



Trends and hotspots in intra-articular injection for arthroscopic procedures: A bibliometric perspective

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Abstract

Background: Bibliometric analysis and visualization tools were used to determine the development trend of intra-articular injection in arthroscopic treatment over the past 20 years, to guide researchers to explore new directions and hotspots in the field in the future.

Method: The Web of Science Core Collection was searched for all articles on the use of intra-articular injection in arthroscopic treatment from 2000 to 2024. Qualitative and quantitative analysis was performed using Web of Science, Vosviewer, and Citespace software.

Result: After excluding non-articles such as reviews and letters, and non-English language articles, 1007 articles were finally included. Over the past two decades, the number of publications on the use of intra-articular injection in arthroscopic treatment has increased. The United States, China, the United Kingdom and Italy have made significant contributions in this field. The most prolific institution was Rush University. The Journal of Arthroscopic and Related Surgery published the largest number of papers. The Journal of Arthroscopic and Related Surgery was also the most cited. The authors with the highest average output and citation frequency were Cole, Brian J, and Choi, Yun-Jin. "Arthroscopy", "osteoarthritis" and "cartilage" were the three most frequent keywords. From the keyword analysis, the current research trend indicates that the primary research hotspots of intra-articular injection in arthroscopic treatment are arthroscopy, osteoarthritis, and cartilage. The frontiers of this field are pain management, osteoarthritis, and cartilage repair and regeneration.

Conclusion: Over the past 23 years, the use of intra-articular injection in arthroscopic treatment has received increasing attention. The results of our bibliometric analysis provide valuable information and research trends for researchers in the field to understand the basic knowledge of the field, and identify current research hotspots, potential collaborators, and future research frontiers.

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Keywords: Intra-articular injection; Arthroscopic treatment; Vosviewer; Bibliometric analysis; Citespace; Web of science.

Introduction

By the mid-1980s, several advantages of arthroscopy over open surgery had been established, making it the preferred treatment method when appropriate [1-4]. Early research indicated that arthroscopy typically resulted in less pain and postoperative swelling compared to open surgery, and it often lowered the risk of complications such as infection and arthrofibrosis, enabling patients to return to work and normal activities more quickly [5]. It is widely accepted that the optimal management of osteoarthritis involves a combination of nonpharmacologic and pharmacologic treatments, including acetaminophen, non-steroidal anti-inflammatory drugs, or selective COX2 inhibitors [6,7]. For patients with inadequate response to analgesics and anti-inflammatory drugs, or contraindications to these medications, intra-articular therapy serves as a viable alternative [8]. To enhance pain relief and recovery after arthroscopy, intra-articular injections have been employed [9]. After therapeutic arthroscopic knee surgery, the combined use of intra-articular local anesthetic, morphine, and methylprednisolone has proven rational and effective in reducing pain and inflammation, thereby shortening recovery time following arthroscopic meniscectomy [10,11].

Osteoarthritis (OA) is a common and debilitating joint disease with limited therapeutic options available in clinical practice [12]. Recent research indicates that exosomes derived from Mesenchymal Stem Cells (MSCs) can reduce the severity of OA in animal models, suggesting that MSC-derived exosomes could be a promising treatment strategy for OA [13]. Another study evaluated the safety and feasibility of intra-articular autologous tolerogenic Dendritic Cells (toIDC) in patients with inflammatory arthritis and an inflamed knee, finding that IA toIDC therapy was safe, feasible, and well-accepted by patients [14]. Additionally, a therapeutic case series study assessed the clinical outcomes of intra-articular injection of stem cells combined with arthroscopic lavage for treating knee OA in elderly patients. The results showed that adipose-derived stem cell therapy was effective in promoting cartilage healing, reducing pain, and improving function in elderly patients with knee OA [15,16].

