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Evolution and Hotspots in Bilateral Total Joint Arthroplasty Research: A Bibliometric Analysis

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Background: Total joint arthroplasty (TJA) is a potent treatment for degenerative joint disorders. Bilateral total joint arthroplasty (BTJA) encompasses both bilateral total knee arthroplasty (BTKA) and bilateral total hip arthroplasty (BTHA). Both BTKA and BTHA can be performed as either a simultaneous procedure or a staged procedure. The goal of this study was to investigate trends in BTJA research, including pertinent authors, journals, countries, and papers. We also evaluated frequent keywords and topics to predict potential future study fields.

Methods: Articles published between 1982 and 2022 were retrieved from the Web of Science Core Collection of Clarivate Analytics. The search query included "hip" OR "knee" (Topic) AND "arthroplasty" OR "replacement" (Topic) AND "bilateral" OR "simultaneous" (Topic) AND 1992–2022 (Year published) AND Article (Document type). Metrics were imported for further analysis with Bibliometrix and VOSviewer.

Results: A total of 736 articles associated with BTJA were retrieved, originating from 44 countries with the United States being the biggest contributor. Top institutions were Cornell University and Ewha Womans University. Kim YH was the most productive and impactful author. *The Journal of Arthroplasty* had the highest impact and the greatest number of articles and citations. Williams Russo had the most cited article. Co-occurrence visualizations highlighted predominant topics in the literature.

Conclusions: Since 1982, there has been a growing interest in BTJA research. The United States institutions have been the primary providers in global scholarly production. This bibliometric analysis identified previous, present, and emergent tendencies in BTJA with the goal of forecasting new potential hotspots.

Keywords: *Bibliometrics, Arthroplasty, Replacement, Hip, Arthroplasty, Replacement, Knee, Trends*

Total joint arthroplasty (TJA) is an effective procedure to treat end-stage osteoarthritic joint diseases.[1] Common degenerative osteoarthritis joint diseases include osteoarthritis of the hip or knee.[1,2] Bilateral TJA (BTJA) includes bilateral total knee arthroplasty (BTKA) and bilateral total hip arthroplasty (BTHA).[3] BTJA can be performed in either simultaneous or staged procedures.[4,5] Simultaneous BTJA procedures are performed in 1 operative and hospital course. Staged procedures are performed with a postoperative recovery interval prior to a second procedure, frequently requiring another hospitalization admission and anesthesia episode.[4,5]

Total hip arthroplasty (THA) is a successful cost-effective treatment for end-stage hip osteoarthritis and other hip degeneration disorders with a high benefit-risk ratio.[2] THA procedures have been increasing in the last decade in

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the United States (US), increasing 105% between 2000 and 2014.[6] The demand is further expected to increase 71.2% by 2030, approaching 635,000 procedures yearly.[6] Approximately 42% of patients diagnosed with osteoarthritis of the hip frequently have degenerative abnormalities in the contralateral joint, often necessitating interventions in bilateral hips.[7] Although THA has a proven track record of safety and efficacy, complications can occur. A meta-analysis by Ramezani et al.[2] demonstrated that when compared to staged BTHA, simultaneous BTHA resulted in a reduction in deep vein thrombosis (DVT) and pulmonary, local, and systemic complications, but an increased risk of pulmonary embolism and periprosthetic fractures.

The current epidemiology of total knee arthroplasty (TKA) is 4.0 million in the US, accounting for 4.2% of the age over 50 population.[1] The projected number of TKA in the US is expected to increase from 500,000 procedures in 2005 to 3.48 million in 2030.[1] There has been a growing demand for simultaneous BTKA despite the predominant procedure of staged BTKA.[1] Compared to those of staged BTKA, advantages of simultaneous BTJA are decreased anesthesia episodes, hospitalization admissions, and rehabilitation time with greater patient-reported satisfaction.[1] However, compared with staged BTKA, simultaneous procedures showed an increased risk of complications and mortality.[1]

This study aimed to examine the trends in BTJA research. The authors sought to identify the relevant authors, journals, countries, and articles. Moreover, it evaluated the most common keywords and themes to highlight trends in research attention throughout this period and attempt to predict probable future topics of interest. We posited a tendency towards emphasis on double-blind TJA research, outcomes, perioperative complications, and morbidity/mortality minimization.

