Observational Study

Medicine

OPEN

Mapping knowledge landscapes and emerging trends of robotic-assisted knee arthroplasty

A bibliometric analysis

Dongping Wan, MM[a,b], Rui Wang, MM[b], Jie Wei, MM[c], Qiang Zan, MM[a], Lei Shang, MD[d], Jianbing Ma, MD[a], Shuxin Yao, MM[a], Chao Xu, MD[a,*]

Abstract

The robotic-assisted knee arthroplasty has gained increasing attention in the research field. To date, no comprehensive bibliometric analysis has been carried out on this topic. The present study aimed to introduce the research status and hotspots and explore the field of robotic-assisted knee arthroplasty from a bibliometric perspective. The Web of Science Core Collection database was utilized to retrieve articles and reviews on robotic-assisted knee arthroplasty published between 1993 and 2023. CiteSpace, VOSviewer, Scimago Graphica, Pajek, and a bibliometric online analysis platform (http://bibliometric.com/) were employed to analyze the regions, institutions, journals, authors, and keywords, aiming to predict the latest trends in research related to robotic-assisted knee arthroplasty. This study encompasses 697 records. The annual publication count pertaining to robotic-assisted knee arthroplasty demonstrates consistent growth. The United States leads with the highest number of studies (298), trailed by the United Kingdom (110) and France (49). The Hospital for Special Surgery emerges as the most prolific institution, while Professor Mont, Michael A holds significant author influence. The Journal of Arthroplasty reigns supreme in this field, boasting the highest publication and citation figures. Funding sources predominantly include Stryker (34), Smith Nephew (19), and the National Natural Science Foundation of China (17). Noteworthy research themes within robotic-assisted knee arthroplasty encompass patient satisfaction, kinematic alignment, and clinical benefits. The landscape of robotic-assisted knee arthroplasty research is thriving. Anticipated trajectories of research will be geared toward refining the precision of robotic technology and enhancing clinical outcomes within the realm of robotic-assisted knee arthroplasty.

Abbreviations: AC = average citations, HI = Hirsch index, TC = total number of citations, TKA = total knee arthroplasty, UKA = unicompartmental knee arthroplasty, WoSCC = web of science core collection.

Keywords: bibliometric, CiteSpace, knee arthroplasty, robotic-assisted, VOSviewer

1. Introduction

Knee osteoarthritis is a degenerative joint disease that results in disability, characterized by pain, stiffness, and limited function of the knee joint.[1] The global prevalence of knee osteoarthritis has been steadily increasing, experiencing a rise of 122.42% from 163.91 million cases in 1990 to 364.58 million cases in 2019.[2–4] This escalation can be attributed to factors such as population growth, aging demographics, and the obesity epidemic.[5]

While knee arthroplasty is considered an effective intervention for osteoarthritis, alleviating pain and improving knee joint function,[6] there has been a significant surge in knee arthroplasty surgeries globally due to the growing similarity in population structures. Countries like the United States, South Korea, Italy, and others have projected a minimum 40% increase in knee arthroplasty surgeries by 2050, presenting a considerable public health challenge.[7–10] However, despite the efficacy of knee arthroplasty, a notable proportion of patients (10%–20%) express dissatisfaction with the procedure.[11,12] Contributing

DPW, RW, and JW contributed equally to this work.

This work was supported by Key R & D Program of Shaanxi Province (Grant no. 2023-YBSF-464); General Research Plan of Xi'an Health Commission (2023yb30); the National Natural Science Foundation of China (Grant no. 82173627). The funding body played no direct role in the design of the study and collection, analysis, and interpretation of data and in writing the manuscript.

The authors have no funding and conflicts of interest to disclose.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Supplemental Digital Content is available for this article.

[a] Department of Knee Joint Surgery, Honghui Hospital, Xi'an Jiaotong University, Xi'an, Shaanxi Province, China, [b] The First Clinical Medical College, Shaanxi University of Chinese Medicine, Xi'an, Shaanxi Province, China, [c] State Key Laboratory of Cancer Biology, Department of Pathology, The First Affiliated Hospital of Air Force Military Medical University, Xi'an, Shaanxi Province, China, [d] Department of Health Statistics, Faculty of Preventive Medicine, the Air Force Military Medical University, Xi'an, Shaanxi Province, China.

**Correspondence: Chao Xu, Department of Knee Joint Surgery, Honghui Hospital, Xi'an Jiaotong University, No. 555 E. Youyi Rd, Beilin district, Xi'an, Shaanxi, 710000, China (e-mail: 383697196@qq.com).*

How to cite this article: Wan D, Wang R, Wei J, Zan Q, Shang L, Ma J, Yao S, Xu C. Mapping knowledge landscapes and emerging trends of robotic-assisted knee arthroplasty: A bibliometric analysis. Medicine 2023;102:38(e35076).

Received: 10 July 2023 / Received in final form: 11 August 2023 / Accepted: 14 August 2023

http://dx.doi.org/10.1097/MD.0000000000035076

factors include sociodemographic characteristics, patient expectations, and errors related to surgical technique.[13–17] In the case of manual total knee arthroplasty (TKA), adjustments and balance heavily rely on the physician tactile perception, with procedural precision and soft tissue tension adjustment stemming from surgical technique and experience.[18] Surgical errors, encompassing inadequate calibration and positioning, can adversely impact prosthesis survival rates.[17,19,20]

Since the introduction of the first surgical robotic system in 1985, robotic technology has found wide-ranging adoption in the medical sphere.[21] Within the realm of orthopedics, robotic-assisted total knee arthroplasty has emerged as a notable advancement. Robotic-assisted total knee arthroplasty employs preoperative imaging, such as plain radiographs or computed tomography scans, to construct a 3-dimensional virtual knee model for planning and surgical guidance.[22] This technology offers potential advantages in terms of precision, postoperative comfort, reproducibility, and improved clinical outcomes by minimizing outliers.[22,23] Nevertheless, this approach is not devoid of complications, including pinhole fractures, infections related to needles, iatrogenic injuries to soft tissue and bone, as well as excessive blood loss.[24] Additionally, it entails certain complications, such as pinhole fractures, infections, injuries to soft tissue and bone, excessive blood loss, added costs, and prolonged operation times.[24,25]

Bibliometrics, a systematic method of literature review that employs mathematical and statistical analysis, has gained prominence in scrutinizing research trends and advancements across various medical domains.[26–28] It furnishes a quantitative and qualitative evaluation of progress and forefront trends within a particular research sphere, allowing for graphical visualization and comparisons between countries, institutions, journals, and authors.[29] As such, it has found wide application in fields such as cancer, cardiology, orthopedics, cerebrovascular disease, and other medical domains.[29–33] However, to date, no studies have tackled the bibliometric analysis of robotic-assisted knee arthroplasty. Therefore, the objective of this study is to execute a comprehensive bibliometric analysis of articles within the web of science core collection (WOSCC) database pertaining to robotic-assisted knee arthroplasty. The intention of this analysis is to unveil the developmental trajectory, pinpoint research focal points, and spotlight cutting-edge trends in this domain. Ultimately, the insights garnered from this study will offer valuable guidance to clinicians and researchers engaged in the realm of robotic-assisted knee arthroplasty, fostering further advancements and enhancements in clinical practice.

2. Methods

2.1. Data source and search strategy

The literature pertaining to robotic-assisted knee arthroplasty was sourced from the WOSCC database. The search strategy was formulated as follows: TI = (robot* OR robotic OR robotic assisted OR robotic-assisted OR robot-assisted) AND TI = (knee) NEAR/1 (arthroplasty* OR replacement*). The search spanned from January 1, 1993 to March 6, 2023. The type of literature was limited to articles and reviews, and the language was restricted to English (Supplementary table, http://links.lww.com/MD/J812). The retrieval process was concluded by March 6, 2023 to ensure consistency and mitigate the impact of database updates.

