Periprosthetic joint infection after total knee arthroplasty: a bibliometrics analysis

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Background: Total knee arthroplasty (TKA) has brought hope to patients with malignant knee joint diseases. Infection is one of the serious complications after TKA, and the purpose of this study was to use bibliometrics to analyze the current research status of infection after this surgery, to unmask any deficiencies with current research, and to provide references for future researchers.

Methods: We used the Science Citation Index Expanded (SCI-E) database in the Web of Science Core Collection (WOSCC) as the data source, using the search terms “total knee arthroplasty” and “infection” respectively. The “And” operation was performed on the search results of the two subject terms, and the intersection of the two search results was taken as the final search result. CiteSpace software was used to analyze the results.

Results: The search results consisted of 5,600 documents, with a total citation frequency of 148,871. The average number of citations for each literature was 26.58, and the h-index was 142. The top five countries in the number of publications were the United States, China, Germany, the United Kingdom, and Spain, while the top five centrally ranked countries were the United States, the Netherlands, Germany, the United Kingdom, and France. The top five institutions with the number of publications were Thomas Jefferson Univ, Mayo Clin, Hosp Special Surg, Rush Univ, and Cleveland Clin, while the top institutions for centrality were Thomas Jefferson Univ, Tel Aviv Univ, Univ Melbourne, and Rush Univ. The top five authors of the number of published articles were Parvizi J, Mont MA, Valle CJD, Chen AE, and Hanssen AD, and the top three authors for centrality were Parvizi J, Mont MA, and Valle CJD. The main journals were *J Bone Joint Surg Am*, *Clin Orthop Relat R*, *J Arthroplasty*, *J Bone Joint Surg Br*, and *Int Orthop*, and the top five keywords used were total knee arthroplasty, total hip arthroplasty, replacement, infection, and arthroplasty.

Conclusions: There is a lack of studies with high-level evidence. The focus of related research in recent years has not changed significantly. More randomized controlled studies are required to provide evidence-based medicine.

Keywords: Total knee arthroplasty (TKA); infection; prevention; management; bibliometrics analysis

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Introduction

The development and improvement of total knee arthroplasty (TKA) has brought hope to patients with malignant knee joint diseases. TKA can effectively help patients relieve pain, facilitate the reconstruction of knee joint function, and is of great significance for improving the prognosis of patients (1). However, with the widespread development of TKA, the incidence of postoperative complications including infection, has also increased (2). The incidence of infection after TKA in foreign countries has dropped from 1–23% when the operation was first performed, to 0.8–1.9% at present (3,4), while in China this figure remains relatively high, at 15%. According to the scope of involvement, infection after TKA is divided into superficial infection (not involving the joint capsule) and deep infection (involving the joint capsule), and according to the onset and course of the disease, it is divided into acute or early onset infection (within 2 weeks after TKA) and chronic or delayed infection (2 weeks after TKA). Many factors are associated with infection after TKA, including obesity, diabetes, rheumatic arthritis, cancer, malnutrition, underlying diseases (systematic or local infection, heart diseases, renal diseases, etc.) and no antibiotic prophylaxis (2).

Infections after TKA are usually early and superficial. However, failure to control an infection in a timely manner may result in pathogenic bacteria multiplying and invading the knee prosthesis through blood-borne pathways, inducing new serious infections and causing damage to the prosthesis. In severe cases, disastrous consequences to joint function may occur, further increasing patient suffering, prolonging the postoperative and rehabilitation hospital stay and likelihood of subsequent hospitalizations, raising costs, and attracting the likelihood of long-term antibiotic therapy (5,6). In view of this, the identification of high-risk factors that induce infection after TKA and measures which can guide effective pre-operative, perioperative, and postoperative control are particularly important to physicians (1,7–9), and many studies on the topic have been published. The main treatments for infection after TKA include antibiotic therapy, debridement, insertion of another prosthesis and knee arthrodesis and amputation (2,7). Bibliometrics involves searching literature on a subject and identifying its current status, development trends, and leading research institutions and researchers. It also provides a macro view for future research and reference

to assist the choice of research directions, and avoid duplication and omission of important research targets (10). In a previous study, Li et al conducted a global bibliometric analysis from meta-analysis studies to estimate global PJI research (11). The authors found that the main topics on periprosthetic joint infection were alpha-defensin, antibiotic use, risk factors of intra-articular steroid injections, and the location of prosthetic hip and knee infection (11). The purpose of this study was to use bibliometrics to analyze the current research status of infection after TKA and to identify possible references for future investigations based on all kinds of related literatures about infection after TKA.