METHODS

Sources of Data and Search Strategy

Web of Science (WOS) Core Collection of Clarivate Analytics was utilized due to its widespread usage as a source with access to detailed information. A query of the literature utilized the Science Citation Index Expanded (SCI-Expanded) and the Social Science Citation Index (SSCI). The search terms included "hip" OR "knee" (Topic) AND "arthroplasty" OR "replacement" (Topic) AND "bilateral" OR "simultaneous" (Topic) AND 1992-2022 (Year Published) AND Article (Document type). In order to minimize possibility of omission, this search utilized articles as the document type and indexes of SCI-Expanded and SSCI within the timeframe of 1982–2022. The search terminology was identified on the basis of published articles on BTJA.

Data Extraction

Two authors (FHN, MMEO) completed the data screening, and all pertinent information for the subsequent analysis was collected. Bibliometric information collected include title, authors, journal published, citations, references, institution, countries, abstracts, publication year, and impact factor.

Bibliometric Analysis

WOS database's bibliometric indicators were retrieved in excel format and importation for additional analysis. Data deficiencies were cross-referenced against the WOS database. Country-specific categories were used to group information from diverse areas of interest. Data visualization of co-authorship, topic trend, co-citation, dual-map overlay, thematic map, and knowledge maps of scientific production and thematic evolution was performed with VOSviewer (version 1.6.19.0; Leiden University) and Bibliometrix (University of Naples Federico).

RESULTS

Publication Data

WOS database search retrieved 736 articles associated with BTJA published between 1982 and 2022, with an average of 20.35 citations per document. Fig. 1 demonstrates the upward trend in global scientific production with an annual growth rate of 8.69% (Fig. 1). The biggest increase in publication was in 2020–2021 (23 papers), followed by 2008–2009 (15 papers), 2010–2011 (14 papers), and 2018–

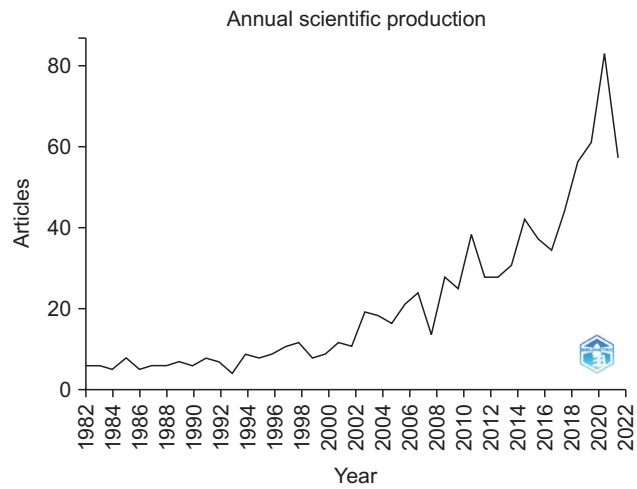

Fig. 1. Annual scientific production showing an increase in global article production in bilateral total joint arthroplasty.

Table 1. Global Scientific Production

Region	Frequency
US	496
China	196
South Korea	160
India	104
Japan	93
Türkiye	87
UK	61
Denmark	49
France	46
Australia	45
Italy	39
Canada	27
Pakistan	23
Iran	20
Germany	18
Saudi Arabia	18
New Zealand	17
Switzerland	16
Singapore	15
Thailand	14
Sweden	8
Ireland	7
Norway	7
Belgium	6
Austria	5
Greece	5
Malaysia	5
Croatia	4
Israel	4
Netherlands	4
Poland	4
Serbia	4
Spain	4
Finland	3
Lebanon	3
Indonesia	2
Portugal	2
Chile	1
Egypt	1
Hungary	1
Kuwait	1
Myanmar	1
Nepal	1
Sudan	1

2019 (13 papers).

Countries

Table 1 illustrates global scientific production. Published articles originated from 44 countries with the US being the greatest contributor (30.5%). The top 10 producing countries following the US were China (12%), South Korea (9.8%), India (6.4%), Japan (5.7%), Türkiye (5.3%), UK (3.7%), Denmark (3.0%), France (2.8%), Australia (2.8%), and Italy (2.4%). The US had the greatest number of citations (n = 6,212) (Supplementary Fig. 1) and highest yearly production (Fig. 2)

Institutions/Authors

A total of 767 institutions published a minimum of 1 manuscript on BTJA. Fig. 3 demonstrates the top 3 institutions with Cornell University contributing the most with 113 articles, followed by Ewha Womans University of South Korea with 29 articles and Hospital for Special Surgery with 26 articles. The greatest annual production was from Cornell University in 2013, 2015, and 2022 with 16, 12, and 12 articles, respectively. This was followed by Ewha Womans University with 5 articles in both 2007 and 2009 and Hospital for Special Surgery with 4 articles in 2018 and 2022 (Fig. 3).

