneous evidence, the demand for these procedures continues to rise. Therefore, bibliometric analysis is essential to direct research towards patient satisfaction and generate more reliable and significant evidence proving the true benefits of robotic surgery for patients, rather than merely technical success. This study employed bibliometric analysis to explore trends and evaluate publications on patient outcomes and satisfaction in robotic-assisted hip and knee surgery using the Scopus database. The analysis identified core concepts, trends, and research connections, providing insights into emerging areas in the field. The bibliometric analysis of 324 documents from 2007 to 2025 reveals a significant increase in research, focusing on surgical precision, rehabilitation, and long-term effectiveness. While countries like the US, UK, and China are leading contributors, there is a notable lack of similar research in ASEAN countries, particularly Indonesia. Future research should address gaps in areas like surgical revision, patient perception, and improving patient-reported outcomes.

Keywords: *Bibliometric analysis, Hip and knee arthroplasty, Patient outcome, Patient satisfaction, Robotic-assisted surgery*

ABSTRAK

Penerapan bedah penggantian pinggul dan lutut dengan bantuan robot semakin populer dalam bedah ortopedi karena presisi, pemulihan yang lebih cepat, dan peningkatan penyelarasan yang berpotensi meningkatkan hasil pasien. Meskipun bukti yang ada masih bervariasi dan heterogen, permintaan terus meningkat. Oleh karena itu, analisis bibliometrik diperlukan untuk mengarahkan penelitian pada kepuasan pasien guna menghasilkan bukti yang lebih dapat diandalkan dan signifikan terkait manfaat sebenarnya dari bedah robotik bagi pasien, bukan hanya keberhasilan teknis. Penelitian ini menggunakan analisis bibliometrik untuk mengeksplorasi tren dan mengevaluasi publikasi tentang hasil dan kepuasan pasien dalam bedah penggantian pinggul dan lutut dengan bantuan robot menggunakan database Scopus. Analisis

Received: *25 August 2025* ***Accepted***: *9 December 2025* ***Published***: *28 December 2025*

ini mengidentifikasi konsep inti, tren, dan hubungan penelitian, memberikan wawasan tentang area yang sedang berkembang dalam bidang ini. Hasil analisis bibliometrik terhadap 324 dokumen dari tahun 2007 hingga 2025 menunjukkan adanya peningkatan signifikan dalam penelitian ini, dengan fokus pada presisi bedah, rehabilitasi, dan efektivitas jangka panjang. Penelitian di negara-negara seperti AS, Inggris, dan China mendominasi, namun terdapat kekurangan penelitian serupa di negara-negara ASEAN, termasuk Indonesia. Penelitian lebih lanjut diharapkan dapat mengisi kekurangan ini, khususnya terkait revisi bedah, persepsi pasien, dan hasil yang dilaporkan oleh pasien.

Kata Kunci: *Analisis bibliometrik, Artroplasti pinggul dan lutut, Hasil luaran pasien, Kepuasan pasien, Bedah dengan bantuan robot*

INTRODUCTION

Robotic-assisted hip and knee arthroplasty has become an important advancement in joint replacement surgery, offering surgeons enhanced precision, improved implant alignment, and greater consistency during operative procedures (Kow *et al*., 2024). The integration of robotic systems aims to reduce human error, optimize component positioning, and ultimately improve clinical outcomes for patients (Biswas *et al.*, 2023; Fontalis *et al.*, 2021). As the global burden of degenerative joint disease continues to rise particularly among aging populations, the demand for hip and knee arthroplasty has increased substantially (Steinmetz *et al*., 2023; Favreau *et al*., 2024). Projections suggest that by 2025, robotic-assisted procedures will account for nearly 23.9% of total hip arthroplasties (THA) and up to 35% of unicompartmental knee arthroplasties (UKA), reflecting a rapid shift toward robotic-assisted technologies in orthopedic practice (Matharu *et al.*, 2022; Bagaria *et al.*, 2020).