Methods

Data source

The Web of Science Core Collection (WOSCC) Science Citation Index Expanded (SCI-E) database was used as the data source, and the publication time of the documents was from inception to (July 6, 2021).

Retrieval strategy

Subject term retrieval with the terms “total knee arthroplasty” and “infection” was used. The “And” operation was performed on the search results of the two subject terms, and the intersection of the two search results was taken as the final search result. The final search result and cited record were then exported in plain text format to form the original data set for the next analysis.

Statistical analysis

Data is expressed in quantity and percentage, and as no statistical comparison and correlation analysis were performed, no P value was set. CiteSpace software was used to analyze the original search results data set, and the content of the analysis included the annual change of the number of publications, the annual change of the number of citations of these publications, the distribution of countries/institutions and journals, the distribution of authors, the use of keywords, and cooperation between countries, institutions, and authors. According to the analysis results, co-occurrence diagrams among countries, institutions, authors, and keywords were drawn to reflect the research status of infection after TKA.

Table 1 Document type analysis of search results

Document types	Records	% of n=5,600
Original article	4,933	88.09
Review	541	9.66
Proceedings paper	308	5.50
Early access	64	1.14
Editorial material	62	1.11
Letter	32	0.57
Meeting abstract	23	0.41
Correction	5	0.09
Book chapter	4	0.07
Note	2	0.04
Book review	1	0.02
Discussion	1	0.02
Retracted publication	1	0.02

Table 2 Annual changes in the number of papers

Year	Records	% of 5,600
2021	290	5.18
2020	619	11.05
2019	525	9.38
2018	485	8.66
2017	479	8.55
2016	437	7.80
2015	351	6.27
2014	331	5.91
2013	257	4.59
2012	235	4.20
2011	192	3.43
2010	177	3.16
2009	145	2.59
2008	123	2.20
2007	130	2.32
2006	125	2.23
2005	99	1.77
2004	87	1.55
2003	79	1.41
2002	56	1.00
2001	67	1.20
2000	42	0.75
1999	36	0.64
1998	35	0.63
1997	35	0.63
1996	36	0.64
1995	36	0.64
1994	23	0.41
1993	22	0.39
1992	12	0.21
1991	23	0.41
1990	4	0.07
1988	2	0.04
1987	1	0.02
1985	1	0.02
1983	1	0.02
1977	1	0.02
1975	1	0.02

Results

Basic information

Preliminary search results revealed a total of 5,977 related research literature records, of which 377 duplicates were excluded. Of the remaining 5,600 publications, 4,933 were original articles, 541 reviews, 308 proceedings papers, and 64 were early access articles. There were 62 editorial materials, 32 letters, 23 meeting abstracts, five corrections, four book chapters, two notes, one book review, one discussion, and one retracted publication (*Tables 1, 2, Figure 1*). From the perspective of the publication time and quantity of the literature, the research on this subject has received extensive attention for a long duration, and related research is generally increasing year by year. The citation frequency of documents totaled 148,871, while the average citation frequency of each document was 26.58, and h-index (which is an index reflecting the influence of a specific author or article, the higher h-index, the higher influence) was 142 (*Figure 2*). The citation frequency of documents also showed an obvious increasing trend.

Distribution of countries and institutions

CiteSpace V software was used to analyze the distribution of countries and institutions of document sources. The national visualization map (*Figure 3*) shows N=106 and

Figure 1 Trends in the number of annual papers published.

Figure 2 Annual trend of the number of documents cited.

$E=436$, where N represents the number of network nodes, and one node represents one country or region, E represents the number of connections, and one connection represents two countries appearing together in one document. This shows there are many countries participating in research in this field. The organization visualization map (Figure 4) shows $N=884$ and $E=1508$, where N represents the number of institutions, and E represents the relationship between institutions, that is, each link represents the institutions at both ends of the link appearing in one document at the same time. This shows many institutions have carried out research in this field. The top five countries with the highest number of publications were the United States, China, Germany, the United Kingdom, and Spain, while the top five with centrality were the United States, the Netherlands, Germany, the United Kingdom, and France (Tables 3 and 4). The top five institutions with the highest

number of publications were Thomas Jefferson Univ, Mayo Clin, Hosp Special Surg, Rush Univ, and Cleveland Clin (Table 5), while the top for centrality were Thomas Jefferson Univ, Tel Aviv Univ, Univ Melbourne, and Rush Univ (Table 6).