In total, 2,648 researchers contributed in the BTJA literature. The most productive authors were Kim YH (38) and Kim JS (27), both from The Joint Replacement Center of Korea, Kwan Jin-Gu, Seoul (Supplementary Fig. 2). The most frequently cited authors were Sculco TP (349), followed by Parvizi J (286), Memtsoudis SG (278), Della Valle AG (203), and Kim YH (193) (Supplementary Fig. 3). The most impactful authors by h-index were Kim YH (24),

followed by Kim JS (20), Sculco TP (15), Memtsoudis SG (13), and Husted H (11) (Supplementary Fig. 4).

Journals

In total, 148 journals contributed with BTJA-specific articles. Within the list of journals, the *Journal of Arthroplasty* had the greatest number of articles and citations with 161 articles and 3,236 citations, followed by *Clinical Orthopaedics and Related Research* with 45 articles and 2,747 citations and *Journal of Bone and Joint Surgery-American Volume* with 41 articles and 2,414 citations. The most frequently cited sources and production over time are presented in Supplementary Fig. 5 and Fig. 4, respectively. The greatest annual production from the *Journal of Arthroplasty* in BTJA was in 2020 and 2016 with 12 articles each. The top 5 journals based on the journal impact assessed by h-index include *Journal of Arthroplasty* (35), Clinical Orthopaedics and Related Research (28), *Journal of Bone and Joint Surgery-American Volume* (27), *Journal of Bone and Joint Surgery-British Volume* (21), and *International Orthopaedics* (14) (Supplementary Fig. 6).

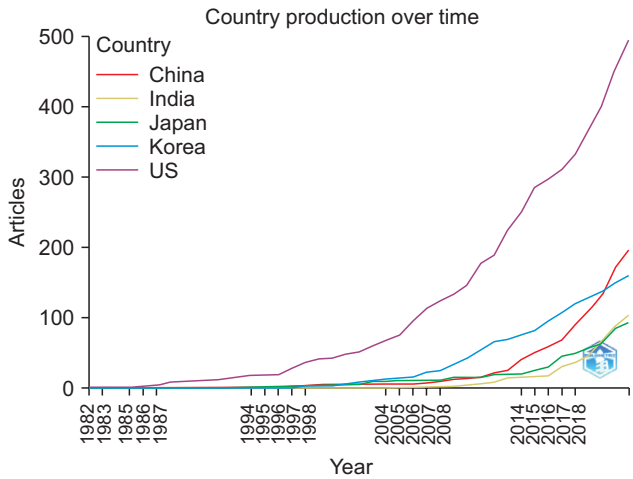

Fig. 2. Country production over time in bilateral total joint arthroplasty research, with the US having the highest yearly production.

Most Influential Articles

The 10 most cited articles are presented in Supplementary Fig. 7, and the most influential article was Williams Russo's in 1992[8] with 224 citations. The biggest burst in citation was noted in the study by Reuben et al.[9] (190) and the study by Restrepo et al.[10] (189).

Keywords

Of the total 1,057 keywords, a total of 40 keywords occurred at least 15 times, with the term "replacement" occurring 310 times (Supplementary Fig. 8). Fig. 5 illustrates the co-occurrence visualization of keywords within BTJA literature. Among retrieved keywords, 44 had enough link in order to form occurrence clusters. As shown in Fig. 5A, the circle's size is proportional to the frequency of occurrence. Fig. 5C shows the density clusters of topics, and Fig. 6 shows the evolution in topic from 1982 to 2022. An evolution in themes as seen in Fig. 6 demonstrates the trend towards double blind studies, tranexamic acid, rates, 2 stage, morbidity, and infection.

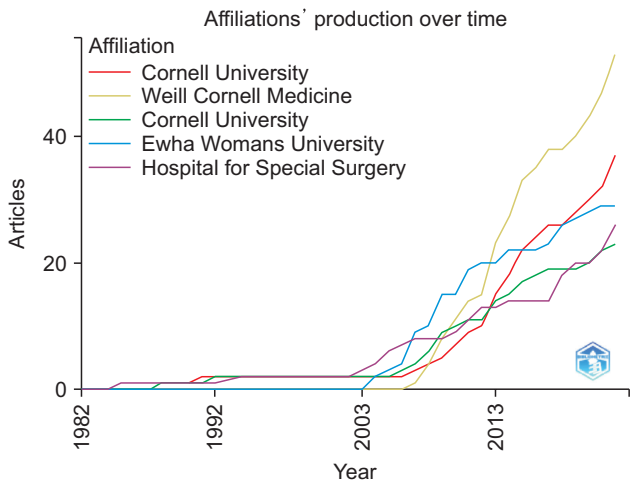

Fig. 3. Affiliations' production over time in bilateral total joint arthroplasty research. The highest contribution was made by Cornell University with 113 articles, followed by Ewha Womans University of South Korea with 29 and Hospital for Special Surgery with 26.