A total of 806 publications were initially identified, out of which 109 irrelevant records were excluded. This left a final dataset of 697 valid publications, which were subjected to subsequent analysis (Fig. 1). The data extracted encompassed details such as authorship, title, publication, citation frequency, geographical origin, affiliations, journal source, highly cited articles, references, and keywords. Journal information encompassed impact factors and quartile categorizations (Q1, Q2, Q3, and Q4) as per the 2021 Journal Citation Report. The assessment of the Hirsch index (HI) was performed using the WOS methodology.

2.2. Data analysis

Visualization software, including VOSviewer (Section 1.6.18, Leiden University, Leiden, the Netherlands), CiteSpace (Section 6.1.R2, Drexel University, Philadelphia), Pajek (5.16), and Scimago Graphica were employed in this study. Scimago Graphica was used to map the global distribution of national publications. The online literature metrological analysis platform (https://bibliometric.com) was employed to visually represent the collaborative network among countries. VOSviewer facilitated the visualization of co-authorship analysis for both organizations and authors. Additionally, VOSviewer and Pajek were employed to depict co-occurrence patterns among keywords. Parameter settings for VOSviewer were configured as follows: the minimum publication count for institutions was set at ≥6, for countries it was set at ≥5, for authors it was set at ≥5, and for keywords, a minimum frequency of occurrence of ≥5 was applied. For cited references, the minimum citation count was set to ≥25. Subsequently, CiteSpace was employed for reference co-citation analysis and keyword burst detection. Parameters were set as follows: the time frame spanned from 1993 to 2023, each temporal slice represented a single year, the scale factor was established as k = 10, and the selection criterion was defined as Top N = 50. Cluster labels were generated using the log-likelihood ratio method. Subsequent parameter adjustments adhered to the original software presets. For statistical analysis, IBM SPSS 26.0 was utilized, while Microsoft Excel 2019 served for data organization. The statistical plots were generated using OriginPro 9.1.

2.3. Ethical considerations

As there were no human participants or animal subjects involved in this study, ethical approval was unnecessary.

3. Results

3.1. Trends in publications and citations

A total of 697 publications were meticulously incorporated into the analysis, consisting of 596 (85.5%) articles and 101 (14.5%) reviews. The entire corpus of publications was composed exclusively in the English language. The detailed distribution of annual publications on robotic-assisted knee arthroplasty is shown in Figure 2A. It becomes evident from our observations that the annual count of publications and corresponding citations concerning robotic-assisted knee arthroplasty is progressively escalating. Remarkably, the volume of publications has exhibited a substantial rise, surging from a mere 1 (0.002%) in 1993 to a notable 169 (24.2%) by the year 2022. The cumulative total number of citations (TC) spanning the entirety of the publications tallied at 10,862. The average number of citations per publication (AC) was computed to be 15.58, and the HI reached a value of 51. Collectively, these results suggested that studies related to robotic-assisted knee arthroplasty are attracting significant attention and have reached a stage of rapid development.

3.2. Analysis of countries

A total of 41 countries have contributed to the literature in this field. The majority of publications were from North America, Europe, and East Asia, as evidenced by the global distribution of contributions on the countries world map (Fig. 2B). Specifically, Table 1 shows that the United States has published led with the

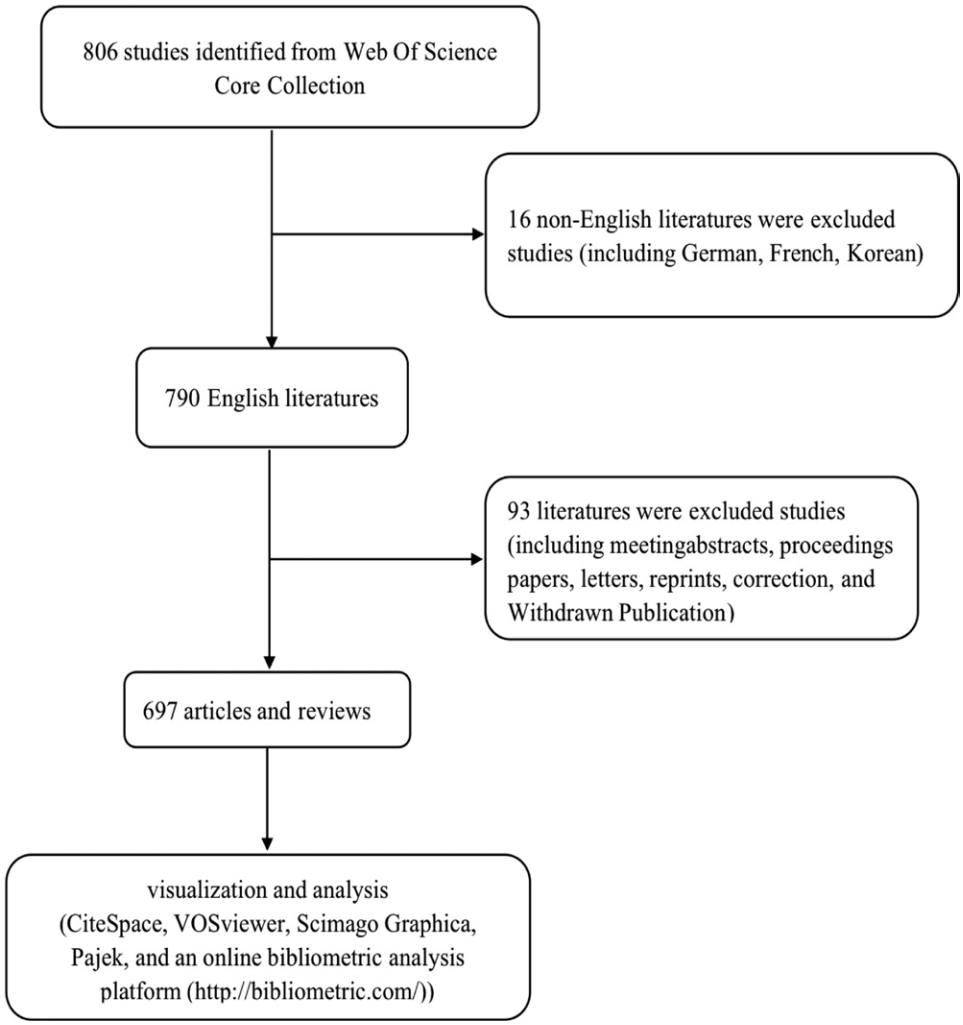

Figure 1. Flowchart of the screening process.

largest number of articles in this field, up to 298 publications, followed by UK (110 publications), France (49 publications), Australia (48 publications) and China (48 publications), while the total number of papers published by other countries is <150. Notably, the USA holds the top rank in both TC and HI, with the UK following suit. Concerning AC, South Korea claims the foremost position, trailed by the UK and the USA. As shown in Figure 2C, the United States has dominantly shaped the landscape of papers within this field since 2008. Figure 2D showcases international collaborations among distinct countries. The thickness of the lines between the 2 countries shows the strength of cooperation, which is closest between the United States and Germany, Britain and the United States, France and Australia, while the research of East Asian countries is independent, and the cooperation with other countries is less.

3.3. Analysis of institution

Regarding publication ranking, the top ten contributive institutions are listed in Figure 3A and Table 2. Among these, 5 institutions are situated within the USA, 3 within the UK, and 2 within France. Securing the foremost position is the Hospital for Special Surgery, boasting an impressive 40 publications. Following closely is the Cleveland Clinic Foundation, with a substantial 38 publications, while the University of London claims the third spot with 36 publications. Figure 3B shows the network of inter-agency cooperation, indicating that Cleveland Clinic Foundation has a strong cooperative relationship with Lenox Hill Hospital and Hospital for Special Surgery, and University College London Hospitals has a strong cooperative relationship with Prince Grace Hospital.

