**Artificial
Intelligence Surgery**

Original Article

Toward precision and efficiency: a bibliometric study on robotic-assisted unicompartmental knee arthroplasty research and development

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Abstract

Aim: With the increasing prevalence of knee diseases affecting human health and quality of life, it is essential to explore more advanced surgical assistive technologies to improve the precision, safety, and success rate of unilateral knee replacement surgery. This study aims to conduct a comprehensive bibliometric analysis of robotic-assisted unicompartmental knee arthroplasty (r-UKA) to understand its current status, trends, and future directions.

Methods: Retrieve articles about r-UKA in the Web of Science Core Collection (WOSCC) database. Data from 128 selected articles, including author information, publication details, citations, and evidence level, were analyzed.

Statistical analyses and data visualizations explored publication and citation trends, research interests, core author groups, and cooperative networks.

Results: Interest in r-UKA research has grown, particularly after 2013, which is evident from increased publications and citations. The United States is the largest contributor, followed by the United Kingdom, both of which have prominent medical research institutions and universities actively involved in r-UKA research. Frequent keywords such as "alignment", "accuracy", "revision", and "survivorship" highlight the focus on surgical precision, implant longevity, and patient outcomes.

Conclusion: Robotic-assisted unicompartmental knee arthroplasty has gained significant attention, promising improved surgical precision and patient outcomes. Collaboration between researchers and medical institutions globally has driven progress in this field. However, long-term outcomes and clinical efficacy compared to traditional techniques require further investigation. As robotic technology evolves, its application in knee replacement surgery holds potential for better therapeutic effects and advancements toward more accurate, safe, and efficient procedures, benefiting patients and advancing unicompartmental knee arthroplasty (UKA).

Keywords: Bibliometric analysis, knee, robot-assisted, robotic technology, unicompartmental knee arthroplasty

INTRODUCTION

Unicompartmental knee osteoarthritis, of which anteromedial osteoarthritis is a notable subtype, constitutes a prevalent categorization within the broader spectrum of knee osteoarthritis. Historically, it has been predominantly treated through the surgical intervention of total knee arthroplasty[1-3]. Recently, UKA has emerged as an increasingly significant alternative[4-7]. Performed millions of times annually across the globe, UKA offers advantages such as greater preservation of native tissue, reduced invasiveness, diminished postoperative pain, and enhanced patient satisfaction[8,9].

Despite the success of UKA, it is acknowledged as a procedure requiring meticulous skill. Precise surgical positioning and prosthesis placement are imperative, given the constraints of a smaller operative field and limited prosthetic surrogate capacity[10]. Experienced surgeons tend to achieve superior postoperative outcomes and prosthesis longevity. The literature also highlights a considerable learning curve associated with unicondylar replacement[11,12].

The introduction of robot-assisted technology has provided a novel dimension to UKA surgery[13]. Robotic-assisted unicompartmental knee arthroplasty (r-UKA) utilizes advancements in computer vision and positioning systems, facilitating accurate surgical planning and manipulation[14]. The robotic system's capacity for three-dimensional skeletal reconstruction enhances the precision of implant positioning, thus improving the surgical success rate[15-17].

However, comprehensive analyses of r-UKA remain limited, particularly in the field of bibliometrics. Compared to robotic-assisted total knee replacement, r-UKA is a more recent development, with a paucity of in-depth studies. Bibliometrics, a method used to evaluate the quality, scope, and impact of scientific literature, has been applied to various orthopedic research domains, including total hip and knee replacements, periprosthetic joint infections, and various other orthopedic conditions. However, it is notably absent in r-UKA analyses.

The aim of this paper is to conduct a bibliometric analysis of r-UKA, providing an overview of existing knowledge and identifying gaps in the literature. By examining frequently cited articles and analyzing
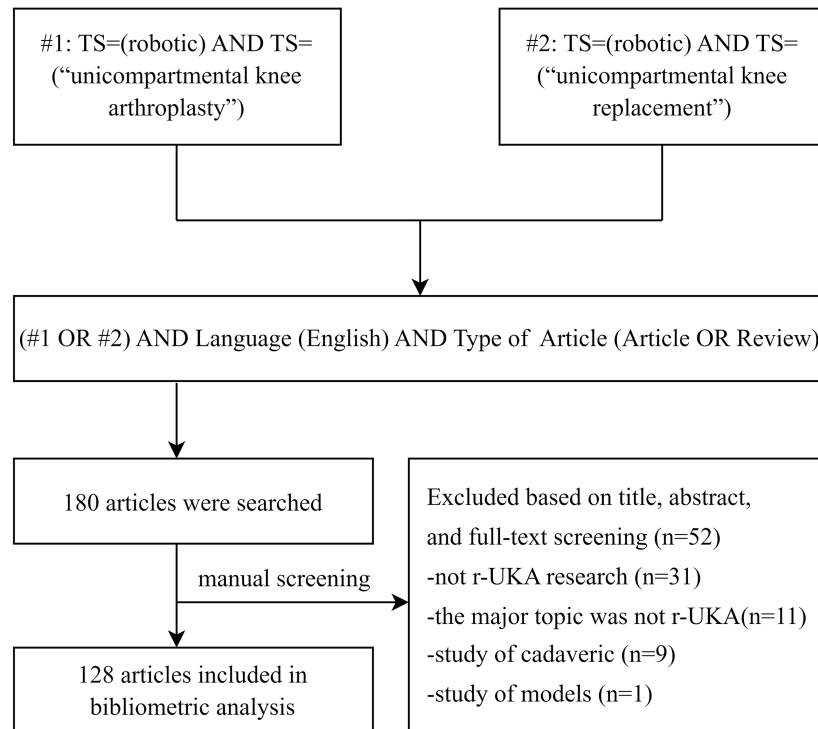
Figure 1. Flowchart for retrieving, selecting and excluding publications.

literature quality, this study seeks to contribute to the field's advancement. Ultimately, this study will contribute to evidence-based r-UKA guidelines that will improve the quality of life for patients with unicompartmental osteoarthritis of the knee.