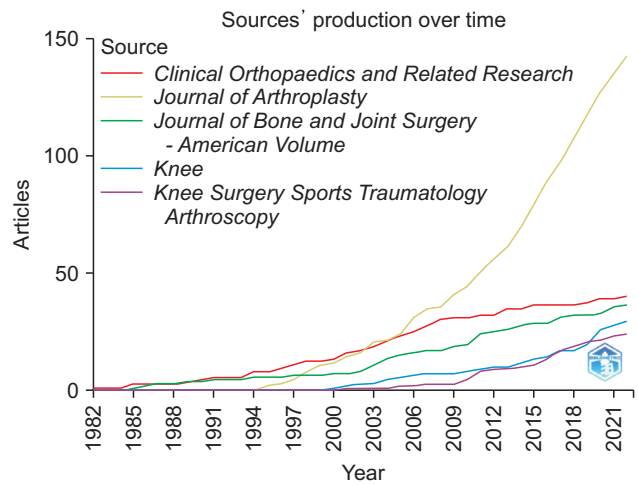

Fig. 4. Sources' production over time in bilateral total joint arthroplasty research showing that the *Journal of Arthroplasty* is leading with the highest cumulative occurrences since 2003.

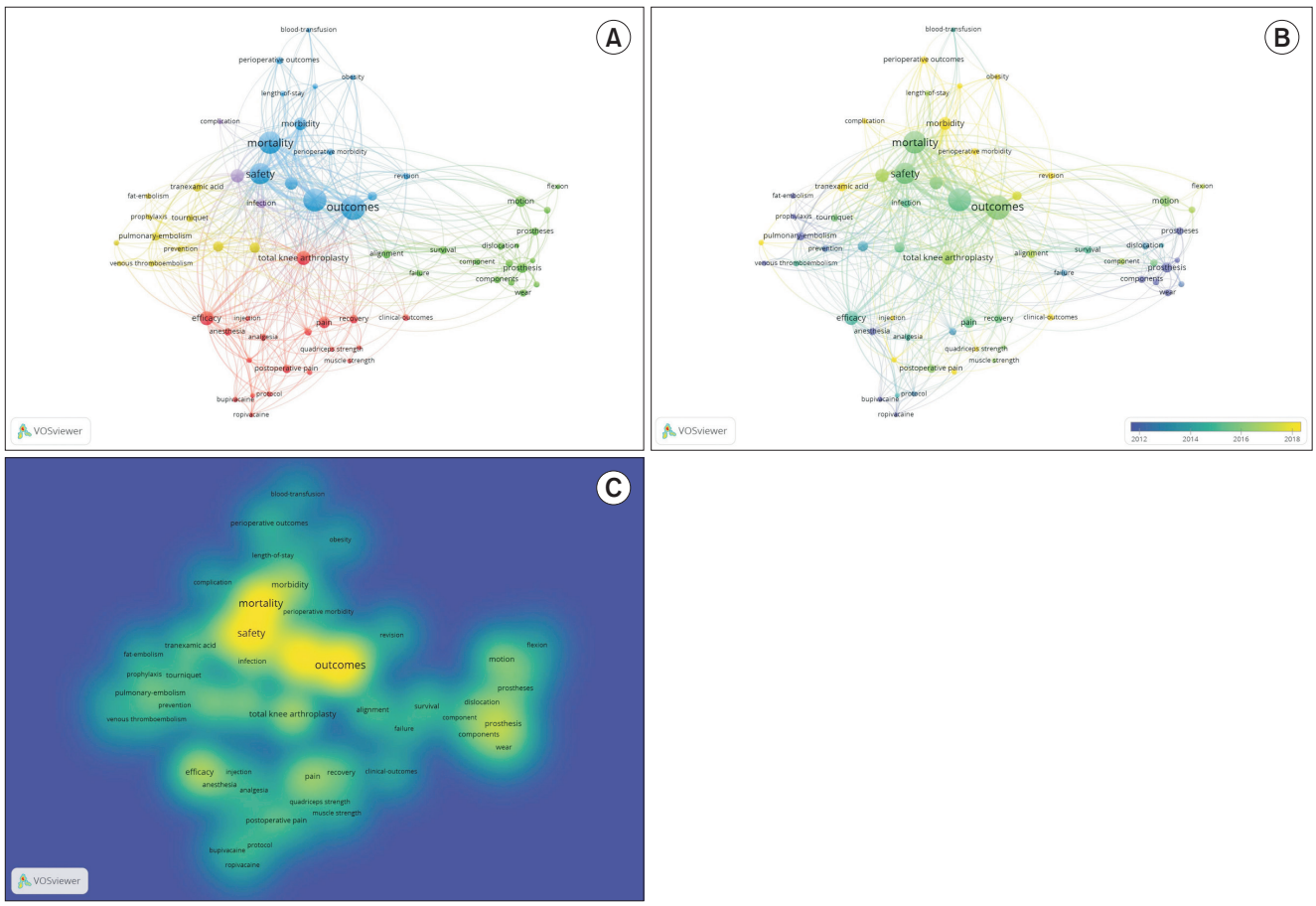

Fig. 5. (A) Keywords co-occurrence overlay in bilateral total joint arthroplasty (BTJA) research with the circle's size being proportional to the frequency of occurrence. (B) Co-occurrence overlay in BTJA showing the thematic keywords evolution from 2012 to 2018. (C) Density clusters of topics in BTJA research showing an emphasis on mortality, safety, and outcomes.

DISCUSSION

This study performed a bibliometric analysis to determine prevailing themes in BTJA research. The relevant authors, articles, collaborations, journals, institutions, countries, and keywords are demonstrated to identify hotspots in the current literature.

An upward trend in global scientific production has been highlighted with an annual growth rate of 8.69%. The greatest burst in publication was in 2021 with 23 papers.

The United States was the most relevant and influential country with the most published papers, yearly production, and total citations. The United States accounted for 30.5% of all publications published globally, with 6,212 total citations. As shown in Fig. 7, global collaborations were predominantly between the United States and other countries with the top 3 collaborating countries including China (9), France (5) and India (3) (Fig. 7).

The primary academic institutions for conducting BTJA research was Cornell University and Ewha Womans University. Kim YH was the most relevant and influential author with 38 total publications and an h-index of 24. Supplementary Fig. 9 depicts collective author production, highlighting Lotka's Law, which demonstrates a decreasing number of authors as the number of articles published increases (Supplementary Fig. 9). Fig. 8 displays a three-field plot depiction of the most relevant articles, frequently cited authors, and associated keywords.

The *Journal of Arthroplasty* was the most relevant and influential within this topic with the highest h-index, total articles, and citations. With 161 total articles, the *Journal of Arthroplasty* was followed by *Clinical Orthopaedics and Related Research* with 45 articles and by *Journal of Bone and Joint Surgery-American Volume* with 41 articles.

This study identified the most common articles with the biggest citation bursts. Identification of these publications is critical for assessing trends in themes and forecasting prospective areas of interest in the future. Most