Authors analysis

The top five authors of the number of published documents were (regardless of the order of the signature of the author): Parvizi J, Mont MA, Valle CJD, Chen AF, and Hanssen AD (Table 7), and for centrality, the top three authors were Parvizi J, Mont MA, and Valle CJD (Figure 5, Table 8). The top five authors of co-cited records were Parvizi J, Kurtz SM, Bozic KJ, Kurtz S, and Insall JN, and there were 10 authors with co-cited centrality scores above 0.03 (Figure 6, Tables 9,10).

Figure 3 National visualization map.

Figure 4 Visualization map of institutions.

Table 3 Top 10 countries for number of papers published

Rank	Countries	Records
1	The United States	2,423
2	China	517
3	Germany	491
4	England	390
5	Spain	180
6	Canada	178
7	France	169
8	Italy	151
9	Netherlands	135
10	Australia	134

Table 4 Top 10 countries for centrality

Rank	Countries	Centrality
1	The United States	0.60
2	Netherlands	0.21
3	Germany	0.18
4	England	0.15
5	France	0.14
6	China	0.10
7	Italy	0.10
8	Spain	0.07
9	Canada	0.07
10	South Korea	0.07

Table 5 Top 10 institutions in the number of papers published

Rank	Institutions	Records
1	Thomas Jefferson Univ	243
2	Mayo Clin	216
3	Hosp Special Surg	138
4	Rush Univ	114
5	Cleveland Clin	103
6	Duke Univ	73
7	Univ Calif San Francisco	71
8	New York University	60
9	Univ Penn	54
10	Sichuan Univ	46

Table 6 Top 10 institutions for centrality

Rank	Institution	Centrality
1	Thomas Jefferson Univ	0.07
2	Tel Aviv Univ	0.05
3	Univ Melbourne	0.04
4	Rush Univ	0.04
5	Charite Univ Med Berlin	0.03
6	Univ Penn	0.03
7	Cleveland Clin	0.03
8	Hosp Special Surg	0.03
9	Mayo Clin	0.03
10	Univ Helsinki	0.02

Table 7 Top 10 authors of papers published

Rank	Authors	Records
1	Parvizi J	198
2	Mont MA	96
3	Valle CJD	67
4	Chen AF	59
5	Hanssen AD	55
6	Higuera CA	51
7	Abdel MP	45
8	Berry DJ	44
9	Schwarzkopf R	42
10	Tan TL	41

Journal distribution

The 5,600 articles in the search results were from 596 journals and among them, 11 journals had more than 100 articles (*Table 11*) and published 2,907 articles, accounting for 51.91% of the total number of articles (*Table 11*). The top five journals cited by frequency were *J Bone Joint Surg Am*, *Clin Orthop Relat R*, *J Arthroplasty*, *J Bone Joint Surg Br*, and *Int Orthop* (*Table 12*), and the top three journals with centrality scores were *Arthritis Rheum*, *Ann Intern Med*, and *Am J Surg* (the other seven journals in the top 10 journals all had a centrality score of 0.03, *Table 13*).

Keyword analysis

CiteSpace V software was used to analyze the use of

Figure 5 Visualization map of authors co-authored.

Table 8 Top 10 authors for centrality

Rank	Authors	Centrality
1	Parvizi J	0.07
2	Mont MA	0.05
3	Valle CJD	0.05
4	Chen AF	0.02
5	Abdel MP	0.02
6	Browne JA	0.02
7	Hanssen AD	0.01
8	Higuera CA	0.01
9	Berry DJ	0.01
10	Schwarzkopf R	0.01

keywords and draw a keyword co-occurrence map (Figure 7), where $N=730$, that is, a total of 730 keywords were used in these documents and $E=7,088$, that is, the frequency of these keywords pairwise appearing in the literature at the same time was 7,088 times. The top five keywords used were total knee arthroplasty, total hip arthroplasty, replacement, infection, and arthroplasty (Table 14), and the top five keywords in the centrality score were total knee arthroplasty, infection, total hip arthroplasty, replacement, and prosthesis (Table 15). We

further used CiteSpace to perform Burst detection on keywords with high frequency of use, and the results show that in recent years, relevant research on rehospitalization for renovation has attracted more attention (Figure 8).

Discussion

In this study, 5,600 publications on infection after TKA were retrieved from the SCI-E database using subject terms, and the analysis revealed the topic has been receiving extensive attention, with research literature and citation records showing an increasing trend over time. While most countries have conducted related research, the main countries doing so are the United States, Germany, the United Kingdom, and the Netherlands, and the proportion of international cooperative research is also relatively high. The main research institutions are also based in these countries, with the most prolific being Thomas Jefferson Univ in the United States. Authors who have published more documents and cooperated most are also from these major institutions and countries. Keyword analysis results showed that the current second revision after knee arthroplasty is the focus of research.