METHODS

Search methodology

The literature search was completed using the search terms "robotic", "unicompartmental knee arthroplasty", and "unicompartmental knee replacement" in the Web of Science Core Collection (WOSCC) database. In addition, the type of article was limited to article or review, and the language was limited to English. To avoid the impact of database updates, the export and search of all data were completed on June 25, 2023.

Article screening

Initially, we retrieved a total of 180 records from the WOSCC database. These records were further screened by reading the abstract or full text to exclude unsuitable articles. The specific screening process is illustrated in Figure 1. Ultimately, 128 records were included in our study; the detailed bibliography of the collection is shown in Supplementary Table 1. Two independent authors conducted the article screening and later data extraction. In cases of disagreement between the two authors, a third author was involved to discuss and reach a consensus.

Collection and extraction of data

The 128 records meeting the requirements were annotated and exported from the WOSCC database. Subsequently, these records are imported into different software for the next step of analysis. The following was retrieved from the articles: author information (author name, institution, country, corresponding author, or reprint author), publication information (journal, year of publication, and impact factor), article

information (evidence levels and keywords), and reference information (the total citations). The hierarchy of evidence is categorized into five levels. Level I represents the highest quality of evidence, typically derived from randomized controlled trials (RCTs) or their systematic reviews. Level II includes prospective cohort studies and lower-quality RCTs, offering evidence of a slightly lesser quality than Level I. Level III primarily comprises case-control studies and retrospective cohort studies, which are subject to greater bias. Level IV consists of case-series studies, which generally lack a control group and thus are of lower quality. Finally, Level V represents the lowest quality of evidence, often based on expert opinion or descriptive studies. This hierarchical structure assists clinicians in evaluating the quality of studies and thereby informs clinical decision making. The evidence level was evaluated according to the guidelines of *The Journal of Bone and Joint Surgery*[18].

Statistics analysis

The Kolmogorov Smirnov test was used to evaluate the level of evidence and the normality of the distribution of the cited data to investigate the correlation between the two parties. Normally distributed data were expressed as mean ± standard deviation, while non-normally distributed data were expressed as median (first and third quartiles). Spearman's test was utilized to analyze correlations, and Statistics were significant at $P < 0.05$ (both sides). All statistical analyses were performed using R software version 4.2.2 (https://www.r-project.org/about.html). Additionally, the Mann-Kendall test of mutations was performed with MATLAB software to analyze the change in the trend of publications and citations over the time series.

Data visualization

Bar and line plots are plotted to show overall trends in publications and citations for each year, and future trends are predicted based on the results. Keyword clustering co-occurrence networks and time coverage maps were utilized to analyze the main research hotspots of these articles in recent years. The countries conducting research in this field were marked with different colors on a world map to visualize their geographical distribution and the status of publications. Additionally, in order to examine the cooperation between the various entities, networks of cooperation with each other were analyzed. We used several tools to create data visualizations, including VOS viewer version[19] 1.6.18 (Center for Scientific and Technological Research, Leiden University), the R package Bibliometrix[20] version 4.0 (http://www.bibliometrix.org), MapChart (https://www.mapchart.net), Charticulator (https://charticulator.com), and GraphPad Prism version 8.0.2 (https://www.graphpad.com).

RESULTS

Annual publications and citations

It was illustrated in Figure 2 that the annual distribution of publications and citations for all the articles analyzed in this study were published between the years 2006 and 2023. It was noted that there was a steady rise in the number of research papers related to r-UKA starting from 2013, with over two-thirds of them being published within the last five years. The citation count reached its peak between 2016 and 2019, but subsequently started to decline gradually.

Mann-Kendall mutation test shows that the mutations are present in both article publications and citations. A notable change in the number of publications appeared around 2017, marking a point where the UF curve intersects with the UB curve. The UF curve shows a rising tendency in the number of papers after 2014 and a significant growing tendency after 2018 at the significance level α = 0.05 [Figure 3A]. Similarly, an abrupt change in the number of citations was noted in the year 2013, when the UF curve intersects the UB curve. After 2016, a trend of increasing number of citations was shown in the UF curve [Figure 3B].
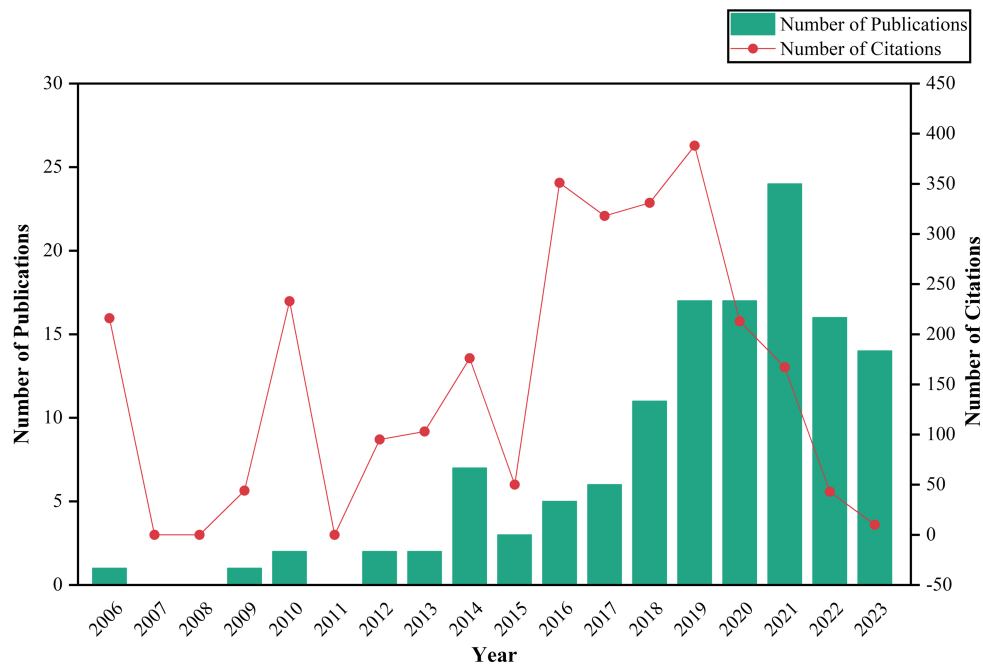
Figure 2. Number of publications and citations per year.