3.4. Analysis of authors and co-cited authors

The top ten authors have published 217 papers, accounting for 31.1% of all papers in the field. Mont, Michael Albert, from Sinai Hospital of Baltimore, have published the most studies, with 41 publications, followed by Batailler, Cécile with 24 publications, and Sodhi, Nipun, Pearle, Andrew D and Servien, Elvire ranked third (21 publications). In addition, Mont, Michael Albert was also the author with the highest TP, TC and, HI. Kayani, Babar was the author with the highest AC (Table 3). VOSviewer software was used to visualize the network between authors. A total of 78 authors who have published at least 5 studies have used VOSviewer for analysis (Fig. 3D). The 5 authors with the largest total link strength are Mont, Michael Albert (total link strength = 96 times), Batailler, Cécile (total link strength = 66 times), Lustig, Sébastien (total link strength = 66 times), Servien, Elvire (total link strength = 61 times), and Sodhi, Nipun (total link strength = 61 times). As illustrated in Table 4, Kayani, Babar (532 citations), Song, Eun Kyoo (250 citations), and Lonner, Jess H. (237 citations) are the top 3 co-cited authors. As shown in Figure 3D, authors from the same country collaborate

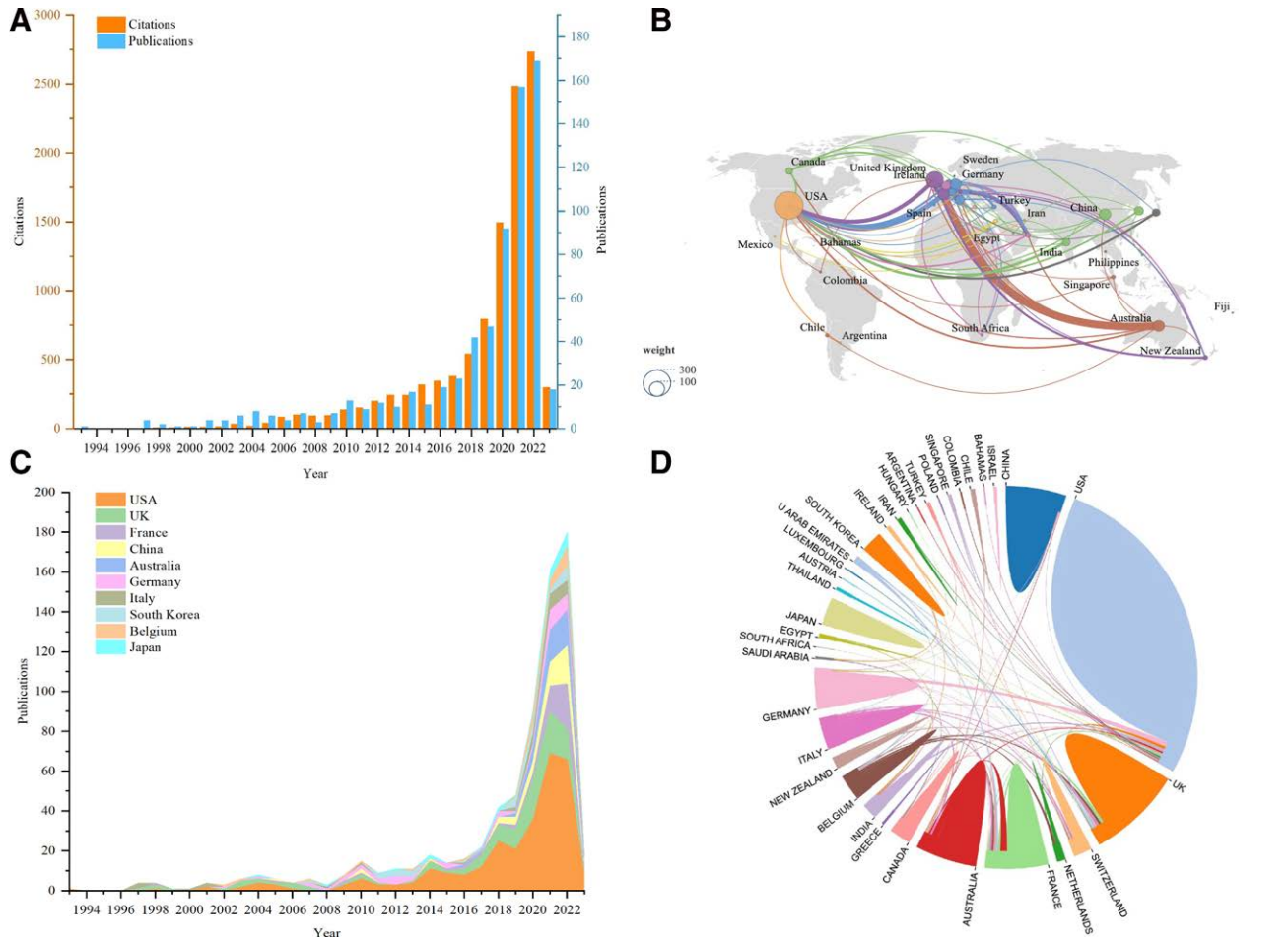

Figure 2. Visualization of citations, publications and country analysis. (A) Trends in annual citations and publications from 2011 to 2022. (B) World map of the number of publications from each country. (C) Trends in annual publication count in the top 10 prolific countries. (D) Network diagram of cooperation among countries.

Table 1

Top 10 countries with the most publications on robotic-assisted knee arthroplasty.

Rank	Country	TP	TC	AC	HI
1	USA	298	5163	17.33	40
2	UK	110	866	26.05	29
3	France	49	805	16.43	14
4	Australia	48	432	9	13
5	China	48	266	5.54	10
6	Germany	47	681	4.49	14
7	Italy	34	310	9.12	12
8	South Korea	30	837	27.9	13
9	Belgium	29	463	15.97	12
10	Japan	22	190	8.64	8

AC = average citations, HI = Hirsch index, TC = total number of citations, TP = total number of publications.

frequently. However, the links between authors from different countries are still insufficient.

3.5. Analysis of journals, co-cited journals and grants

The top ten journals have a total of 352 (50.5%) articles. As shown in Table 5, the output of the Journal of Arthroplasty (71, 10.2%) is the highest, followed by the Journal of Knee Surgery (56, 8.0%) and Knee Surgery Sports Traumatology Arthrocopy (55, 7.9%). Half of the top ten academic journals belong to Q1 and Q2. Bone & Joint Journal has the highest impact factors value, followed by Knee Surgery Sports Traumatology Arthroscopy and Journal of Arthroplasty. As shown in Table 6, regarding co-cited journals, the top 3 positions are occupied by Journal of Arthroplasty (3750 citations), Clinical Orthopaedics and Related Research (2528 citations), and Knee Surgery, Sports Traumatology, Arthroscopy (1750 citations). Regarding grants, Stryker grants the most terms (34 publications), followed by Smith Nephew (19) and National Natural Science Foundation of China (17 publications), while other grants are <15, as shown in Table 7.