Shoulder stiffness, commonly known as frozen shoulder, can result from various factors. While conservative treatment is typically the first line of action, arthroscopic capsular release may be necessary for cases of refractory stiffness. Postoperative rehabilitation is essential for achieving satisfactory outcomes [17-

19]. A network meta-analysis was conducted to determine the most effective treatment for arteriovenous Temporomandibular Disorders (TMDs) [20,21]. The results indicated that minimally invasive procedures, especially those combined with intra-articular injection of adjuvant pharmacological agents, were significantly more effective than conservative treatments in reducing pain and improving mouth opening in TMD patients [22,23].

Bibliometrics is a valuable tool for evaluating published articles using mathematical and statistical methods, and it has been widely applied across various medical disciplines [24]. This method allows beginners to gain an intuitive, systematic, and comprehensive understanding of the development and hot trends in a specific field [25]. CiteSpace and Vosviewer are software programs that visualize information to identify and present emerging trends [26]. These tools are easy to obtain, operate, and interpret, making them popular for bibliometric analysis and other research areas [27]. Currently, research on intra-articular injection in arthroscopic treatment primarily focuses on mechanisms and clinical observations. However, there is a lack of clear analysis regarding hotspot trends and intuitive structural displays in this field. This study aims to analyze the application of intra-articular injection in arthroscopic treatment over the past 23 years using bibliometric analysis. By presenting authors, publishing institutions, keywords, and other elements in the form of knowledge maps, the study seeks to provide a comprehensive understanding of the research background, predict future development trends and hotspots, and offer references for further related research.

Methods

Data collection and search strategy

Given that the Web of Science (WoS) is a prominent academic database widely used for bibliometric analysis, we selected the WoS core collection as our literature source [28]. The search covered the period from 2000 to 2024. Our search strategy was as follows: TS = (Joint injection OR intra-articular therapy OR intra-articular injection or intra-synovial injection) and TS= (Arthroscopic or Arthroscopy or Arthroscope). This search yielded 1106 studies, of which 1007 articles were exported for records and cited references in plain text format. As all data utilized in this study were obtained from public databases, ethics committee approval or informed consent was not required. The detailed retrieval strategy is outlined in Table 1.

Table 1: Data sources and flow of retrieval strategy.

Content	Web of science core collection	Number	
Data sources	2000.1.1-2024.2.24		
Publication date	English only		
Languages	Article and Review		
Document Type			
Search strategy			
	#1	18233	TS = (Joint injection or Intra-articular therapy or Intra-articular injection or Intra-synovial injection)
	#2	31166	TS = (Arthroscopic or Arthroscopy or Arthroscope)
	#3	1106	#1 and #2
	#4	1072	Document types: (Article and Review)
	#5	1011	Language: (English)
	#6	1007	Year: 2000-2024

Statistical analysis

Information on annual publications and journal distributions was obtained from the WoS database, and the chart of annual publications was generated using Origin Pro 2023. Vosviewer 1.6.18 software was selected to batch import Chinese and English literature data, dynamically adjusting the author's publication value for optimal display [29]. We utilized Overlay Visualization and Network Visualization for visualization and analysis. Association Strength was chosen as the parameter in the Method functional area, with dynamic adjustments to the Attraction and Repulsion parameters to achieve the best display effect [30]. In the Clustering functional area, we set the Resolution and Min. cluster size parameters to 1.00 and 1, respectively, while also adjusting the Scale, Labels, Lines, and Colors parameters in the Visualization Display functional area to enhance clarity and aesthetics [31].

For the bibliometric analysis using CiteSpace 6.2R7, we selected the "Full Record with Cited References" option, exporting the fully documented and cited reference data from the WoS database to a "plain text" file for import into CiteSpace [32]. Parameters were set to split time slices by one year, using the cosine algorithm to calculate network uniform strength and extract the top 10% of targets in each time slice [33]. Node type selection and keyword threshold (Top N) were set to 50, with the g metric (k=10) used for extraction node thresholds, while default values were applied to all other parameters [34]. Pathfinder and pruned slice networks were employed to crop each slice and merge the networks, highlighting significant network structures. The LSI algorithm was utilized to cluster literature keywords, identifying the top-ranked title words as cluster labels [35].