Numerous studies have demonstrated that robotic-assisted total knee arthroplasty (RA-TKA) offers benefits such as reduced postoperative pain, faster functional recovery, and greater patient satisfaction compared with conventional techniques (Chen *et al*., 2018; Fan *et al*., 2023; Aneja *et al*., 2024; Marchand *et al*., 2017). Robotic-assisted total hip arthroplasty (RA-THA) has also shown favorable short-term clinical and patient-reported outcomes, with lower complication rates in several studies (Perets *et al.*, 2018; Prinos *et al.*, 2024). However, despite these advantages, other research reports no substantial differences in long-term outcomes between robotic-assisted and conventional arthroplasty (Kort *et al.*, 2021; Riantho *et al.*, 2023; Ruangsomboon *et al.*, 2024). High acquisition and maintenance costs, variability in surgeon learning curves, and inconsistent clinical results across centers remain barriers to broader adoption of robotic surgery (Li *et al*., 2021). These discrepancies underscore the need for more comprehensive and patient-focused evidence, including long-term functional outcomes, patient satisfaction, and real-world recovery measures (Khatri *et al.*, 2024; Daoub *et al.*, 2024).

While the application of robotic systems in joint replacement has grown rapidly, existing bibliometric studies have primarily concentrated on technological innovation, surgical precision, and system mechanics rather than patient-centered outcomes (Kow *et al*., 2024). Currently, there remains a global lack of comprehensive evidence linking robotic-assisted arthroplasty directly to patient-reported outcomes, long-term satisfaction, and functional recovery especially in developing regions where research output is limited. Because of this gap, bibliometric analysis is essential to systematically quantify existing research output and uncover trends, citation patterns, influential publications, thematic clusters, and overlooked areas related to patient outcomes in robotic-assisted hip and knee arthroplasty (Passas, 2024). Bibliometric analysis also provides a structured, quantitative means of synthesizing evidence across large datasets to better understand how research has evolved, how influential authors and countries contribute to the field, and which areas remain underexplored (Musbahi *et al.*, 2022; Rushforth *et*

al., 2018). Bibliometric mapping further facilitates identification of core research themes including surgical revision, long-term recovery, complications, patient perception, and quality-of-life outcomes and allowing researchers to pinpoint knowledge gaps that require further investigation to advance patient-centered evidence.

While early research on robotic-assisted arthroplasty focused largely on implant positioning and intraoperative accuracy, recent studies have increasingly shifted toward outcomes such as clinical recovery, patient satisfaction, and cost-effectiveness. Despite this shift, research addressing patient-reported outcomes remains limited, particularly in developing regions such as ASEAN countries, where robotic systems are less accessible and research infrastructures are still evolving. As robotic surgery continues to expand globally, evaluating its true value from the patient's perspective including pain reduction, functional improvement, and quality of life has become essential for guiding clinical decision-making, optimizing rehabilitation strategies, and informing healthcare policy.

Given these gaps in the literature, this study aims to analyze global trends, patterns, and research developments in robotic-assisted hip and knee arthroplasty with a specific focus on patient outcomes and patient satisfaction. The objectives of this bibliometric analysis are to map thematic structures within the literature, identify influential authors, institutions, and countries contributing to the field, highlight underexplored topics such as revision surgery, long-term outcomes, and patient perception, and examine disparities in research contributions between developed and developing regions. By identifying these trends and gaps, this study provides a foundation for future research and supports the advancement of patient-centered approaches in robotic-assisted joint replacement.

MATERIALS AND METHODS

Search Strategy and Study Selection

This study used bibliometric analysis to explore trends in patient outcomes and satisfaction in robotic-assisted hip and knee arthroplasty, utilizing the Scopus database for its broad global coverage (Kow *et al*., 2024; Passas, 2024). Bibliometric analysis was selected because it is well suited for evaluating publication growth, collaboration patterns, and emerging thematic areas in rapidly evolving fields such as robotic-assisted surgery (Oliveira *et al*., 2020). Following established methodologies, the analysis consisted of three steps (Figure 1): first, data gathering involved selecting specific keywords to locate relevant articles, with Scopus database was chosen as the primary data source due to its extensive global coverage, multidisciplinary indexing, and robust citation tracking capabilities, offering advantages over PubMed and Web of Science for mapping research influence and citation networks (Powell & Peterson, 2017; AlRyalat *et al.*, 2019). The collected data was then processed and visualized using VOSviewer and the bibliometrix R package, which facilitated organized presentation and clustering of the information. Finally, the data was analyzed to identify core concepts and trends, offering a comprehensive understanding of the primary thematic areas (Dirgahayu *et al.*, 2024; Ilyas *et al*., 2024; Mirawati *et al*., 2024; Sumarwoto *et al*., 2023).