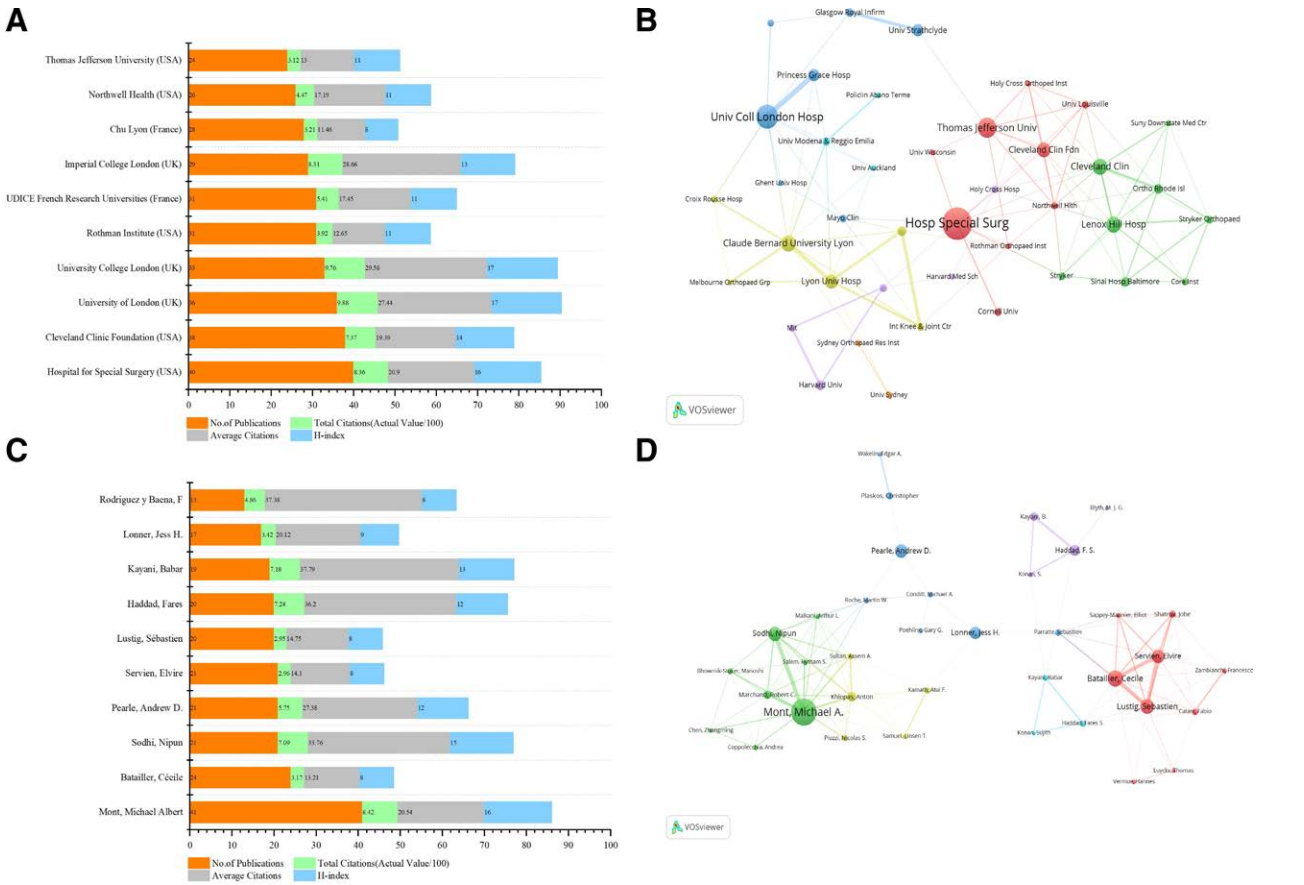

Figure 3. Visualization of institution and authors analysis. (A) The top 10 prolific institutions. (B) Cooperation network among institutions. (C) The top 10 prolific authors. (D) Visualization diagram of co-authorship analysis for authors.

Table 2

Top 10 institutions with the most publications on robotic-assisted knee arthroplasty.

Rank	Institution	TP	TC	AC	HI
1	Hospital for Special Surgery (USA)	40	836	20.9	16
2	Cleveland Clinic Foundation (USA)	38	737	19.39	14
3	University of London (UK)	36	988	27.44	17
4	University College London (UK)	33	976	29.58	17
5	Rothman Institute (USA)	31	392	12.65	11
6	UDICE French Research Universities (France)	31	541	17.45	11
7	Imperial College London (UK)	29	831	28.66	13
8	Chu Lyon (France)	28	321	11.46	8
9	Northwell Health (USA)	26	447	17.19	11
10	Thomas Jefferson University (USA)	24	312	13	11

AC = average citations, HI = Hirsch index, TC = total number of citations, TP = total number of publications.

3.6. Analysis of highly cited literature

Cited and co-cited references were visualized by VOSviewer (Fig. 4A and B). A total of 129 articles in this field have been cited ≥25 times. Table 8 lists the 10 articles with the highest number of references. "Hands-on robotic unicompartmental knee replacement-A prospective, randomized controlled study of the Acrobot system" was cited by 214 articles, followed by "Robotics in Arthroplasty: A Comprehensive Review" which was cited by 172 articles. The third highest number of citations is "Robotic-assisted TKA Reduces Postoperative Alignment Outliers and Improves Gap Balance Compared to Conventional TKA" with 172 citations. In addition, we used the citation burst value to reflect the references of interest to researchers in specific fields in a certain period.[34] In the current study, the top 25 references with the strongest citation bursts were identified by CiteSpace and presented in Figure 4C. The article titled "Improved Accuracy of Component Positioning with Robotic-Assisted Unicompartmental Knee Arthroplasty: Data from a Prospective, Randomized Controlled Study" published in 2016, ranked first (strength = 15.32).

3.7. Overview of research hotspots and frontiers

The co-cited references were analyzed by VOSviewer (Fig. 4B) to show the most influential documents. The references in

Table 3

The top 10 authors with the most publications on robotic-assisted knee arthroplasty.

Rank	Authors	TP	TC	AC	HI
1	Mont, Michael Albert	41	842	20.54	16
2	Batailler, Cécile	24	317	13.21	8
3	Sodhi, Nipun	21	709	33.76	15
4	Pearle, Andrew D.	21	575	27.38	12
5	Servien, Elvire	21	296	14.1	8
6	Lustig, Sébastien	20	295	14.75	8
7	Haddad, Fares	20	724	36.2	12
8	Kayani, Babar	19	718	37.79	13
9	Lonner, Jess H.	17	342	20.12	9
10	Rodriguez y Baena, F	13	486	37.38	8

AC = average citations, HI = Hirsch index, TC = total number of citations, TP = total number of publications.

Table 4

The top 10 co-citation of authors on robotic-assisted knee arthroplasty.

Rank	Author	Co-citations
1	Kayani, Babar	532
2	Song, Eun Kyoo	250
3	Lonner, Jess H.	237
4	Marchand, Robert C.	212
5	Liow, Ming Han Lincoln	207
6	Bellemans, Johan	148
7	Pearle, Andrew D.	124
8	Batailler, Cécile	124
9	Cobb, Justin	123
10	Parratte, sebastien	120

Table 5

The top 10 productive journals on robotic-assisted knee arthroplasty.

Rank	Journal	TP	TC	AC	HI	IF	JQ
1	Journal of Arthroplasty	71	1931	27.2	25	4.435	Q1
2	Journal of Knee Surgery	56	851	15.2	17	2.501	Q3
3	Knee Surgery Sports Traumatology Arthroscopy	55	1098	19.96	19	4.114	Q1
4	Archives of Orthopaedic and Trauma Surgery	31	207	6.68	9	2.928	Q2
5	Bone & Joint Journal	28	737	26.32	15	5.385	Q1
6	International Journal of Medical Robotics and Computer Assisted Surgery	28	236	8.43	7	2.483	Q3
7	International Orthopaedics	28	217	7.75	7	3.479	Q2
8	Knee	27	658	24.37	13	2.423	Q3
9	Clinical orthopedics And Related Research	15	907	60.47	12	4.837	Q1
10	Journal of Orthopaedics	13	76	5.85	4	X	Q3

AC = average citations, HI = Hirsch index, JQ = JIF quartile, TC = total number of citations, TP = total number of publications.

Table 6

The top 10 co-citation of journals on robotic-assisted knee arthroplasty.

Rank	Journal	Co-citations
1	Journal of arthroplasty	3750
2	Clinical Orthopaedics and Related Research	2528
3	Knee Surgery Sports Traumatology Arthroscopy	1750
4	The Journal of Bone and Joint Surgery-American Volume	1586
5	Bone & Joint Journal	1020
6	The Journal of Bone and Joint Surgery-British Volume	986
7	knee	962
8	Journal of Knee Surgery	931
9	International orthopedics	414
10	Archives of Orthopaedic and Trauma Surgery	311

Table 7

Top 10 funds with the most publications on robotic-assisted knee arthroplasty.