Results

Annual publication outputs and trends

Research in the field of intra-articular injection in arthroscopic treatment primarily focuses on basic scientific research and clinical studies. As shown in Figure 1, which plots the annual distribution of publications with the year on the x-axis and the number of publications on the y-axis, the continuous exploration of intra-articular injection in arthroscopic treatment is depicted. From 2000 to 2004, the number of publications was the lowest, ranging between 14 and 24 per year. However, since 2005, the number of publications has steadily increased, reaching 61 in 2019 and 74 in 2021. This trend indicates growing interest and attention in the study of intra-articular injections in arthroscopic treatment.

In terms of citation frequency, the period from 2000 to 2004 experienced low citation numbers, ranging from 1 to 120 citations per year. Since 2005, citation frequency has shown a significant upward trend, reaching 2,410 citations in 2019 and 3,144 in 2021. This rise suggests that the research outcomes on intra-articular injections in arthroscopic treatment have gradually gained recognition and are being increasingly cited in both academic and clinical settings.

It is noteworthy that both the number of publications and citation frequency exhibit a slight decline starting from 2022. This may be attributed to progress made in the field leading to a saturation of hot topics or increased competition from other emerging research areas. Nonetheless, research on intra-articular injections in arthroscopic therapy continues to maintain a high level of output and impact.

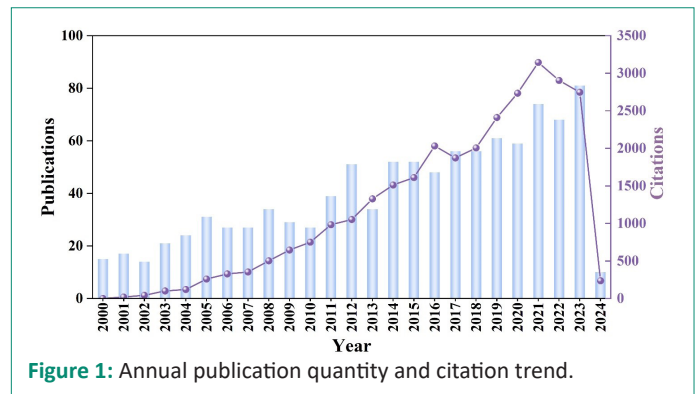


Figure 1: Annual publication quantity and citation trend.

Analysis of countries

The 1,107 articles in this study originated from 68 different countries or regions. The United States (USA) was the most prolific, contributing 350 articles, followed by China with 93 articles, and England with 63 articles. Italy and Turkey ranked fourth and fifth, with 59 and 56 articles, respectively.

In terms of total citations, the USA led with 10,171 citations, followed by England with 2,218, Italy with 2,145, South Korea with 2,094, and Scotland with 2,033 citations. Figure 2 illustrates that the size of the node circles corresponds to the level of centrality. This visualization suggests possible collaborative networks, with the USA leading in article volume, citation frequency, and link strength.

The USA's dominance in both the number of publications and citation frequency highlights its significant research activity and impact in the field of intra-articular injections in arthroscopic therapy. The high citation count further underscores the substantial influence of US research on the academic community.