The search was conducted on January 16, 2025, using the query ("patient satisfaction" OR "patient-reported outcomes" OR "clinical outcomes") AND ("robotic-assisted surgery" OR "robot-assisted surgery" OR "robotic surgery") AND ("hip replacement" OR "knee replacement" OR "hip surgery" OR "knee surgery"). The initial search yielded 387 records. To refine the dataset, several filters were applied, restricting the results to English-language publications, peer-reviewed articles and reviews, fully published documents, and studies classified within the field of medicine. Excluded materials included non-English documents, articles in press, letters, editorials, book chapters, and other non–peer-reviewed items. After applying these criteria, 335 publications from 2007–2025 remained. Title and abstract screening produced a final dataset of 324 relevant publications addressing robotic-assisted arthroplasty and patient-focused outcomes. All records were exported in CSV format for compatibility with

bibliometric software. Data cleaning involved removing duplicates, correcting inconsistencies in author names, journal titles, and affiliations using Zotero, and validating entries to ensure accurate citation and metadata classification. The cleaned dataset was used for subsequent co-authorship, co-occurrence, and citation network analyses.

Data Extraction, Visualization, and Analysis

Bibliometric analyses were performed using the bibliometrix R package within RStudio, supported by its graphical interface, Biblioshiny, to facilitate structured scientometric evaluation without the need for advanced programming expertise (Aria & Cuccurullo, 2017; Darvish, 2018; Lim *et al.*, 2024). VOSviewer was used as a complementary visualization tool to generate high-resolution bibliometric maps, including co-authorship networks, institutional collaboration structures, and keyword co-occurrence diagrams (van Eck & Waltman, 2010; van Eck & Waltman, 2017). In these maps, node size represented frequency, while color-coded clusters indicated thematic groupings based on link strength (Koca, 2024; In *et al*., 2024). This approach enabled identification of major research domains such as robotic surgical precision, postoperative recovery, patient satisfaction, revision surgery, and long-term outcomes.

The combined use of bibliometrix R and VOSviewer enabled detailed assessment of publication trends, citation impact, collaborative networks, and thematic evolution across the field (Aria & Cuccurullo, 2017; van Eck & Waltman, 2010). Bibliometrix provided key statistical indicators such as citation counts, H-index trends, leading authors, influential journals, and thematic progression while VOSviewer helped identify major research domains including robotic surgical precision, postoperative recovery, patient satisfaction, revision surgery, and long-term outcomes (Darvish, 2018; van Eck & Waltman, 2010; van Eck & Waltman, 2017). Together, these tools offered a comprehensive and integrated understanding of the intellectual structure and emerging directions within research on robotic-assisted hip and knee arthroplasty.

RESULTS AND DISCUSSION

Result

Description of Included Studies

This study analyzed 324 documents from 73 journals, books, and reliable sources, spanning from 2007 to 2025. A total of 324 documents were analyzed, with an impressive annual growth rate of 8.01% and an average citation per document of 19.27, reflecting the academic impact and relevance of the topic. The average document age is 3.16 years, supported by 9.662 references. Key insights were identified through 1,581 “Keywords Plus” and 540 author keywords. The research involved 1347 authors, with 5 single authors, indicating a highly collaborative nature, with an average of 6.11 co-authors per document and 20.06% of documents involving international collaborations. This research highlights the growing focus on patient-centered outcomes in robotic-assisted hip and knee surgery.

Publication Trends

Publication output from 2007 to 2025 demonstrates a clear upward trajectory in research on robotic-assisted hip and knee arthroplasty, particularly regarding patient outcomes and satisfaction. Early publications from 2007 to 2013 were sparse and inconsistent, reflecting the emerging nature of robotic technology during this period. Beginning in 2014, the number of studies increased steadily, with a pronounced surge after 2020. The peak occurred in 2024 with 82 publications, indicating heightened global academic interest in evaluating the clinical and patient-centered impact of robotic-assisted procedures. This consistent rise underscores the growing recognition of robotic-assisted arthroplasty as an important area of research, particularly for understanding how technological advancements influence patient-reported outcomes and satisfaction (Figure 2).