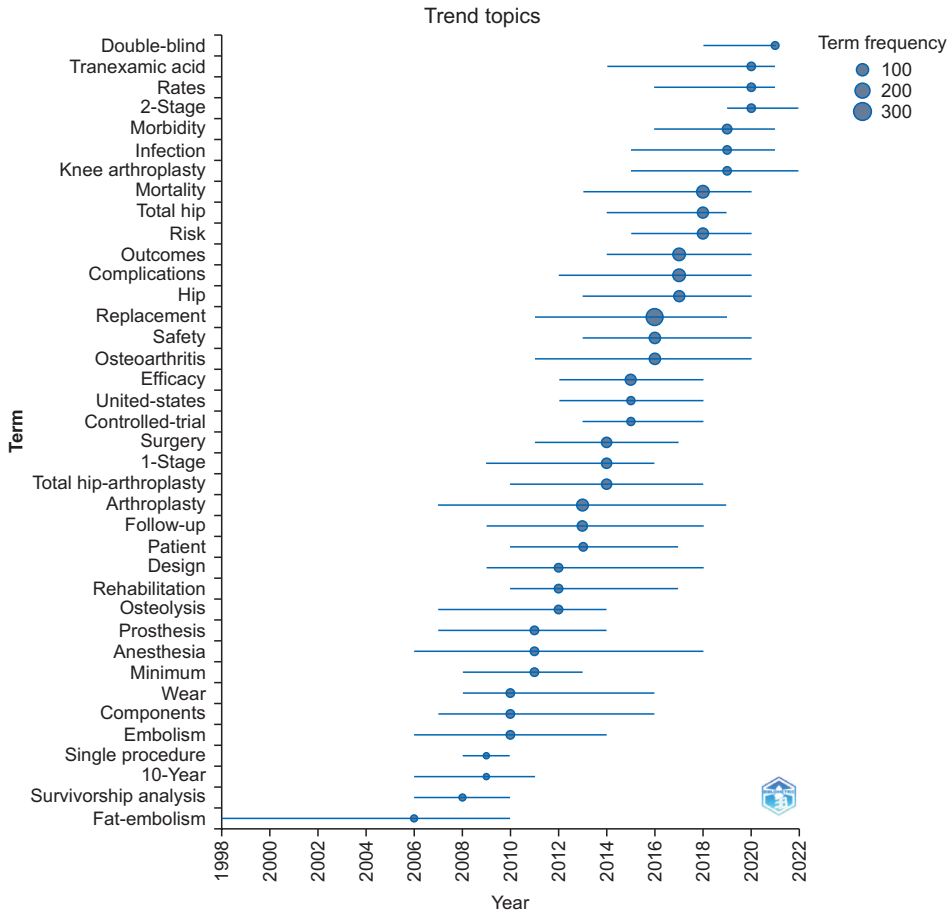

Fig. 6. Trend topics evolution in bilateral total joint arthroplasty research from 1998 to 2022 with an increased focus on "double-blind," "tranexamic acid," "rates," and "2-stage."

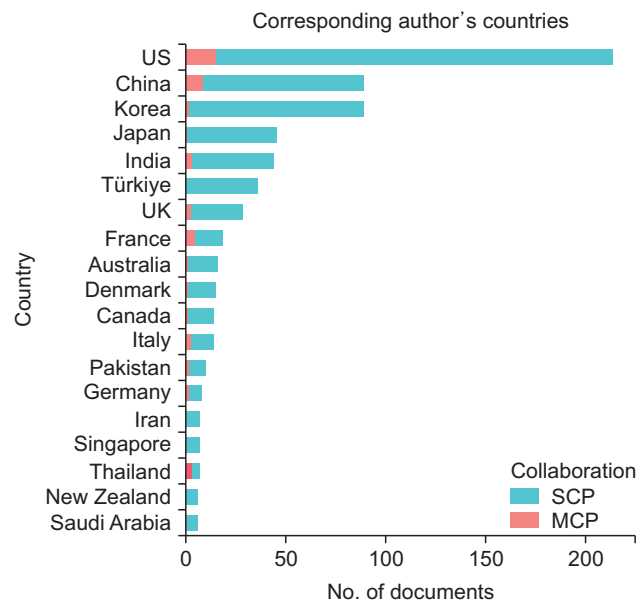

Fig. 7. Corresponding author's countries in bilateral total joint arthroplasty research. Global collaborations with the United States are predominantly with China, France, and India. SCP: single country publications, MCP: multiple country publications.

relevant articles were "Post-operative delirium: predictors and prognosis in elderly orthopedic patients" by Williams-Russo et al.,[8] "Cost comparison between bilateral simultaneous, staged, and unilateral total joint arthroplasty" by Reuben et al.,[9] and "Safety of simultaneous bilateral total knee arthroplasty: a meta-analysis" by Restrepo et al.[10]

Clusters and affiliated keywords are represented in the co-occurrence overlay and density map in Fig. 5. Between 2016 and 2018, "outcomes," "safety," and "mortality" were the most popular keywords. This is consistent with the emerging trend in preoperative optimization to address hazards with protocol development.[11] Fig. 5B displays the keyword clusters and their respective time frames. For example, the General Postoperative Outcomes cluster garnered increasing traction in 2016, with keywords such as "mortality," "outcomes," and "safety," and keyword linkage to "morbidity" and "revision" in 2018.

A relevant keyword search yielded 4 clusters with the following cluster themes categories of perioperative pain management: Component Specific Survivorship and Outcomes Analysis, Perioperative Blood Management, and Clotting Risk and General Postoperative Outcomes.