Rank	Funds	TP	TC	AC	HI
1	Stryker	34	672	19.76	14
2	Smith Nephew	19	239	12.58	7
3	National Natural Science Foundation of China (NSFC)	17	138	8.12	6
4	National Institutes of Health (NIH-USA)	11	252	22.91	8
5	Zimmer	10	164	16.4	5
6	UK Research Innovation (UKRI)	9	158	17.56	6
7	United States Department of Health Human Services (HHS-USA)	9	241	26.78	7
8	Mako surgical Corp	8	535	66.88	8
9	National Key Research and Development Program of China	8	13	1.63	2
10	Engineering Physical Sciences Research Council (EPSRC-UK)	7	128	18.29	5

AC = average citations, HI = Hirsch index, TC = total number of citations, TP = total number of publications.

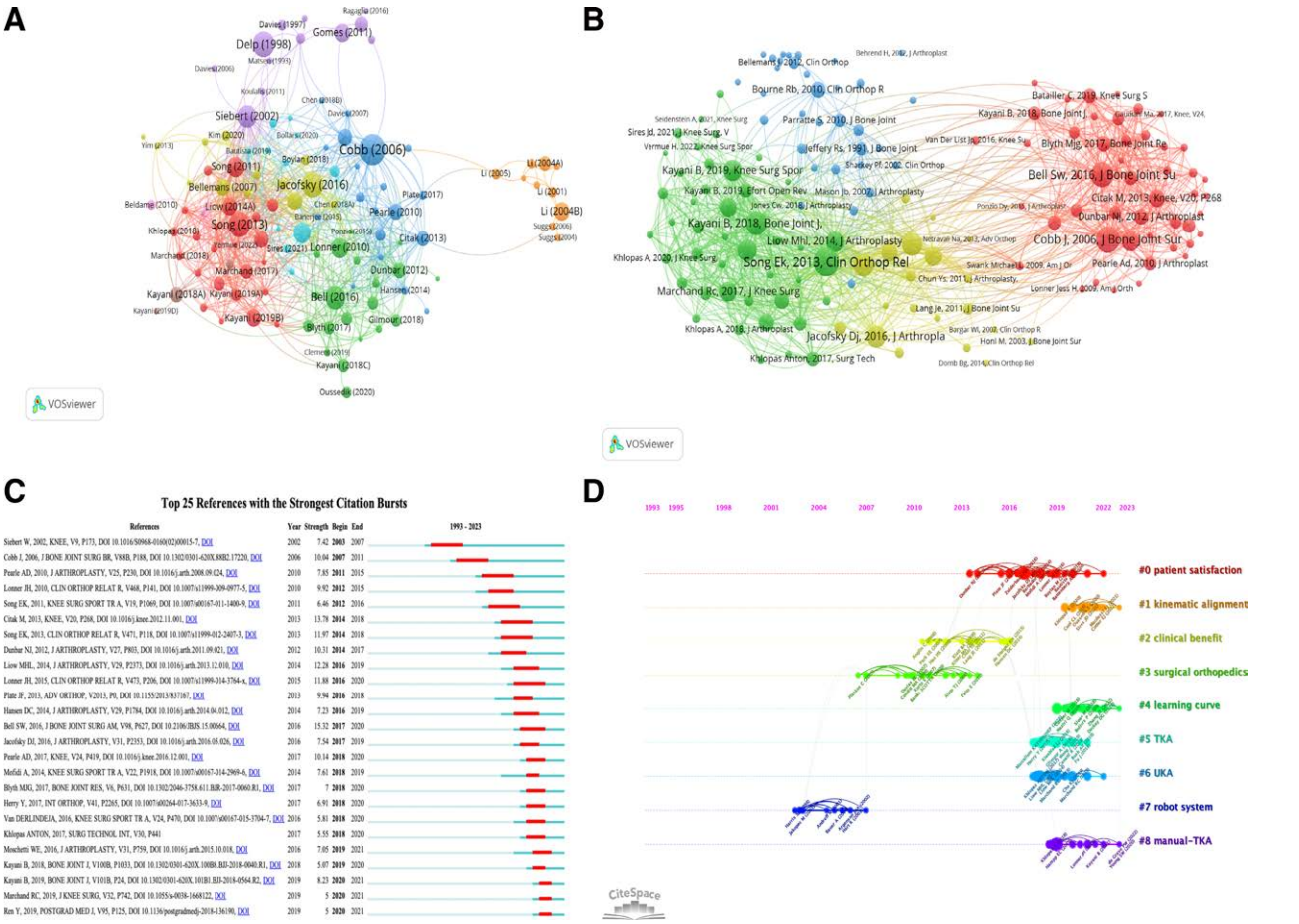

Figure 4. Visualization of reference analysis. (A) Network map of citation analysis of documents with more than 25 citations. (B) Network map of co-citation analysis of references. (C) The top 25 references with the strongest citation bursts. (D) The timeline graph of co-cited reference clusters.

the co-citation network were divided into 8 different groups according to cluster analysis, as shown in the timeline (Fig. 4D). References in the same group were arranged in the same timeline as the publication order. These clusters are marked by extracting terms from the titles of cited papers using the log-likelihood ratio algorithm.[35] As shown in Figure 4D, "patient satisfaction" is the largest cluster (# 0), followed by "kinematic alignment" (# 1) and "clinical benefit" (# 2). In addition, the evolution characteristics of each cluster can be seen in this timeline view. We observed that kinematic alignment (# 1) and learning curve (# 6) had been hot topics in recent years.

3.8. Analysis of keywords

Figure 5A shows the visualization of keywords that appear more than 5 times in the research on robotic-assisted knee arthroplasty. A total of 153 keywords were divided into 5 groups. The keywords of each group could be summarized as follows: # 1 total knee arthroplasty, # 2 accuracy, # 3 outcomes, # 4 and # 5 survival, # 6 and # 7 alignment. The top 25 keywords with the strongest citation burst are listed in Figure 5B, and the top 10 keywords with the strongest citation burst include computer-assisted surgery, orthopedic, prosthesis, implantation,

Table 8

Top 10 documents with the most citations in the field of robot associated with knee arthroplasty.

Rank	Article title	First author	Yr	Journal	TC	AC
1	Hands-on robotic unicompartmental knee replacement - A prospective, randomized controlled study of the Acrobot system	Cobb, J	2006	Journal Of Bone And Joint Surgery-British Volume	214	11.89
2	Robotics in Arthroplasty: A Comprehensive Review	Jacofsky, David J.	2016	Journal Of Arthroplasty	172	21.5
3	Robotic-assisted TKA Reduces Postoperative Alignment Outliers and Improves Gap Balance Compared to Conventional TKA	Song, Eun-Kyoo	2013	Clinical Orthopaedics And Related Research	172	15.64
4	Computer assisted knee replacement	Delp, SL	1998	Clinical Orthopaedics And Related Research	167	6.42
5	Improved Accuracy of Component Positioning with Robotic-Assisted Unicompartmental Knee Arthroplasty	Bell, Stuart W.	2016	Journal Of Bone And Joint Surgery-American Volume	154	19.25
6	Technique and first clinical results of robot-assisted total knee replacement	Siebert, W	2002	Knee	148	6.73
7	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 A PROSPECTIVE COHORT STUDY	Kayani, B.	2018	Bone & Joint Journal	134	22.33
8	Robotic Arm-assisted UKA Improves Tibial Component Alignment A Pilot Study	Lonner, Jess H.	2010	Clinical Orthopaedics And Related Research	128	9.14
9	Simultaneous bilateral total knee arthroplasty with robotic and conventional techniques: a prospective, randomized study	Song, Eun-Kyoo	2011	Knee Surgery Sports Traumatology Arthroscopy	127	9.77
10	Surgical robotics: Reviewing the past, analyzing the present, imagining the future	Gomes, Paula	2011	Robotics And Computer-Integrated Manufacturing	115	8.85

AC = average citations, TC = total number of citations, TKA = total knee arthroplasty, UKA = unicompartmental knee arthroplasty.