The distributions of the counts of publications [Figure 4A] and citations [Figure 4B] for different evidence levels are as follows. The median citation counts were 14 (2, 44) and 7 (1, 19) for articles at levels I and II of evidence, respectively, and articles with levels of evidence III and IV had median citations of 6 (2, 27) and 11 (3, 19), respectively. A non-parametric test using Spearman's test revealed that there was no significant correlation between citation counts and evidence levels ($P > 0.05$). Thus, the level of evidence for an article did not significantly influence its citation frequency.

Top publishing journals

The top 10 journals, ranked by article count and citations, are presented in Tables 1 and 2, respectively, with a total of 13 journals included in both tables. It is worth noting that there were differences in the rankings resulting from the two sorting methods. It is interesting to note that *The Journal of Arthroplasty* emerged as the top journal both in publications and citations, with 15 articles published and 562 citations received. Close behind, *Knee Surgery Sports Traumatology Arthroscopy* published 14 articles and received 322 citations, while *The Bone & Joint Journal* issued 13 articles and obtained 350 citations. The 13 journals listed in Tables 1 and 2 collectively contributed to about 67% of the articles analyzed in this study, indicating their significance in this research domain. Furthermore, the 10 most cited articles are primarily from two journals, *The Journal of Arthroplasty* and *The Knee* [Table 3].

Research interests

The study conducted a keyword analysis to identify points of interest and hotspots in the research field by examining the frequency and timing of keyword occurrences. The aim was to explore prevalent academic interests or new research directions within the field. Co-occurrence cluster analyses for keywords with more than five occurrences are shown in Figure 5A. In this analysis, the size of each node represents the frequency of occurrence; the larger the node, the more frequent the occurrence. Some of the key nodes identified in the analysis are "alignment", "accuracy", "revision", and "survivorship". These keywords are central to the field and have a significant impact on the research literature.
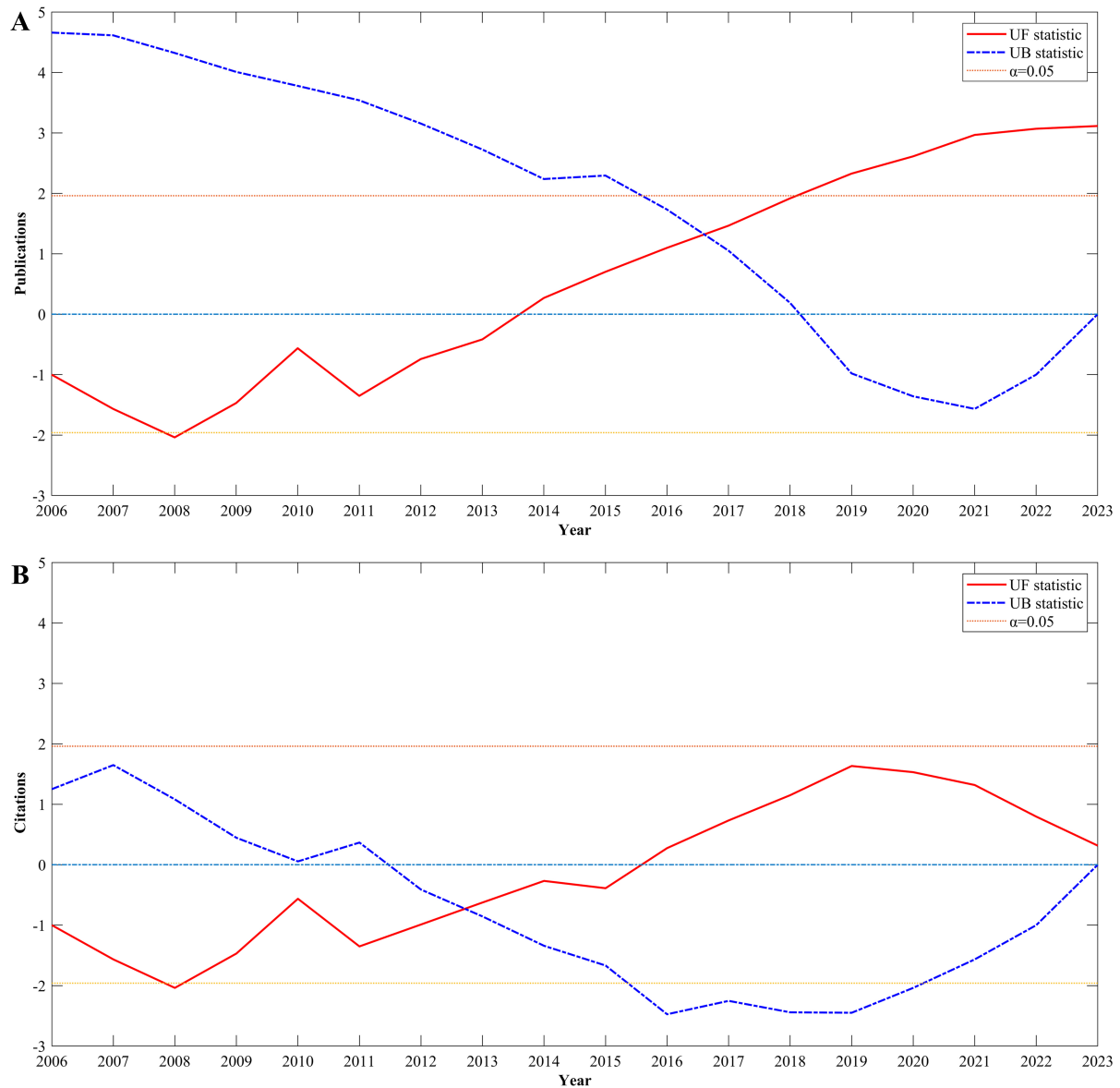
Figure 3. (A) Mann-Kendall trend test for publications and (B) Mann-Kendall trend test for number of citations. The UF curve indicates the changing trend, the UB curve is the reversal of the UF curve, positive UF values mean an upward trend, and vice versa means a downward trend. If the level of significance were set at 0.05, the corresponding value would be ±1.96, and the point of intersection within the confidence interval (±1.96) would be the turning point. If the UF value is higher than 1.96, it represents a clear upward trend, whereas less than -1.96, it represents a clear downward trend.