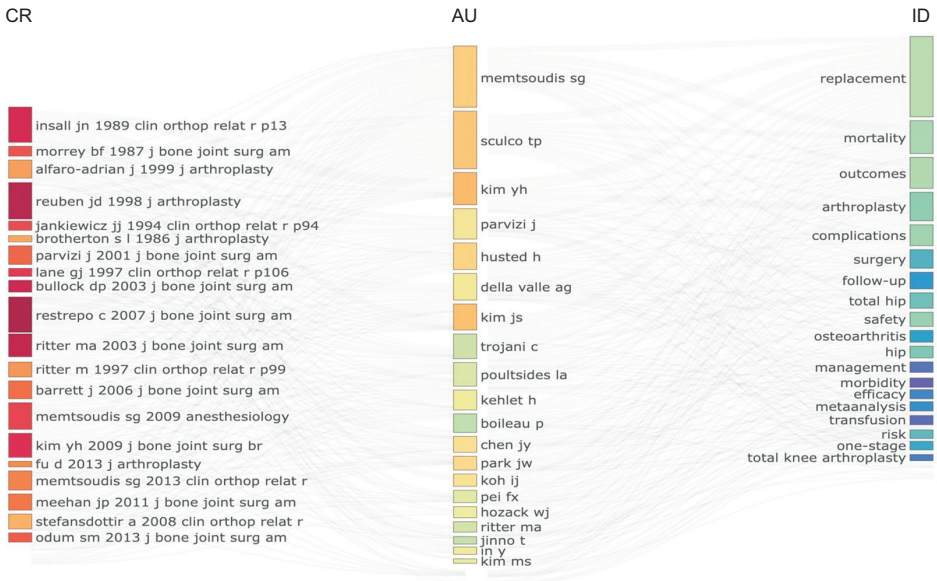

Fig. 8. Three-field plot of the most relevant articles, frequently cited authors, and associated keywords in bilateral total joint arthroplasty research. CR: references, AU: authors, ID: authors' keywords.

Complication, Infection, and Transfusion were labeled as a separate fifth cluster that was connecting Perioperative Blood Management with Clotting Risk and General Postoperative Outcomes, highlighting the correlation of transfusion with infection as a complication that crosses the blood management and outcomes clusters.

Perioperative Pain Management cluster included keywords of analgesia, anesthesia, bupivacaine, local infiltration analgesia, pain management, recovery, ropivacaine, and TKA. Monotherapy alone may not provide postoperative adequate pain relief.[12] The use of multimodal anesthesia played a major role in improving postoperative pain management.[13] This included preemptive analgesia, opioids and COX-2 inhibitors in the preoperative setting, local infiltration analgesia, spinal and epidural anesthesia in the intraoperative setting, and peripheral nerve blockade and/or patient-controlled analgesia in the postoperative setting.[13] Despite the implementation of multimodal analgesia, an optimal protocol has yet to be recommended.[13] Pain management has been a growing theme since 2012 with increased focus on "recovery," "postoperative pain," and "analgesia" around 2016 (Fig. 5B). Additionally, the frequency of the item "anesthesia" appeared at least 100 times with a trend concerning this topic from 2006 to 2018 (Fig. 6).

Component-Specific Survivorship and Outcomes Analysis included keywords of components, dislocation, failure, fixation, fixed bearing, implants, kinematics, motion, reconstruction, survival, and wear. The "survivorship analysis" theme was predominant from 2006 to 2010, with a peak in 2008 (Fig. 6). Levy et al.[14] found a 98.4% mean survivorship at a mean follow-up of 5 years after simultaneous BTKA. A retrospective study by Bohm et al.[15] demonstrated the cumulative rate of implant revision at 3 year postoperatively was higher for unilateral TKA with 2.3%, compared to BTKA with 1.4%. Additionally, a retrospective database study by Namba et al.[16] demonstrated BTKA reduces the chances of requiring revision. This study identified increasing traction towards "outcomes" as one of the most relevant words with 115 occurrences from 2014 to 2020, with a peak in 2017 (Fig. 6). Further research with higher quality evidence is needed to elucidate the effect of BTJA.

Perioperative Blood Management and Clotting Risk cluster included keywords of blood loss, DVT, fat-embolism, pulmonary embolism, transfusion, tranexamic acid, and THA. Concerns about postoperative anemia and subsequent blood transfusion can be observed in a study by Villa et al.[17] who suggested BTHA increased transfusion rate by 6 compared to staged THA. A study by Zhang et al.[18] demonstrated that blood loss and transfusion rate were significantly decreased in simultaneous BTHA using a hypotensive anesthesia with a mean arterial pressure of 70–80 mmHg compared to standard general anesthesia. Therefore, hypotensive anesthesia is an effective option for perioperative blood management.[18] Hatano et al.[19] demonstrated no significant difference in the occurrence of DVT 7 days postoperatively after BTHA or unilateral THA without anticoagulation therapy. In simultaneous BTKA, the use of closed suction drains increases the risk of infections, needs nursing care, and may compromise physiotherapy.[20] Replacing drains with tranexamic acid injections

significantly reduced the postoperative anemia and transfusion rate while avoiding possible complications of suction drains.[20] However, in a retrospective cohort study by Masrouha et al.,[21] simultaneous BTKA had an increased risk of venous thromboembolism and bleeding 30 days postoperatively without increases in mortality compared to unilateral TKA. Further research is needed to determine individual patients' susceptibility factors and further optimization to decrease hazards.[21] The continuous study of perioperative blood management emerges as an evolving cluster in the BTJA literature, with a linkage burst on "tranexamic acid" and "complication" in 2018 (Fig. 5B). Additionally, "Tranexamic acid" is a trending topic 2014 to 2021, with a peak in 2020 (Fig. 6).