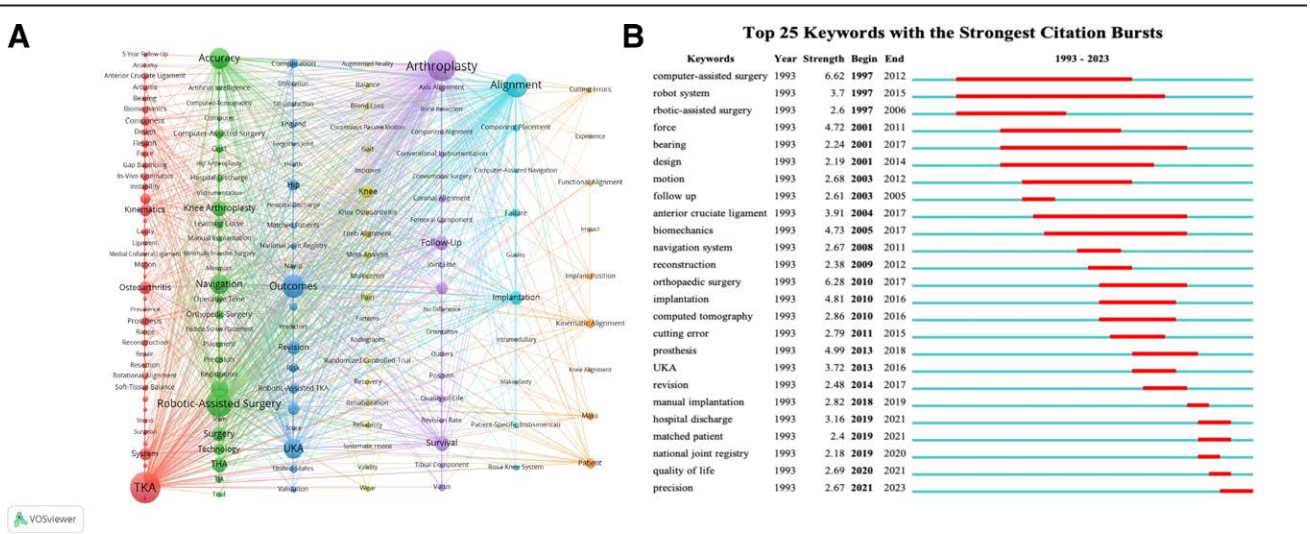

Figure 5. Visualization of keywords analysis. (A) The co-occurrence view of the keywords, in which each column represents a cluster of studies generated by VOSviewer. The size of the node is proportional to the number of keyword occurrences; the thickness of the line is proportional to the number of keyword co-occurrences. (B) The top 25 keywords with the strongest citation bursts.

biomechanics, force, anterior cruciate ligament, unicompartmental knee arthroplasty (UKA), robot system, hospital discharge. The keywords with the latest citation burst include quality of life and precision.

4. Discussion

4.1. General information

This study undertook a comprehensive bibliometric analysis of research in the realm of robotic-assisted knee arthroplasty, thus providing a platform for newcomers to grasp the developmental trajectory and prevailing trends within this field. Our findings reflect a noteworthy and consistent increase in both TP and TC pertaining to robotic-assisted knee arthroplasty over the last decade, underscoring significant advancements in technology, implant design, materials, and biomechanical principles.[36,37] This trend indicates that the field has sustained the attention of scholars, which may be attributed to the enhancement of prosthesis technical accuracy through robotic assistance, leading to optimal mechanical alignment. Notably, the precision achieved in robotic-assisted implant positioning surpasses that of manual arthroplasty. However, it crucial to acknowledge that clinical outcome scores might not fully capture this improvement.[38–40]

Therefore, the prime challenge for future robot research and development resides in enhancing post-surgical patient clinical outcomes.

Our study highlights the United States as the world leader in terms of TP, TC, and HI, solidifying its role as a prolific contributor and leader in research on robotic-assisted knee arthroplasty (Fig. 2B and Table 1). Remarkably, the UK takes the lead in AC, with South Korea and the United States trailing closely. This pattern mirrors the high level of research quality exhibited by these countries. It noteworthy that while China ranks fifth in TP, its performance in terms of TC and HI is less robust, and its AC is lower. This discrepancy could be attributed to the recent publication surge from China that may not have yet accumulated sufficient citations, or it could signify that the quality of research hasn't garnered the attention of peers.

In the context of scientific institutions, the top ten contributors are predominantly from Europe and the USA (Table 2). Of these, the top 2 are US-based, with the Hospital for Special Surgery notably achieving the highest TP and TC, solidifying its prominence in the domain of robotic-assisted knee arthroplasty research. However, the 3 UK institutions—University of London, University College London, and Imperial College London—demonstrate superior performance in terms of TC, AC, and HI. This observation suggests a notably high average level of research quality within this cluster. As evidenced in Figures 2B, D, and 3B, collaborative ties appear stronger between institutions in North America and Europe, whereas interactions between other institutions are comparatively weaker. Hence, we advocate for deeper and more comprehensive research collaborations spanning Asia, Europe, and North America.

Regarding authors, Michael Albert Mont (Sinai Hospital of Baltimore) emerges as a dominant figure (Table 3; Fig. 3C and D). His team has been at the forefront of comparative studies investigating the nuances between robot-assisted joint arthroplasty and manual joint arthroplasty. Their exploration spans aspects such as accuracy, clinical outcomes, learning curves, satisfaction, cost, soft tissue injuries, revision rates, and hospital stay duration. In a recent study, data clustering analysis on 853 TKA patients revealed enhanced WOMAC pain and function scores post-robot-assisted TKA, highlighting its correlation with improved physiological function and pain relief.[41] Moreover, collaboration analysis (Figs. 2D and 3D) suggests a scattered network of research relationships among authors across different countries, indicating limited academic interaction and exchange. Therefore, we encourage authors from diverse countries and institutions to intensify their collaboration efforts to collectively advance the study of robotic-assisted knee arthroplasty. Figures 3C and 4A point towards Mont, Michael Albert, Cobb, J, Song, Eun-Kyoo, and Jacofsky, David J as potentially the authors with the highest citation frequency, signifying international recognition and prominence in this sphere.

Highly cited literature serves as a reservoir of valuable and influential research, guiding researchers in shaping subsequent studies (Table 6; Fig. 4). For instance, the article "Hands-on robotic unicompartmental knee replacement: a prospective, randomized controlled study of the acrobot system" (2006) by Cobb, J et al stands as the most cited with 170 citations.[42] This study compared the acrobot system performance with conventional surgery for UKA, concluding that robotic-assisted UKA offers higher accuracy, albeit at a longer operative time, with fewer complications compared to conventional UKA. Notably, Jacofsky, David J et al's publication "Robotics in arthroplasty: a comprehensive review" follows closely in citation ranking,[43] encompassing a thorough assessment of various robot auxiliary systems in manual joint arthroplasty. These systems include robot arms based on active, semi-active, or passive control mechanisms, robot-guided cutting fixtures, and robot milling systems, with the semi-active system currently predominant. The advantages of robot-assisted joint arthroplasty in terms of improved placement accuracy, satisfaction, and reduced complications are acknowledged. However, the cost-effectiveness of these technologies necessitates further exploration. Equally significant, the study by Bell, Stuart W et al garners the highest citation burst value, indicative of widespread short-term citations.[44] The research demonstrates that robotic-assisted UKA leads to enhanced axial, coronal, and sagittal component positioning accuracy compared to conventional UKA. Furthermore, Citak, Mustafa et al's article ranks second in terms of citation burst value.[45] The study reveals the enhanced accuracy of UKA through a semi-active robotic system and dynamic bone tracking, outperforming manual techniques. The article by Song, Eun-Kyoo et al secures the third-highest citation burst value.[46] Following up patients who underwent robot-assisted TKA and conventional manual techniques for at least 41 months, the results underscore comparable postoperative outcomes between the 2 groups, with the robotic-assisted cohort displaying no mechanical axis outliers in contrast to the conventional group 24%. However, the robotic-assisted group did require an additional 25 minutes for the procedure. Collectively, these seminal works have significantly influenced the course of research in robotic-assisted knee arthroplasty.