Top Article

Based on the analysis of the top-cited documents, the study by Jacofksy et al (2016) in *The Journal of Arthroplasty* is the most influential, with 321 citations and an average of 32,1 citations per year, shaping the field of robotic-assisted joint

replacement surgery and patient outcomes. Kayani et al (2018) in *The Bone and Joint Journal* had the highest citation rate, with 32.38 citations per year, highlighting surgical precision and recovery improvements. Schulz et al (2007) in *The International Journal of Medical Robotics and Computer-Assisted Surgery* laid the groundwork for robotic surgery in hip and knee arthroplasty with 129 citations and 6.79 citations per year. These studies represent key milestones in the evolution of this research area (Table 1).

Table 1. Top 10 Most Globally Cited Documents About Patient Outcomes and Satisfaction in Robotic-Assisted Hip and Knee Joint Replacement Surgery

No	Title	Author	Source	Year	Citation	Citation/Year
1	Robotics in Arthroplasty: A Comprehensive Review	Jacofsky, David J. *et al*.	The Journal of Arthroplasty, Volume 31, Issue 10, 2353 - 2363	2016	321	32.10
2	Robotic-arm assisted total knee arthroplasty is associated with improved early functional recovery and reduced time to hospital discharge compared with conventional jig-based total knee arthroplasty	Kayani B, Konan S, Tahmassebi J, Pietrzak JRT, Haddad FS	*Bone Joint J*. 2018;100-B(7):930-937.	2018	259	32.38
3	Results of total hip replacement using the Robodoc surgical assistant system: clinical outcome and evaluation of complications for 97 procedures	Schulz, AP., *et al*.	*Int J Med Robot*. 2007;3(4):301-306.	2007	129	6.79
4	Improved implant position and lower revision rate with robotic-assisted unicompartmental knee arthroplasty	Batailler, C., *et al.*	*Knee Surg Sports Traumatol Arthrosc* 27, 1232–1240	2019	120	17.14
5	Technology-Assisted Hip and Knee Arthroplasties: An Analysis of Utilization Trends	Boylan, M., *et al*.	The Journal of Arthroplasty, Volume 33, Issue 4, 1019 – 1023	2018	117	14.63
6	Robotic-arm assisted total knee arthroplasty is associated with improved accuracy and patient reported outcomes: a systematic review and meta-analysis	Zhang, J., *et al*.	Knee Surg Sports Traumatol Arthrosc 30, 2677–2695	2022	108	27.00
7	Survivorship and patient satisfaction of robotic-assisted medial unicompartmental knee arthroplasty at a minimum two-year follow-up	Pearle, Andrew D., *et al.*	The Knee, Volume 24, Issue 2, 419 – 428	2017	106	11.78
8	Robotic Arm–Assisted Total Knee Arthroplasty	Khlopas, Anton *et al.*	The Journal of Arthroplasty, Volume 33, Issue 7, 2002 – 2006	2018	101	12.63

No	Title	Author	Source	Year	Citation	Citation/Year
9	Robotic Total Knee Arthroplasty with a Cruciate-Retaining Implant: A 10-Year Follow-up Study	Yang HY, Seon JK, Shin YJ, Lim HA, Song EK	Clin Orthop Surg. 2017 Jun;9(2):169-176.	2017	99	11.00
10	Clinical and Radiological Outcomes in Robotic-Assisted Total Knee Arthroplasty: A Systematic Review and Meta-Analysis	Agarwal, Nikhil *et al.*	The Journal of Arthroplasty, Volume 35, Issue 11, 3393 - 3409.e2	2020	89	14.83

Top Authors / Institutions/ Journal

Several authors and institutions have made notable contributions to the advancement of robotic-assisted hip and knee arthroplasty. Fares S. Haddad and Babar Kayani of University College Hospital are among the most prominent figures, significantly influencing the field through research on surgical precision and postoperative outcomes. Michael A. Mont has also contributed extensively to clinical innovation and patient-centered evaluations. Cecile Batailler stands out for her impactful work, with her 2019 study receiving 120 citations and averaging 17.14 citations per year, reflecting ongoing influence in the literature (Figure 3).

Key journal and institutions have played vital roles in disseminating and supporting this research. The *Journal of Arthroplasty* leads with 33 articles, followed by *Knee Surgery, Sports Traumatology, Arthroscopy* with 24 articles, while *International Orthopaedics* and the *Journal of Knee Surgery* contribute 20 articles each, serving as centers for knowledge advancement. Similarly, University College Hospital leads institutional contributions with 56 articles, followed by the Cleveland Clinic (32), the University of Warwick (29), the Hospital for Special Surgery (28), and Azienda Ospedaliero Universitaria Di Modena (24), underscoring their critical role in driving research and innovation in robotic-assisted joint replacement surgery (Figures 4a and b).