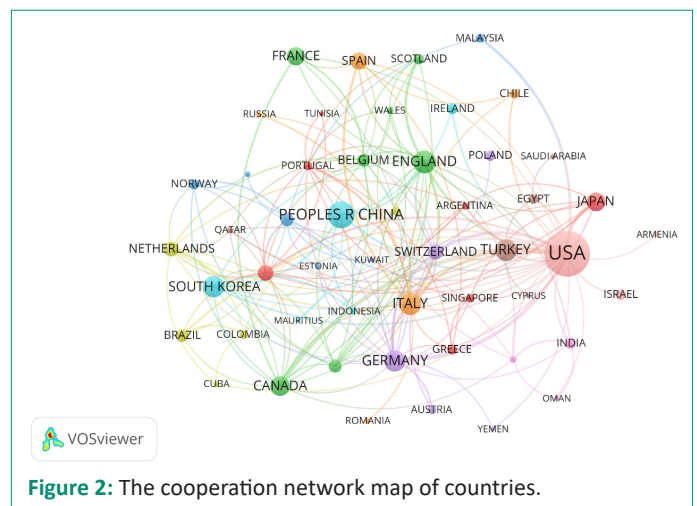


Figure 2: The cooperation network map of countries.

Analysis of institutions

A total of 1,471 institutions have been involved in research on intra-articular injections. The top five institutions in terms of publication volume were Rush University (20 publications), Hospital for Special Surgery (18), Mayo Clinic (17), Stanford University (14), and McMaster University (13). Notably, all but McMaster University are based in the USA.

Figure 3 highlights the intricate and extensive collaboration among these institutions, revealing that Rush University leads in publication count, citation frequency, and link strength, indicating its significant partnerships with other research entities. Despite the strength of these institutions in scientific research, the limited connectivity between nodes suggests relatively weak overall collaboration among institutions. Rush University stands

out as the most active and influential institution in this field, showcasing its leadership, substantial research foundation, and strong collaborative efforts in the study of intra-articular injections in arthroscopic treatment.

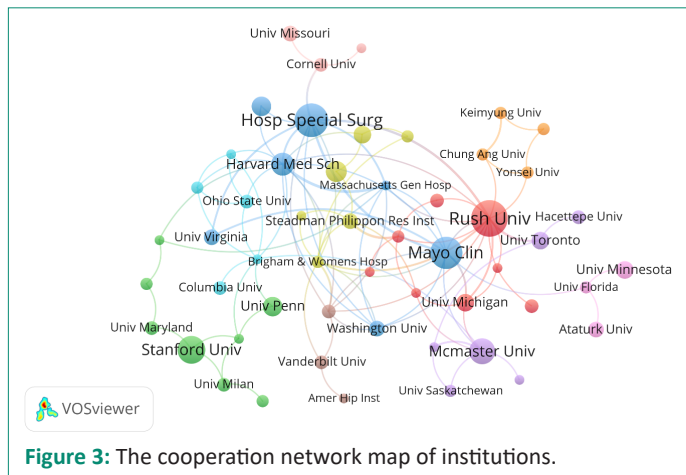


Figure 3: The cooperation network map of institutions.

Analysis of journal

Figure 4 illustrates the collaborative network of journals focused on the application of adjuvant injections in arthroscopic treatment. Journals serve as crucial platforms for disseminating research findings and fostering collaboration, significantly contributing to the advancement of scientific knowledge. Between 2000 and 2024, 323 journals published research on intra-articular injections in arthroscopic therapy. Table 2 lists the top 10 journals in this field, highlighting their impact.

Arthroscopy: The Journal of Arthroscopic & Related Surgery led with 78 publications on intra-articular injections in arthroscopic therapy. Knee Surgery, Sports Traumatology, and Arthroscopy ranked second with 50 publications but was only fourth in citation frequency (1,517). The Impact Factors (IF) of these top 10 journals range from 0.9 to 5.3. Among them, four journals have an IF greater than 4.0, six have an IF between 1.0 and 4.0, and one journal has an IF below 1.0. The Journal of Bone and Joint Surgery-American Volume has the highest IF of 5.3

among the top 10 journals based on the number of publications.

Figure 5 presents the dual-map overlay of the literature, where the left clusters represent the journals where the records were published, and the right clusters indicate the citation sources. The dataset reveals four main citation paths, predominantly covering the following domains: (1) Medicine, Medical, Clinical, and (2) Neurology, Sports, and Ophthalmology. The literature was most influenced by the following domains: (1) Molecular Biology and agents; (2) Health, Nursing, and Medicine; and (3) Psychology, Education, and Social. This multidisciplinary influence underscores the diverse perspectives contributing to the citation landscape.