Overall, this analysis furnishes a comprehensive understanding of the existing landscape, enabling researchers to make informed decisions and further advancements in the realm of robotic-assisted knee arthroplasty.

4.2. Research hotspots and emerging trends

The utilization of cluster analysis, along with the timeline perspective, facilitates the identification of prevalent research topics and unveils burgeoning areas of interest within this domain.[35] As depicted in Figure 4D, the co-cited references have been grouped into 8 clusters through the utilization of Citespace software, with 2 prominent ones being kinematic alignment (#1) and learning curve (#4), which have emerged as particularly noteworthy in recent years. Furthermore, the phenomenon of keyword bursts serves to identify terms that experience rapid escalation in popularity over a condensed timeframe, thereby capturing the focal points of research within specific periods.[47] As shown in Figure 5B, the hot keywords have notably converged on precision and quality of life concerns associated with robotic-assisted knee arthroplasty in recent times.

The quest for accuracy in robotic-assisted knee arthroplasty has perennially remained a focal point in this arena. Researchers have construed surgical accuracy as an objective benchmark to gauge the technology efficacy. Initially, the exploration of robot-assisted knee arthroplasty accuracy employed cadavers as research subject.[48–50] As robotic surgery progressed, an increasing number of studies have sought to discern whether robot-assisted knee arthroplasty offers enhanced implant positioning accuracy compared to conventional surgical methods. In a parallel vein, other investigations have demonstrated that robotic-assisted knee arthroplasty optimizes the technical precision of prostheses, culminating in impeccable mechanical alignment.[43,46,50]

While a consensus may be emerging regarding the current utility of robot-assisted knee arthroplasty in enhancing accuracy and component positioning, discord remains concerning the survival rates and patient-reported outcome measures post-knee arthroplasty. This discord has raised concerns about the routine application of robotic technology.[20,39,43,46,51–53] For instance, Maritan, Guido et al[54] exhibited excellent clinical outcomes and revision rates in both robotic arm-assisted and manual techniques for lateral UKA, with no discernible clinical disparities in medium- to long-term follow-up results. Considering the long-term horizon, as the robotics industry strives to attain heightened productivity, precision, and cost reduction,[43] the crux lies in achieving enhanced clinical outcomes while preserving

efficiency—a pivotal concern in the future trajectory of robotic-assisted knee arthroplasty.

5. Limitations

Firstly, due to the limitation of literature metrology software, the research data were collected only from the WOSCC database, which may cause publication bias. Secondly, this study did not carry out the periodical double-graph superposition analysis because cluster analysis and timeline reflected the evolution of research trends in this field. Finally, since new studies are updated daily, we may have ignored the influence of the newly published research.

6. Conclusion

Robotic-assisted knee arthroplasty research is flourishing. This study stands as the first comprehensive quantitative analysis of the convergence between robotics and knee arthroplasty. Our systematic overview of global publication trends equips scholars with insights into prominent authors, institutions, and influential journals in this field. The future research will continue to focus on refining robotic precision and enhancing clinical outcomes. By contributing to the advancement of knowledge in robotic-assisted knee arthroplasty, we hope to drive progress in this evolving arena.

Author contributions

Conceptualization: Qiang Zan, Chao Xu.
Data curation: Dongping Wan, Lei Shang, Shuxin Yao.
Formal analysis: Rui Wang, Qiang Zan.
Funding acquisition: Lei Shang, Chao Xu.
Investigation: Dongping Wan, Jianbing Ma.
Methodology: Dongping Wan, Rui Wang, Chao Xu.
Project administration: Qiang Zan, Lei Shang, Jianbing Ma.
Resources: Rui Wang, Lei Shang, Jianbing Ma.
Software: Dongping Wan.
Supervision: Rui Wang, Jie Wei, Lei Shang, Jianbing Ma, Shuxin Yao.
Validation: Jie Wei, Jianbing Ma, Chao Xu.
Visualization: Jie Wei.
Writing – original draft: Dongping Wan, Jie Wei.
Writing – review & editing: Qiang Zan, Shuxin Yao, Chao Xu.