Top Countries

Our dataset includes contributions from a total of 30 countries. Figure 5 highlights the top 10 countries with the highest number of contributing authors from 2007 to 2025. The data shows that the United States is the leading contributor, with 75 articles (23.1%), including 59 single-country publications. The United Kingdom (36 articles) and China (28 articles) follow, with France standing out for its high international collaboration rate (62.5% of its 16 articles). Smaller contributors, such as Belgium and countries like the UAE, Austria, and Egypt, show 80–100% international collaborations, while nations like Turkey, India, and Malaysia focus exclusively on single-country studies. This pattern reflects a clear disparity, with research in this field being predominantly driven by developed countries, while contributions from developing nations remain limited.

Keywords and Cluster Analysis

A bibliometric analysis using VOSviewer identified 88 keywords related to patient outcomes and satisfaction in robotic-assisted knee and hip joint replacement. After removing irrelevant terms, 57 keywords met the inclusion criteria. The results are shown in Figure 6, where the size of each circle represents the frequency and importance of the keywords. Larger circles indicate higher frequency. VOSviewer grouped the keywords into four clusters, highlighting key research patterns and revealing both well-studied and underexplored areas. Table 2 provides a breakdown of the cluster analysis, organizing keywords into two categories: keywords with more than ten occurrences were classified as “most frequent,” while those with fewer than ten were categorized as “least frequent.” This classification helps pinpoint major trends and suggests areas for further research.

Table 2. The result of cluster analysis on Patient Outcomes and Satisfaction in Robotic-Assisted Hip and Knee Joint Replacement Surgery publications

Cluster	Most Frequent Keywords	Least Frequent Keywords
1st cluster (18 items)	Robotic surgery (78), total hip arthroplasty (40), robotics (39), arthroplasty (37), outcomes (28), knee replacement (11)	Clinical outcomes (10), technology (9), computer navigation (8), patient satisfaction (8) hip (6), learning curve (5), satisfaction (5), direct anterior approach (3), dislocation (3), function (3), hip replacement (3), pain (3),
2nd cluster (16 items)	Robotic arm-assisted (70), Unicompartmental knee arthroplasty (42), osteoarthritis (19), Mako's robotic arm (17), patient-reported outcome measures (PROMs) (13), alignment (11), knee arthroplasty (11)	Survivorship (9), inverse kinematic alignment (4), component positioning (4), cost (3), kinematics (3), length of stay (3), medial unicompartmental knee arthroplasty (3), robotic arthroplasty (3), surgical technique (3),
3rd cluster (14 items)	Total knee arthroplasty (109), complications (18), robotic-assisted total knee arthroplasty (11)	Conventional (9), Rosa knee system (9), accuracy (7), fuctional outcomes (6), implant positioning (4), joint line (4), coronal alignment (3), forgotten joint score (3), knee alignment (3), mechanical axis (3), surgical revision (3)
4th cluster (9 items)	Knee (34), patient-reported outcomes (13)	Fuctional alignment (9), kinematic alignment (8), mechanical alignment (8), minimally clinically important difference (5), manual (3), postoperative outcome (3), valgus (3)

Trend Topics

Recent studies on robotic-assisted hip and knee arthroplasty highlight the importance of surgical precision, rehabilitation, and long-term effectiveness. As robotic technology improves, it enhances surgical accuracy, reduces errors, and ensures proper implant positioning. Research increasingly focuses on patient outcomes, including pain management, range of motion, and overall satisfaction. Keywords like "revision arthroplasty" and "patient perception" reflect the shift towards considering patient experiences. Future research will likely explore robotic technology's impact on revision rates, functional recovery, and patient satisfaction, solidifying its role in advancing orthopedic (Figures 7 and 8).