A chronological coverage plot of the keywords is displayed in Figure 5B, with darker colors indicating earlier occurrences and lighter colors indicating later occurrences. The research interests were observed over time by analyzing the chronological distribution. Notably, the keywords "patient-reported outcomes" and "clinical outcomes" emerged in the last two years, suggesting that these topics have gained increasing attention in recent research. Overall, the keyword analysis provided useful access to general interest and emerging trends within research areas, revealing key emphasis areas and developments in research over time.
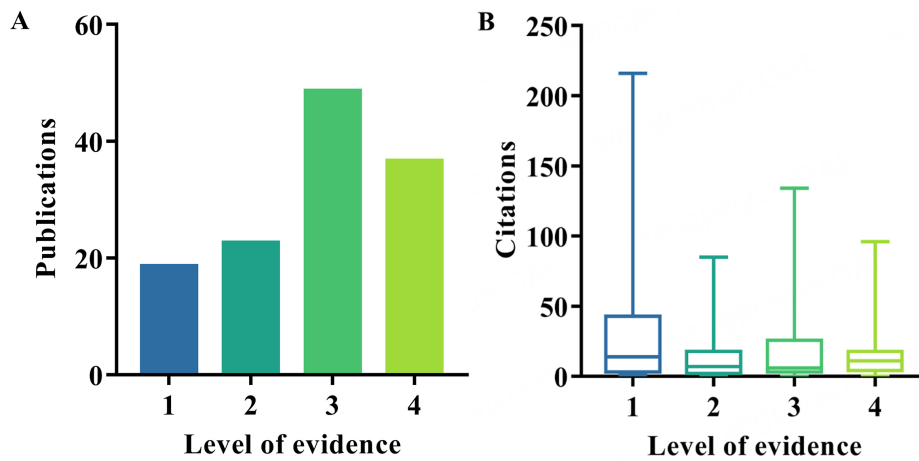
Figure 4. (A) Publication and (B) citation counts for different evidence levels. (The 128 articles included in the study were evaluated according to the guidelines provided by *The Journal of Bone and Joint Surgery* based on their level of evidence. The number of publications and citations corresponding to each level of evidence was also recorded.)
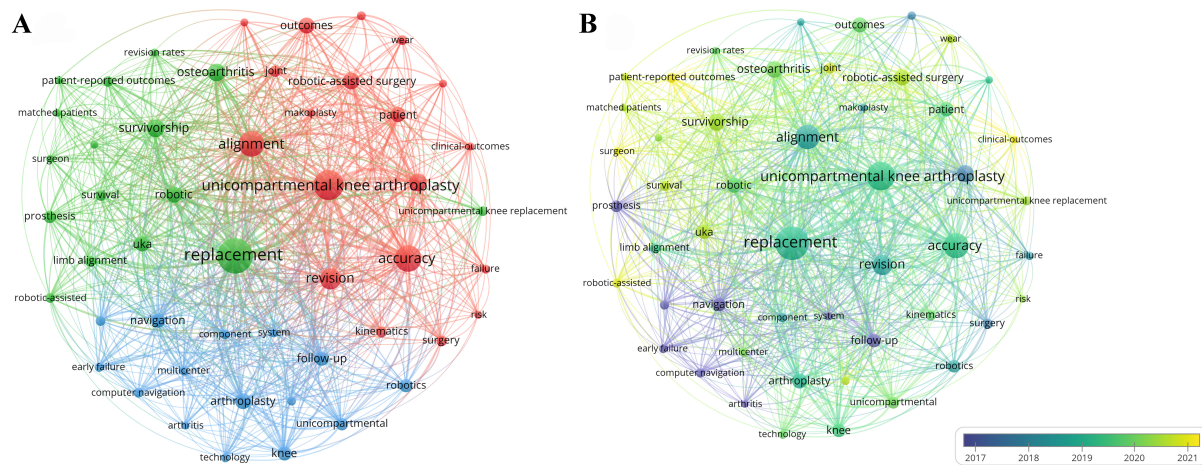

Figure 5. (A) co-occurrence of keyword networks; (B) Keyword appearance time distribution graph.

Author core group and collaborative networks

In this study, research on r-UKA was conducted in 23 countries or regions, and their global distribution is illustrated in Figure 6A. Notably, the United States, with 57 articles, was the major contributor, followed by the United Kingdom with 27 articles. The highly cited articles listed in Table 3 were also predominantly from these two countries, indicating their significant impact on the field.