Osteoarthritis is a degenerative disease which usually occurs in weight-bearing joints with ageing, and the number of knee osteoarthritis patients is increasing over time due (12,13). One major reason for this relates to our

Figure 6 Visualization map of authors co-cited.

Table 9 Top 10 co-cited authors

Rank	Authors	Frequency
1	Parvizi J	1,323
2	Kurtz SM	947
3	Bozic KJ	842
4	Kurtz S	807
5	Insall JN	728
6	Zimmerli W	537
7	Fehring TK	463
8	Trampuz A	404
9	Jansen E	403
10	Rand JA	390

Table 10 Top 10 co-cited authors for centrality

Rank	Authors	Centrality
1	Buchholz HW	0.07
2	Barrack RL	0.05
3	Insall JN	0.04
4	Fehring TK	0.04
5	Whiteside LA	0.04
6	Charnley J	0.04
7	Fitzgerald RH	0.04
8	Lidwell OM	0.04
9	Friedman RJ	0.04
10	Bozic KJ	0.03

aging society, with prolonged life expectancy driving the number of patients with degenerative disease higher, and a second results from improvements in material living conditions worldwide, which has caused the number of obese patients to rise rapidly (1,14). TKA can effectively improve knee joint function and relieve pain (1), and with advances in total knee replacement technology and the continuous improvement of materials, more patients are

receiving this treatment. However, postoperative local infection has always troubled clinicians and patients (9), and much research is undertaken to both relieve and prevent this. The prevention of infection is generally divided into three stages: preoperative, intraoperative, and postoperative. Many studies conclude the nutritional status of the patient and blood glucose level should be carefully evaluated (15-17), and some have also found that when the

Table 11 Top 11 journals in number of papers published

Journals	Records	% of 5,600
<i>Journal of Arthroplasty</i>	1,151	20.55
<i>Clinical Orthopaedics and Related Research</i>	419	7.48
<i>Journal of Bone and Joint Surgery American Volume</i>	337	6.02
<i>Bone Joint Journal</i>	164	2.93
<i>Knee</i>	147	2.63
<i>International Orthopaedics</i>	138	2.46
<i>Knee Surgery Sports Traumatology Arthroscopy</i>	127	2.27
<i>Orthopedics</i>	109	1.95
<i>Archives of Orthopaedic and Trauma Surgery</i>	107	1.91
<i>Journal of Bone and Joint Surgery British Volume</i>	105	1.88
<i>Journal of Knee Surgery</i>	103	1.84

Table 12 Top 10 journals cited

Rank	Journals	Frequency
1	<i>J Bone Joint Surg Am</i>	4,796
2	<i>Clin Orthop Relat R</i>	4,753
3	<i>J Arthroplasty</i>	4,575
4	<i>J Bone Joint Surg Br</i>	3,326
5	<i>Int Orthop</i>	1,738
6	<i>Acta Orthop</i>	1,446
7	<i>Orthopedics</i>	1,418
8	<i>New Engl J Med</i>	1,325
9	<i>Clin Infect Dis</i>	1,324
10	<i>Bone Joint J</i>	1,244

Table 13 Top 10 journals for centrality

Rank	Journals	Centrality
1	<i>Arthritis Rheum</i>	0.07
2	<i>Ann Intern Med</i>	0.04
3	<i>Am J Surg</i>	0.04
4	<i>Am J Infect Control</i>	0.03
5	<i>Brit Med J</i>	0.03
6	<i>Arch Surg-Chicago</i>	0.03
7	<i>Arch Intern Med</i>	0.03
8	<i>Brit J Surg</i>	0.03
9	<i>Am J Roentgenol</i>	0.03
10	<i>Am J Epidemiol</i>	0.03

level of glycosylated hemoglobin is higher than 7.5 (14) or 7.7 (16), the risk of postoperative infection is significantly increased. Golladay et. al recommended the nutritional status of patients be evaluated before joint replacement surgery, including indicators such as serum albumin level, lymphocyte count, and transferrin level (17). During the operation, strict disinfection should be performed on the skin of the surgical area (18,19), and the addition of disinfection records can also reduce the risk of infection (20,21). There are many studies on the use of antibiotics for preventive treatment during the perioperative period, but the optimal plan requires further study. A meta-analysis of 26 studies (11,343 patients) indicated that

prophylactic antibiotics can reduce the absolute risk of wound infection by 8% and the relative risk by 81% (22). A systematic review and meta-analysis in 2019 included 23 RCTs, two prospective cohort studies, three retrospective cohort studies, and four case-control studies, enrolling a total of 51,627 patients, with the results confirming the benefits of surgical antibiotic prophylaxis (SAP) in total joint replacement surgery, although the continued use or use for more than 24 hours after surgery did not increase the benefits. However, some authors have also pointed out that the current available evidence is weak, and more research is required (23). Other studies have conducted in-depth discussions on measures to prevent infection during

Figure 7 Keyword co-occurrence map.