Dicussion

Robotic-assisted joint arthroplasty has consistently demonstrated significant improvements in surgical accuracy and clinical outcomes, particularly in hip and knee procedures. Studies by Jacofsky et al. (2016) and Kayani et al. (2018) show that using robotic-assisted systems has been linked to improved implant placement accuracy, reduced need for revision surgery, and faster postoperative recovery times, including shorter hospital stays (Jacofsky & Allen, 2016; Kayani *et al*., 2018). Supporting these findings, Batailler et al. (2019) and Khlopas et al. (2018) reported that robotic-assisted techniques result in more accurate implant positioning, fewer misalignments, and improved soft-tissue handling, which leads to higher patient satisfaction and reduced complications. Although much of the current evidence is based on short-term outcomes, these improvements suggest meaningful advantages over conventional methods (Batailler *et al*., 2019; Khlopas *et al*., 2018). Furthermore, Zhang et al. (2022), through a systematic review and meta-analysis, reinforced the positive impact of robotic systems on both surgical precision and patient-reported outcomes, emphasizing that the benefits of robotic-assisted arthroplasty extend beyond technical accuracy to include better subjective recovery experiences. Together, these studies support the growing role of

robotic assistance as a tool for improving both clinical efficacy and patient-centered care in joint arthroplasty (Zhang *et al*., 2022).

Although evidence on the long-term benefits and cost-effectiveness of robotic-assisted arthroplasty remains limited and variable, current findings suggest a generally favorable impact on patient satisfaction and radiological outcomes. Pearle et al. (2017) demonstrated high short-term survivorship and patient satisfaction in robotic-assisted unicompartmental knee arthroplasty (UKA), particularly when performed in facilities with frequent joint arthroplasty procedures, where it was found to be more cost-effective (Pearle *et al*., 2017). Similarly, Agarwal et al. (2020) reported superior functional outcomes and improved postoperative alignment in patients undergoing robotic-assisted total knee arthroplasty (RATKA) (Agarwal *et al*., 2020). While Boylan et al. (2018) noted that long-term evidence remains inconsistent and Schulz et al. (2007) identified technical issues with earlier robotic systems, the majority of the literature supports the notion that robotic-assisted procedures offer at least equivalent, and often superior, results compared to conventional approaches (Boylan *et al*., 2018; Schulz *et al*., 2007). Complementing these findings, Yang et al. (2017) observed that although overall clinical outcomes and implant survival rates were comparable, robotic TKA significantly reduced postoperative alignment deviations (Yang *et al*., 2017). Overall, these findings suggest that robotic-assisted arthroplasty helps surgeons perform procedures with greater precision and may lead to better long-term radiographic results, especially in high-volume centers where the technology can be used efficiently.

This bibliometric analysis is the first to explore patient outcomes and satisfaction in robotic-assisted hip and knee joint replacement surgery. This study aims to identify the trends and research hotspots using the Scopus database. According to the curve of annual scientific production (Figure 2), research in this field has steadily increased since 2007, with a significant shift towards patient-centered outcomes since 2014. The focus has shifted toward improving clinical outcomes, with patient satisfaction emerging as a critical factor in evaluating the effectiveness of these interventions. This shift coincides with an increase in the number of robotic-assisted hip and knee arthroplasty surgeries (Matharu *et al*., 2022; Bagaria *et al*., 2020; Emara *et al*., 2021). The increase in patient-centered research on robotic arthroplasty indicates a significant shift towards prioritizing patient feedback in measuring the success of hip and knee arthroplasty surgery.

Research on robotic-assisted joint replacement surgery is led by the United States, the United Kingdom, and China, due to their advanced medical infrastructure and funding (Li *et al*., 2021). France stands out for its high level of international collaboration. Many Asian countries, including Turkey, India, and Malaysia, focus on single-country research, while Indonesia has no recorded publications in robotic-assisted joint replacement surgery, highlighting a gap in regional contributions. To advance research, these regions need to collaborate more with global institutions. Strengthening international partnerships, especially for smaller contributors like Belgium and the UAE, will bridge knowledge gaps, accelerate innovation, and make advanced research more accessible worldwide (Figure 5).

The influence of these leading countries is strengthened by top researchers and institutions shaping the field. Researchers like Fares S. Haddad and Babar Kayani, both from University College Hospital, along with Michael A. Mont, have made significant contributions to improving surgical techniques and patient outcomes. Their work is shared through respected institutions such as University College Hospital, the Cleveland Clinic, and the University of Warwick, and published in high-impact journals like The Journal of Arthroplasty and Knee Surgery, Sports Traumatology, and Arthroscopy (Figures 3 and 4). Highly cited studies, as shown in Table 1, highlight the evolution of robotic-assisted hip and knee arthroplasty from early exploration to advanced precision and patient-centered outcomes. Jacofsky et al (2016), the most cited study with 321 citations, offers a comprehensive review that has shaped the development of robotic-

assisted arthroplasty (Jacofsky & Allen, 2016). Kayani et al (2018) highlight the benefits of robotic-assisted knee arthroplasty, particularly in enhancing surgical precision and speeding up recovery (Kayani *et al*., 2018). Schulz et al (2007) provided early insights into robotic technology in hip arthroplasty, laying the groundwork for future advancements in the field (Schulz *et al*., 2007). These studies underscore the field's evolution and highlight the importance of academic collaboration in driving innovation.