The General Postoperative Outcomes cluster included keywords of blood transfusion, BMI, complications, length of stay, morbidity, mortality, outcomes, risk factors, safety, and TJA. Understanding frailty is broadly defined as a "reduction of homeostatic reserves" or "significant decrease in reserve and function various physiological systems."[22] A perioperative assessment of patient's frailty is warranted as frailty is an independent risk factor for complications and longer length of stay.[22] Age over 70 years and history of chronic diseases resulting in severe weight loss may increase clinical suspicion for additional inquiry.[22]

The literature has conflicting findings regarding mortality with some studies reporting simultaneous BTJA resulting in greater mortality rates than staged bilateral procedures[23] and some studies with no significant differences.[24] However, meta-analyses on morbidity and mortality found that simultaneous BTKA is associated with a greater risk of postoperative mortality.[10] Other meta-analyses demonstrated equal rates of thromboembolic, cardiac, and infectious events,[25] yet other studies identified a greater risk of pulmonary and cardiac complications with simultaneous BTKA compared to staged procedures.[10] Staged BTHA is performed in greater frequency compared to simultaneous BTHA.[26] Simultaneous BTHA patients are likely to be younger with lower comorbidity scores.[26] Moreover, in the immediate postoperative period, simultaneous BTHA demonstrated higher estimated blood loss and length of stay compared with unilateral THA, despite similar complication rates.[27] In the global postoperative period, simultaneous BTHA had a higher mortality and revision rate compared to staged BTHA.[28] The co-occurrence overlay demonstrates an increased interest since 2016 in "mortality," "morbidity," "safety," and "outcomes" (Fig. 5B), as mortality and morbidity have been trending topics from 2013 to 2020 with a peak in 2018 and 2016 to 2021 with a peak in 2019, respectively (Fig. 6).

This cluster was determined by the connection of Perioperative Blood Management and Clotting Risk and General Postoperative Outcomes highlighting a correlation between transfusion and complications. These complications demonstrate keyword linkage that crosses between the blood management and outcomes clusters with infection. A retrospective study by Taneja et al.[29] demonstrated allogenic blood transfusion increased surgical-site infection rates in TJA. The actual cause of the relationship between blood transfusion and infection has yet to be determined. Transfusion-induced immunomodulation has been hypothesized as a possible factor.[29] Allogenic transfusion induces the release of interleukin (IL)-4 and IL-10 resulting in the inhibition of the Th1 response, which is crucial for immunological activity.[29] Other authors argue that blood product storage generates suppression from leukocytes including T-cell anergy.[29] Another theory suggests that apoptotic cells may have an immunosuppressive effect.[29] The precise mechanism behind immunomodulation remains unknown.[29] Postoperative hemorrhage management by the orthopedic surgeon is essential to minimize further complications and infection risk. Staged BTHA with hypotensive anesthesia and tranexamic acid administration can be an effective strategy to minimize blood loss while optimizing outcomes.[18] As shown in Fig. 6, the topic "infection" has been an emerging subject since 2015 with a peak frequency in 2019 (Fig. 6).

Since 1982, there has been an increasing traction in BTJA research. This increased interest encouraged participation from foreign nations and various institutions. The United States remains the leading contributor to worldwide scientific production. Cornell University and Ewha Womans University are the most relevant institutions in BTJA research. Kim YH, Kim JS, and Sculco TP were the most impactful authors, and the *Journal of Arthroplasty* was the most influential journal within this topic. This study analyzed keywords to evaluate pain management, survivorship, blood management, postoperative outcomes, and infection risk. This bibliometric study determined the past, current, and emerging patterns in BTJA with the aim of predicting future hotspots. However, despite the increasing number of publications, one must see whether or not the outcomes of these procedures are improving with time.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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SUPPLEMENTARY MATERIAL

Supplementary material is available in the electronic version of this paper at the CiOS website, www.ecios.org.

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