References

[1] McAlindon TE, Bannuru RR, Sullivan MC, et al. OARSI guidelines for the non-surgical management of knee osteoarthritis. Osteoarthritis Cartilage. 2014;22:363–88.
[2] Felson DT, Lawrence RC, Dieppe PA, et al. Osteoarthritis: new insights. Part 1: the disease and its risk factors. Ann Intern Med. 2000;133:635–46.
[3] Prieto-Alhambra D, Judge A, Javaid MK, et al. Incidence and risk factors for clinically diagnosed knee, hip and hand osteoarthritis: influences of age, gender and osteoarthritis affecting other joints. Ann Rheum Dis. 2014;73:1659–64.
[4] Manninen P, Riihimäki H, Heliövaara M, et al. Overweight, gender and knee osteoarthritis. Int J Obes Relat Metab Disord. 1996;20:595–7.
[5] Long H, Liu Q, Yin H, et al. Prevalence trends of site-specific osteoarthritis from 1990 to 2019: findings from the global burden of disease study 2019. Arthr Rheumatol. 2022;74:1172–83.
[6] Carr AJ, Robertsson O, Graves S, et al. Knee replacement. Lancet. 2012;379:1331–40.
[7] Inacio MCS, Paxton EW, Graves SE, et al. Projected increase in total knee arthroplasty in the United States - an alternative projection model. Osteoarthritis Cartilage. 2017;25:1797–803.
[8] Klug A, Gramlich Y, Rudert M, et al. The projected volume of primary and revision total knee arthroplasty will place an immense burden on future heath care systems over the next 30 years. Knee Surg Sports Traumatol Arthrosc. 2021;29:3287–98.
[9] Kim TW, Kang SB, Chang CB, et al. Current trends and projected burden of primary and revision total knee arthroplasty in Korea between 2010 and 2030. J Arthroplast. 2021;36:93–101.
[10] Romanini E, Decarolis F, Luzi I, et al. Total knee arthroplasty in Italy: reflections from the last fifteen years and projections for the next thirty. Int Orthop. 2019;43:133–8.
[11] DeFrance MJ, Scuderi GR. Are 20% of patients actually dissatisfied following total knee arthroplasty? A systematic review of the literature. J Arthroplasty. 2023;38:594–9.
[12] Gunaratne R, Pratt DN, Banda J, et al. Patient dissatisfaction following total knee arthroplasty: a systematic review of the literature. J Arthroplast. 2017;32:3854–60.
[13] Ayers DC, Yousef M, Zheng H, et al. The prevalence and predictors of patient dissatisfaction 5-years following primary total knee arthroplasty. J Arthroplasty. 2022;37:S121–8.
[14] Hawker GA, Conner-Spady BL, Bohm E, et al. Patients' preoperative expectations of total knee arthroplasty and satisfaction with outcomes at one year: a prospective cohort study. Arthr Rheumatol. 2021;73:223–31.
[15] Rissolio L, Sabatini L, Risitano S, et al. Is it the surgeon, the patient, or the device? A comprehensive clinical and radiological evaluation of factors influencing patient satisfaction in 648 total knee arthroplasties. J Clin. 2021;10:2599.
[16] Nakano N, Shoman H, Olavarria F, et al. Why are patients dissatisfied following a total knee replacement? A systematic review. Int Orthop. 2020;44:1971–2007.
[17] Kim Y-H, Park J-W, Kim J-S, et al. The relationship between the survival of total knee arthroplasty and postoperative coronal, sagittal and rotational alignment of knee prosthesis. Int Orthop. 2014;38:379–85.
[18] Lee D-H, Park J-H, Song D-I, et al. Accuracy of soft tissue balancing in TKA: comparison between navigation-assisted gap balancing and conventional measured resection. Knee Surg Sports Traumatol Arthrosc. 2010;18:381–7.
[19] Tompkins GS, Sypher KS, Li H-F, et al. Robotic versus manual total knee arthroplasty in high volume surgeons: a comparison of cost and quality metrics. J Arthroplast. 2022;37:S782–9.
[20] Xu ZH, Li H, Liu ZY, et al. Robot-assisted surgery in total knee arthroplasty: trauma maker or trauma savior? A prospective, randomized cohort study. Burns Trauma. 2022;10:15.
[21] Kwoh YS, Hou J, Jonckheere EA, et al. A robot with improved absolute positioning accuracy for CT guided stereotactic brain surgery. IEEE Trans Biomed Eng. 1988;35:153–60.
[22] Siddiqi A, Mont MA, Krebs VE, et al. Not all robotic-assisted total knee arthroplasty are the same. J Am Acad Orthop Surg. 2021;29:45–59.
[23] Chen AF, Kazarian GS, Jessop GW, et al. Robotic technology in orthopaedic surgery. J Bone Joint Surg Am. 2018;100:1984–92.
[24] Nogalo C, Meena A, Abermann E, et al. Complications and downsides of the robotic total knee arthroplasty: a systematic review. Knee Surg Sports Traumatol Arthrosc. 2023;31:736–50.
[25] Meghpara MM, Goh GS, Magnuson JA, et al. The ability of robot-assisted total knee arthroplasty in matching the efficiency of its conventional counterpart at an orthopaedic specialty hospital. J Arthroplasty. 2023;38:72–77.e3.
[26] Ge Y, Chao T, Sun J, et al. Frontiers and hotspots evolution in psycho-cardiology: a bibliometric analysis from 2004 to 2022. Curr Probl Cardiol. 2022;47:101361.
[27] Wan Y, Shen J, Ouyang J, et al. Bibliometric and visual analysis of neutrophil extracellular traps from 2004 to 2022. Front Immunol. 2022;13:1025861.
[28] Mukherjee D, Lim WM, Kumar S, et al. Guidelines for advancing theory and practice through bibliometric research. J Bus Res. 2022;148:101–15.
[29] Meng T, Wang P, Ding J, et al. Global research trends on ventricular remodeling: a bibliometric analysis from 2012 to 2022. Curr Probl Cardiol. 2022;47:101332.
[30] Yang Z, Lin J, Li H, et al. Bibliometric and visualization analysis of macrophages associated with osteoarthritis from 1991 to 2021. Front Immunol. 2022;13:1013498.
[31] Mutebi M, Lewison G, Aggarwal A, et al. Cancer research across Africa: a comparative bibliometric analysis. BMJ Glob Health. 2022;7:e009849.
[32] Zhao Y, Zhu Q, Bi C, et al. Bibliometric analysis of tumor necrosis factor in post-stroke neuroinflammation from 2003 to 2021. Front Immunol. 2022;13:1040686.
[33] Kokol P, Blazun Vosner H, Zavrsnik J. Application of bibliometrics in medicine: a historical bibliometrics analysis. Health Inf Libraries J. 2021;38:125–38.

[34] Wu F, Gao J, Kang J, et al. Knowledge mapping of exosomes in autoimmune diseases: a bibliometric analysis (2002-2021). Front Immunol. 2022;13:939433.
[35] Wen P, Liu R, Wang J, et al. Bibliometric insights from publications on subchondral bone research in osteoarthritis. Front Physiol. 2022;13:1095868.
[36] Karthik K, Legate-Stone TC, Dasgupta P, et al. Robotic surgery in trauma and orthopaedics A Systematic review. Bone Joint J. 2015;97B:292–99.
[37] Jung M, Morel P, Buehler L, et al. Robotic general surgery: current practice, evidence, and perspective. Langenbecks Arch Surg. 2015;400:283–92.
[38] Kim R, Wakelin EA, Plaskos C, et al. Variation in knee balance as a function of hip-knee-ankle angle and joint line obliquity in robotic assisted total knee arthroplasty. Int Orthop. 2023;47:479–84.
[39] Ren Y, Cao S, Wu J, et al. Efficacy and reliability of active robotic-assisted total knee arthroplasty compared with conventional total knee arthroplasty: a systematic review and meta-analysis. Postgrad Med J. 2019;95:125–33.
[40] Kim YH, Yoon SH, Park JW. Does Robotic-assisted TKA result in better outcome scores or long-term survivorship than conventional TKA? A randomized, controlled trial. Clin Orthop Relat Res. 2020;478:266–75.
[41] Hampp E, Shi S, Scholl L, et al. The association of patient and procedural factors on improved outcomes: a cluster analysis on 853 total knee arthroplasty patients. J Knee Surg. 2022.
[42] Cobb J, Henckel J, Gomes P, et al. Hands-on robotic unicompartmental knee replacement: a prospective, randomised controlled study of the acrobot system. J Bone Joint Surg Br. 2006;88:188–97.
[43] Jacofsky DJ, Allen M. Robotics in arthroplasty: a comprehensive review. J Arthroplast. 2016;31:2353–63.
[44] Bell SW, Anthony I, Jones B, et al. Improved accuracy of component positioning with robotic-assisted unicompartmental knee arthroplasty: data from a prospective, randomized controlled study. J Bone Joint Surg Am. 2016;98:627–35.
[45] Citak M, Suero EM, Citak M, et al. Unicompartmental knee arthroplasty: is robotic technology more accurate than conventional technique? Knee. 2013;20:268–71.
[46] Song E-K, Seon J-K, Yim J-H, et al. Robotic-assisted TKA reduces postoperative alignment outliers and improves gap balance compared to conventional TKA. Clin Orthop Relat Res. 2013;471:118–26.
[47] Kleinberg J. Bursty and hierarchical structure in streams. Proceedings of the eighth ACM SIGKDD international conference on Knowledge discovery and data mining; 2002:91–101.
[48] Moon Y-W, Ha C-W, Do K-H, et al. Comparison of robot-assisted and conventional total knee arthroplasty: a controlled cadaver study using multiparameter quantitative three-dimensional CT assessment of alignment. Comput Aided Surg. 2012;17:86–95.
[49] Kim S-M, Park Y-S, Ha C-W, et al. Robot-assisted implantation improves the precision of component position in minimally invasive TKA. Orthopedics. 2012;35:e1334–9.
[50] Bell SW, Anthony I, Jones B, et al. Improved accuracy of component positioning with robotic-assisted unicompartmental knee arthroplasty. J Bone Joint Surg Am Vol. 2016;98:627–35.
[51] Keeney JA. Innovations in total knee arthroplasty: improved technical precision, but unclear clinical benefits. Orthopedics. 2016;39:217–20.
[52] Arshi A, Sekimura T, Kelley BV, et al. Navigated and robot-assisted technology in total knee arthroplasty: do outcome differences achieve minimal clinically important difference? J Arthroplast. 2022;37:1562–9.
[53] Luyckx T, Monk AP, Müller JH, et al. What are the perceived benefits and barriers to the use of robot-assisted total knee arthroplasty? A survey of members of the European Knee Society. Int Orthop. 2023;47:405–12.
[54] Maritan G, Franceschi G, Nardacchione R, et al. Similar survivorship at the 5-year follow-up comparing robotic-assisted and conventional lateral unicompartmental knee arthroplasty. Knee Surg Sports Traumatol Arthrosc. 2023;31:1063–71.