The network of collaborations between countries that had at least three publications was investigated, resulting in 13 countries. Among these, 11 countries were involved in international collaborations [Figure 6B]. The width of the arc in the figure represents the number of publications, while the lines indicate collaboration between countries. The United States, France, and Australia were notably more involved in global cooperation. However, it is interesting to observe that almost all countries involved in international collaborations were developed countries, with China and Chile not participating in any collaborations.

Table 1. Top 10 published journals

Journal	Publications	Citations	Average citations/publications	Impact factor
The Journal of Arthroplasty	15	562	37.47	3.5
Knee Surgery Sports Traumatology Arthroscopy	14	322	23.00	3.8
The Bone & Joint Journal	13	350	26.92	4.6
The Knee	10	255	25.50	1.9
The Journal of Knee Surgery	8	64	8.00	1.7
International Orthopaedics	5	81	16.20	2.7
Archives of Orthopaedic and Trauma Surgery	5	55	11.00	2.3
The Journal of Bone and Joint Surgery-American Volume	4	232	58.00	5.3
Journal of Orthopaedics	4	26	6.50	1.5
Journal of Robotic Surgery	3	28	9.33	2.3

Table 2. Top 10 journals by citations

Journal	Citations	Publications	Average citations/publications	Impact factor
The Journal of Arthroplasty	562	15	37.47	3.5
Bone & Joint Journal	350	13	26.92	4.6
Knee Surgery Sports Traumatology Arthroscopy	322	14	23.00	3.8
Knee	255	10	25.50	1.9
The Journal of Bone and Joint Surgery-American Volume	232	4	58.00	5.3
The Journal of Bone and Joint Surgery-British Volume	216	1	216.00	/
Clinical Orthopaedics and Related Research	178	2	89.00	4.2
Bone & Joint Research	106	2	53.00	4.6
International Orthopaedics	81	5	16.20	2.7
The Journal of Knee Surgery	64	8	8.00	1.7

Table 3. Top 10 articles according to the number of citations

| Title	Author	Country	Journal	Year	Citations
Hands-on robotic unicompartmental knee replacement - A prospective, randomized controlled study of the Acrobot system	Cobb, J	United Kingdom	*The Journal of Bone and Joint Surgery-British Volume*	2006	216
Improved Accuracy of Component Positioning with Robotic-Assisted Unicompartmental Knee Arthroplasty	Bell, SW	United Kingdom	*The Journal of Bone and Joint Surgery-American Volume*	2016	162
Robotic Arm-assisted UKA Improves Tibial Component Alignment A Pilot Study	Lonner, JH	United States	*Clinical Orthopaedics and Related Research*	2010	134
Robot-Assisted Unicompartmental Knee Arthroplasty	Pearle, AD	United States	*The Journal of Arthroplasty*	2010	99
Unicompartmental knee arthroplasty: Is robotic technology more accurate than conventional techniques?	Citak, M	United States	*Knee*	2013	96
Accuracy of Dynamic Tactile-Guided Unicompartmental Knee Arthroplasty	Dunbar, NJ	United States	*The Journal of Arthroplasty*	2012	94
Robotic arm-assisted versus conventional unicompartmental knee arthroplasty EXPLORATORY SECONDARY ANALYSIS OF A RANDOMIZED CONTROLLED TRIAL	Blyth, MJG	United Kingdom	*Bone & Joint Research*	2017	85
Improved implant position and lower revision rate with robotic-assisted unicompartmental knee arthroplasty	Batailler, C	France	*Knee Surgery Sports Traumatology Arthroscopy*	2019	80
Can Robot-Assisted Unicompartmental Knee Arthroplasty Be Cost-Effective? A Markov Decision Analysis	Moschetti, WE	United States	*The Journal of Arthroplasty*	2016	80
Survivorship and patient satisfaction of robotic-assisted medial unicompartmental knee arthroplasty at a minimum two-year follow-up	Pearle, AD	United States	*Knee*	2017	79
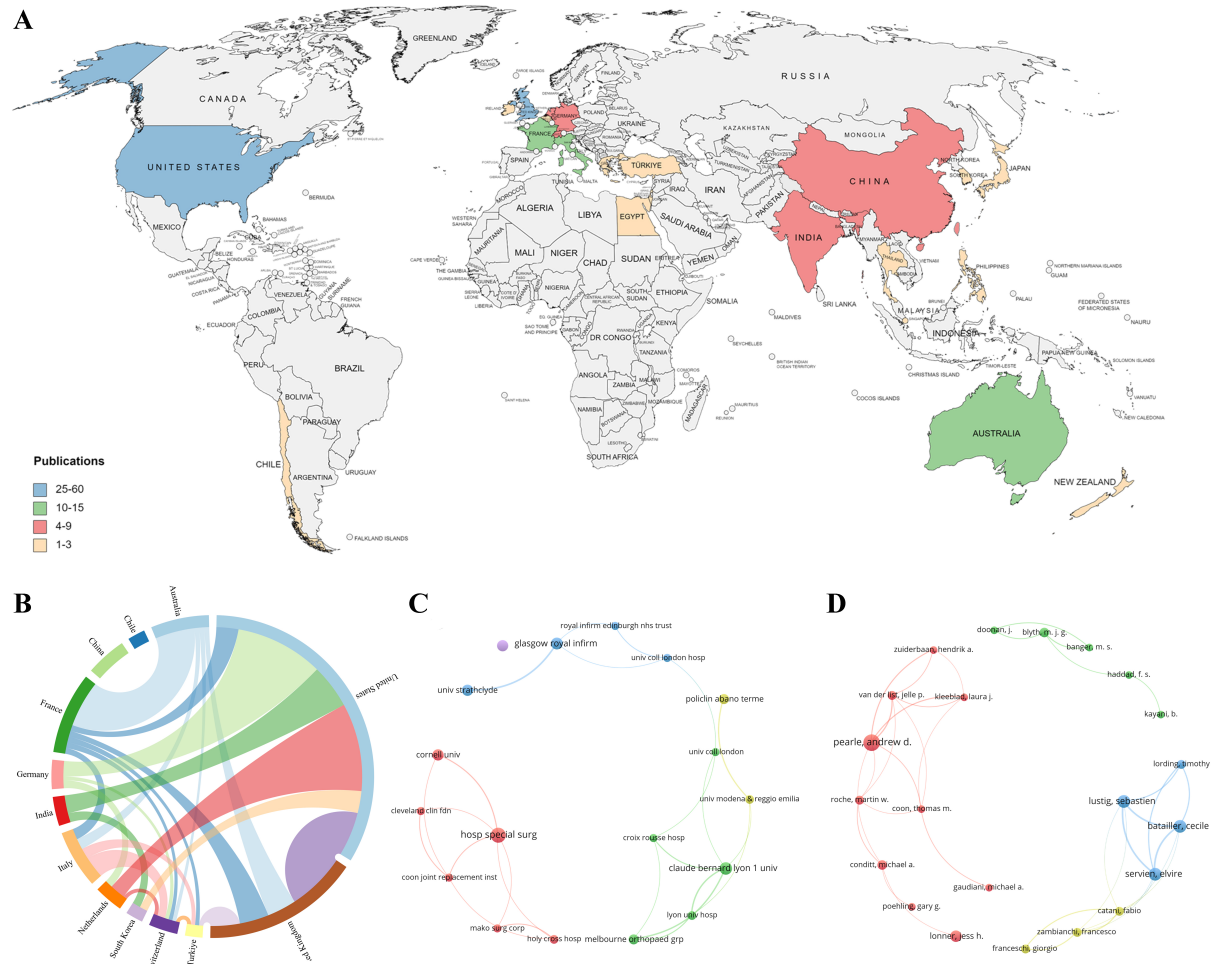
Figure 6. (A) Distribution of countries/areas of publication; (B) National collaboration network visualization (width for number of publications, links for collaboration, publications ≥ 3, countries with no line links indicate that they are not involved in international cooperation); (C) Inter-institutional cooperation network visualization (publications ≥ 4); (D) Visualization of authorship cooperation networks (publications ≥ 4).