Implications for Future Research Directions

Research on robotic-assisted hip and knee arthroplasty is increasingly shifting toward patient-centered outcomes, including satisfaction, rehabilitation progress, and overall quality of life (Andriollo *et al*., 2025; Reddy *et al*., 2023). While earlier studies focused primarily on surgical precision and implant alignment, recent trends emphasize patient-reported outcomes as essential measures of clinical success (Pantaleon, 2019). Commonly appearing keywords such as “patient-reported outcome,” “clinical outcome,” and “postoperative complications” reflect this shift. However, important areas including surgical revision, length of hospital stay, and long-term functional outcomes remain insufficiently studied. To advance the field, future research should prioritize these underexplored themes and expand contributions from developing regions, particularly ASEAN countries, where evidence on patient-reported outcomes in robotic-assisted arthroplasty is still limited.

Implications for Clinical Practice

The application of robotic technology into joint replacement surgery presents significant opportunities to enhance surgical accuracy, reduce complications, and improve patient satisfaction (Zhang *et al*., 2022; Bullock et al., 2022). To keep pace with advancements in robotic-assisted surgery, orthopedic surgeons must invest in specialized training to refine their techniques while also exploring ways to enhance accessibility and broaden the adoption of this technology across diverse healthcare settings. (Reddy *et al*., 2023; Walgrave & Oussedik, 2022). As robotic systems continue to evolve, healthcare institutions must evaluate their cost-benefit implications and develop strategies to make these technologies more accessible while maintaining high standards of patient care (Rajan *et al*., 2022; Maldonado *et al*., 2021; Zhang *et al*., 2023). Ultimately, the successful integration of robotic technology depends on a collaborative effort between surgeons, institutions, and policymakers to ensure its safe, effective, and equitable implementation for the benefit of all patients (Ferrarese *et al*., 2016; Pai *et al*., 2023).

LIMITATIONS

This study has several limitations. First, the analysis relied exclusively on the Scopus database, which may have excluded relevant publications indexed elsewhere and introduced selection bias. Variations in terminology may also have led to missed studies despite a comprehensive search strategy. Because bibliometric methods depend heavily on citation counts and publication metrics, influential studies may reflect popularity or novelty rather than methodological rigor, raising the possibility of citation bias. In addition, while VOSviewer and bibliometrix provide powerful visualization tools, the interpretation of clusters and thematic patterns remains partly subjective. This study examined research trends but did not assess the methodological quality or clinical validity of individual studies. Future research should integrate multiple databases, conduct deeper qualitative assessments of key publications, and evaluate how research trends ultimately relate to patient outcomes.

CONCLUSION

This bibliometric analysis demonstrates a substantial rise in research on robotic-assisted hip and knee arthroplasty since 2014, reflecting a growing shift toward patient-centered outcomes and satisfaction. The field is driven predominantly by contributions from developed countries, particularly the United States, the United Kingdom, and China, while involvement from developing regions remains limited. Influential

authors, leading institutions, and major journals were identified, along with key thematic areas such as robotic-assisted joint arthroplasty, postoperative recovery, and patient-reported outcomes.

From a clinical perspective, these findings underscore the importance of incorporating patient-reported outcomes into the evaluation of robotic-assisted procedures to better understand their real-world value. Continued research is needed to clarify long-term functional outcomes, revision rates, and cost-effectiveness—areas that remain inconsistently reported in the current literature. Finally, strengthening international collaboration and increasing research participation from developing countries, especially ASEAN nations, are essential to addressing existing disparities and advancing equitable, patient-centered innovations in robotic-assisted hip and knee arthroplasty.

ACKNOWLEDGEMENT

The authors acknowledge Muhana Fawwazy Ilyas, MD. for his invaluable teaching and guidance regarding bibliometric analysis procedures during the development of this project.

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