Table 14 Top 10 keywords by frequency

Rank	Keywords	Frequency
1	Total knee arthroplasty	2,895
2	Total hip arthroplasty	1,863
3	Replacement	1,484
4	Infection	1,289
5	Arthroplasty	1,062
6	Complication	695
7	Hip	663
8	Risk factor	638
9	Outcome	630
10	Periprosthetic joint infection	595

Table 15 Top 10 keywords of centrality

Rank	Keywords	Centrality
1	Total knee arthroplasty	0.15
2	Infection	0.08
3	Total hip arthroplasty	0.07
4	Replacement	0.07
5	Prosthesis	0.07
6	Arthroplasty	0.06
7	Total joint arthroplasty	0.05
8	Diagnosis	0.05
9	Complication	0.04
10	Prevention	0.04

the perioperative period, but many have offered different results, and there is no mature regimen to recommend (4).

The treatment of infection after TKA mainly includes anti-infective treatment and surgical treatment (8). Anti-infective treatment should be based on the results of drug susceptibility tests, patient tolerance, and drug side effects to choose a personalized therapy (24). According to different infection stages and surgical treatment options, the treatment time of anti-infection agents is also different (25). The 2018 International Infection Consensus recommends that antibiotics for prosthesis-sparing debridement should

be used for no less than 6 weeks during the acute infection period (7), and for methicillin-resistant *Staphylococcus aureus* (MRSA), parenteral antibiotics and oral rifampicin should be used for 1 to 6 weeks, followed by oral rifampicin and highly bioactive drugs for 3 months (7). Patients with acute dry containment infections with gram-negative bacteria should also receive 6 to 12 weeks of antibiotic treatment according to the type of microorganisms (7,26). In addition, the consensus also recommends that in the treatment of tuberculosis infection physicians must cooperate with infectious disease experts to choose

Top 25 Keywords with the Strongest Citation Bursts

Figure 8 Top 25 keywords with the strongest citation bursts.

antibiotics based on the drug resistance of the pathogen (a combination of four antibiotics is recommended), and the use duration should be at least 6 months (7). The first choice for the treatment of fungal infections is the second-stage revision. Antifungal drugs should be used for no less than 6 weeks between revisions, and antifungal drugs should be taken orally for 3 to 6 months after revision, while for patients who cannot tolerate surgery or whose function cannot improve, or those who refuse surgery, long-term oral antibiotics instead of surgery can be considered (7,26). In addition to drug anti-infective treatment, some patients require surgery (27). Surgery is recommended for acute infection with prosthesis preservation debridement, and chronic infection with secondary revision (7,28). While knee fusion may also allow for limb salvage, it sacrifices the function of the knee joint and can only be used as an adjuvant treatment for infection control (7).

This study showed an overview of related research on infection after TKA. The results of this analysis suggests that while there are many countries and institutions participating in the research on this topic, and cooperation between countries and institutions is extensive, as

mentioned earlier, there is a lack of high-level evidence. Keyword analysis results show that the focus of research in recent years has not changed significantly, suggesting there have been no significant breakthroughs in prevention and treatment. Therefore, research in this field requires further in-depth exploration, and should combine the latest basic scientific research results, artificial intelligence technology, and other measures, while designing more randomized controlled trials to provide stronger high-level evidence, which might be the focus of research in the future.

There are some limitations to this research. Firstly, the study employs descriptive research, only showing the current research situation in this field from a macro perspective, and it is impossible to conduct a detailed analysis of every document. Therefore, it is impossible to clearly analyze the specific links between the documents. In addition, due to the limitation of the search strategy, some documents may be missed. However, this also puts forward new requirements for the documentation of records, because, according to our analysis, the current use of keywords and subject terms is quite confusing. There may be multiple ways of expressing the same meaning, resulting

in the irregular use of subject terms and keywords, which brings difficulties to comprehensive bibliometric analysis.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at <https://dx.doi.org/10.21037/apm-21-2278>). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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