Collaborative network analysis of organizations with at least four r-UKA-related publications [Figure 6C]. There were 18 organizations from five different countries: the United States, the United Kingdom, France, Italy, and Australia. The Hospital for Special Surgery in the United States was the most productive institution with 14 articles, while the Universite Claude Bernard Lyon from France was the most involved institution. Institutions clustered in red within the figure indicated closer collaborations within their home countries. University College London (the United Kingdom), Melbourne Orthopaedic Group (Australia), and Universita di Modena e Reggio Emilia (Italy) were observed to have close collaborations with French institutions. The collaborative network between authors who have published at least four articles is shown in Figure 6D. Pearle, AD from the United States, was the biggest contributor with 18 publications. The red cluster in the figure consists mainly of authors from the United States, indicating their closely knit collaborative system. Similarly, the green cluster represents authors from the United Kingdom with their collaborative network. Notably, the blue and yellow clusters form a collaborative system involving authors from France, Australia, and Italy, which aligns with previous inter-institutional collaborations. Within this system, Batailler, C, Lustig, S, and Servien, E from France play a bridging role and are actively involved in the entire network. The top ten most prolific authors in the field are listed in Table 4. Half of these authors

Table 4. Top 10 authors according to the number of publications

Country	Institution	Publications	Citations
United States	Cornell University	16	459
France	Croix-Rousse Hospital	10	172
France	Croix-Rousse Hospital	10	172
France	Croix-Rousse Hospital	10	172
United States	Thomas Jefferson University	8	248
United States	MAKO Surgical Corp	6	435
United Kingdom	University of Glasgow	6	168
United States	Maimonides Medical Center	5	235
United States	Cornell University	5	166
Australia	Melbourne Orthopaedic Group	5	82

are from the United States, while the three authors from France maintain consistent publication records. Overall, these collaborative network analyses provided valuable insights into the patterns of international and inter-institutional collaborations and highlighted the prominent contributors and researchers within the field of r-UKA.

DISCUSSION

The emergence of r-UKA as a prominent alternative to traditional surgical interventions underscores a paradigm shift in the treatment of unicompartmental knee osteoarthritis[21-23]. By exploring and analyzing the literature related to r-UKA, our study found that the robotic system performs fine surgical positioning through preoperative 3D planning, which reduces bias from manual manipulation as well as unnecessary bone tissue damage, and allows the alignment of the femoral and tibial prostheses to converge to a natural kinematic alignment during extension/flexion rotation [Figure 7]. With the aid of robotics, UKA has improved clinical outcomes, postoperative survival and patient satisfaction, and has a low revision rate[6,22,24-27].

The trends observed in the annual distribution of publications and citations align with the global recognition of r-UKA's potential. The steady rise in research papers since 2013 and the peak citation count between 2016 and 2019 reflect a growing academic and clinical interest in this field. These trends are consistent with previous studies that have noted the increasing adoption of robotic assistance in orthopedic surgeries. In our study, the Mann-Kendall mutation test shows a distribution of mutation time points for publication and citation counts around 2017 and 2013, suggesting that r-UKA's research has received more attention and citations since these time points, which is consistent with the fact that we were informed earlier that two-thirds of the articles were published in the last five years. Similarly, we hypothesize that this is related to the fact that the MAKO Tactile Guidance System (TGS) (MAKO Surgical Corp, Fort Lauderdale, Fla) robotic system was approved by the United States Food and Drug Administration in 2016, and that the advent of the new technology facilitated this field of research, further attracting more study interest. The positive clinical results achieved by this r-UKA have also contributed in part to research in the field of r-UKA. Furthermore, no significant correlation was found between evidence level and citation counts of articles in our study. This may imply that the interest in r-UKA research in academia and clinical practice is mainly based on other factors, such as innovation and reliability of research methods.

It was found in this study that the highly cited articles and prolific authors were mainly from the United States and the United Kingdom, and earlier, we also found that the United States and the United Kingdom have a greater number of studies on the r-UKA field. These two countries have many top medical research
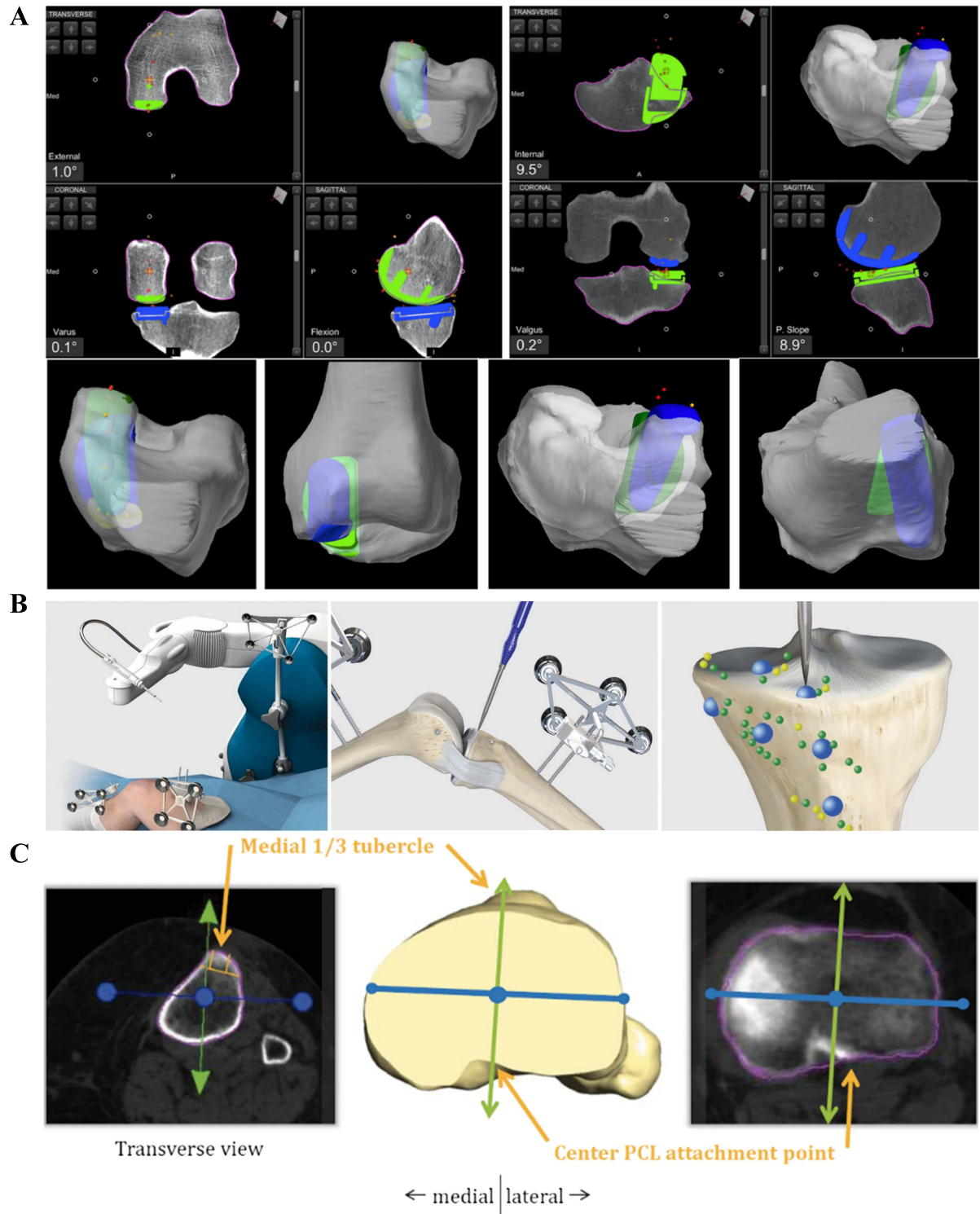
Figure 7. (A) 3D planning of medial/lateral UKA extension and flexion 90° with MAKO® software; (B) Collection of patient landmarks and registration and validation of femoral and tibial checkpoints using the Mako system; (C) Rotational measurement of tibial landmarks using MAKO® software. UKA: Unicompartmental knee arthroplasty.

institutes, universities, and hospitals, which provide favorable conditions for conducting high-quality

research. In the field of medical research, scientists and doctors often have access to state-of-the-art equipment, advanced technology, and large-scale clinical data, which helps them conduct in-depth studies and produce influential papers. It is worth noting that commonly used robotic systems were developed by the United States and the United Kingdom, such as the Acrobot System (The Acrobot Co. Ltd., London, the United Kingdom), the MAKO TGS (MAKO Surgical Corp, Fort Lauderdale, Fla), and NAVIO Surgical System (Smith & Nephew, the United States).

Our analysis of the collaborative networks, particularly the prominence of the United States and the United Kingdom, resonates with the broader pattern of international collaborations in medical research. The focus on developed countries in these collaborations may indicate a concentration of technological advancements and expertise in these regions. However, the concentration of research collaborations in developed countries may challenge the global health equity model, highlighting potential disparities in access to advanced medical technologies like r-UKA. This observation calls for a more inclusive approach to research collaboration and technology dissemination.

We investigated the distributions of journals in which articles were produced and the journal in which the highly cited articles were published, and the results showed that these articles were normally published in prestigious orthopedic journals, like *The Journal of Arthroplasty*, *Knee Surgery Sports Traumatology Arthroscopy*, *The Bone & Joint Journal*, *The Knee*, and *The Journal of Knee Surgery*. These well-known journals usually have a wide readership and international influence, which is conducive to the wider dissemination and sharing of research results. Through these journals, researchers can learn about the latest research results, promote academic exchanges and cooperation, and further promote the development of the field. By observing the journals in which these highly cited papers are published, it may be possible to discover the research hotspots and trends in the field of UKA.

An intriguing aspect of our study was the absence of a significant correlation between citation counts and evidence levels. This finding challenges the conventional expectation that higher evidence levels would correlate with increased citation frequency. It prompts further investigation into the factors influencing citation practices in the field of r-UKA. We should also note that there may be some geographical bias in this result. There may be many important research results in other countries and regions that deserve our attention. In addition, some new high-quality research may fail to receive sufficient international attention and citations due to lack of time or lack of public access. Thus, when analyzing high-citation literature, we must consider many factors, such as study topics, authors, article details and qualities, publishing time, *etc.*, so that we can get a well-rounded picture of the progress and status of research in the area. Then, it is equally essential that investigators do not neglect articles that do not get enough traction owing to timelines or accessible nature.

Through the co-occurrence analysis of keywords, we found that alignment, accuracy, revision, and survivorship were the most frequently occurring nodes, which were the focus of the r-UKA study. It has been reported that more precise alignment of components is crucial for postoperative stability and functional recovery, and higher accuracy can reduce surgical risks and improve surgical outcomes[28]. This advantage brought by r-UKA is favorable to improving implant survival. Despite the advantages of r-UKA over manual UKA, studies have shown that there is no clinically significant difference between the two in terms of functional outcomes in the short- to medium-term follow-up[29-32]. Revision and survivorship are also frequent, reflecting the concern of researchers about the long-term outcomes of the r-UKA procedure. This underscores the need for more robust evidence and longer follow-ups to better assess the long-term complication and revision rates and clinical outcomes of r-UKA.

The emergence of keywords such as "patient-reported outcomes" and "clinical outcomes" in recent years signals a shift toward patient-centered research. This trend reflects a broader movement in healthcare toward personalized and patient-focused care, which can be understood within the framework of Patient-Centered Care (PCC), a model that emphasizes collaboration, communication, and customization in healthcare. This trend toward patient-focused outcomes aligns with the PCC model and reflects a shift in healthcare priorities. It is important to note that current research primarily focuses on the clinical outcomes of r-UKA, with little attention given to the basic research and technological advancements of the robotic systems themselves. However, the improvement of these systems represents a critical area for future development. We anticipate that as science and technology continue to advance, these aspects will be explored more extensively in future research.

We acknowledge certain limitations in our study. First, we only searched the WOSCC, which may have resulted in an incomplete collection of relevant literature. However, WOSCC is one of the most extensive and comprehensive databases globally, encompassing a substantial body of relevant literature that adequately reflects the overall research status in the field and is widely used by scholars. Future research could benefit from combining multiple databases to ensure more comprehensive literature coverage. Second, the focus on English-language articles may have introduced language bias, potentially excluding relevant research published in other languages. The level of evidence was assessed using the grading guidelines of *The Journal of Bone and Joint Surgery* for each paper. However, it is important to note that different studies might have employed alternative classification systems, which could influence the comparison of evidence levels. Additionally, some recently published high-quality articles may not have received sufficient attention due to their novelty, requiring researchers to closely monitor new, valuable studies in ongoing research.

In conclusion, artificial intelligence (AI) technology holds significant promise in preoperative planning, intraoperative navigation, and postoperative rehabilitation management for UKA. By analyzing extensive patient data, AI can guide the selection of optimal prostheses and implantation positions, tailored to individual anatomical and functional characteristics. Furthermore, AI enhances surgical precision, reduces human error, improves the predictability of outcomes, and supports personalized postoperative care. Future research should focus on expanding AI's application in knee arthroplasty, particularly in enhancing surgical safety and reducing complications. We anticipate that advancements in AI will significantly improve UKA outcomes and, consequently, patient quality of life. The success and precision of r-UKA, as demonstrated in our study, contribute to the growing evidence supporting robotic integration in orthopedic surgery. This success underscores the potential for broader clinical adoption, benefiting a larger patient population. However, further investigation into long-term outcomes and clinical efficacy compared to traditional techniques is necessary. Detailed longitudinal studies on patient outcomes and satisfaction would deepen understanding and guide best practices. Continuous education and training in r-UKA are recommended to ensure optimal surgical outcomes.

DECLARATIONS

Authors' contributions
Conceived the idea for this study: Zhang X, Zhu J, Zhu W
Carried out the data extraction: Yang Y, Wang Y, Zhou Y

Performed the statistical analysis: Yang Y, Zhu W, Zheng Z
Conducted image plotting: Yang Y, Chen Y, Wang Y
Drafted the initial manuscript: Yang Y, Chen Y, Zhang X
Provided critical feedback and revisions to the final version: Yang Y, Chen Y
Provided financial support, provided administrative assistance: Zhang X, Zhu J
All authors read and approved the final manuscript.

Availability of data and materials
The datasets during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflicts of interest
All authors declared that there are no conflicts of interest.

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

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