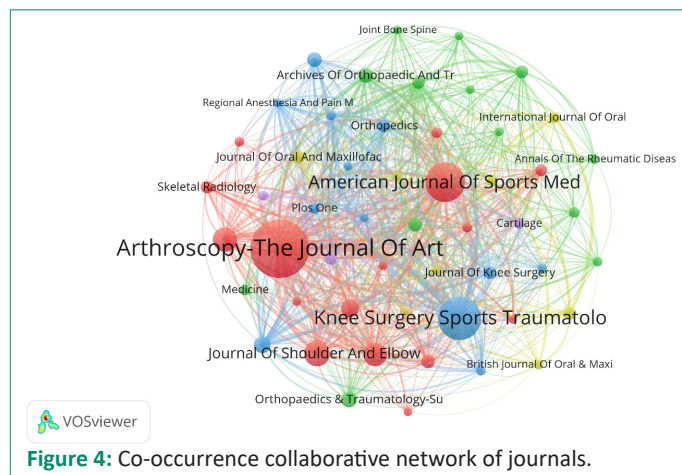


Figure 4: Co-occurrence collaborative network of journals.

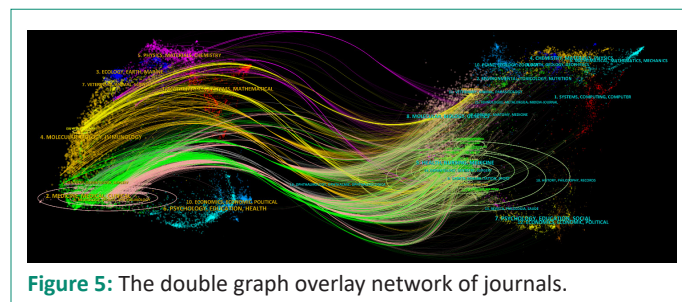


Figure 5: The double graph overlay network of journals.

Table 2: Top 10 Journals with publications related to intra-articular injections in arthroscopic therapy between 2000 and 2024.

Rank	Journal	Publications	TC	IF (2022)	JCR
1	<i>Arthroscopy: The Journal of Arthroscopic & Related Surgery</i>	78	2928	4.7	Q1
2	<i>Knee Surgery, Sports Traumatology, Arthroscopy</i>	50	1517	3.8	Q1
3	<i>American Journal of Sports Medicine</i>	44	1819	4.8	Q1
4	<i>Journal of Shoulder and Elbow Surgery</i>	24	771	3	Q2
5	<i>BMC Musculoskeletal Disorders</i>	22	573	2.3	Q2
6	<i>Orthopaedic Journal of Sports Medicine</i>	21	230	2.6	Q2
7	<i>Journal of the American Academy of Orthopaedic Surgeons</i>	14	581	3.2	Q1
8	<i>Journal of Bone and Joint Surgery-American Volume</i>	13	500	5.3	Q1
9	<i>Orthopaedics & Traumatology: Surgery & Research</i>	12	219	2.3	Q2
10	<i>Archives of Orthopaedic and Trauma Surgery</i>	11	76	0.9	Q3

Analysis of authors and cooperative relationship

Analyzing the authors of the included literature provides insights into key researchers and the primary contributors to this field. The top three authors with the highest number of publications are Brian J. Cole (9), Brian C. Werner (8), and Jourdan M. Cancienne (7). In terms of citation frequency, the leading authors are Yun-Jin Choi (722 citations), Yong-Gon Koh (722 cita-

tions), Elizaveta Kon (507 citations), and Giuseppe Filardo (505 citations).

Brian J. Cole from Rush University, the most prolific author, has concentrated on clinical research, particularly focusing on hyaluronic acid and platelet-rich plasma for managing knee osteoarthritis. Figure 6 presents the collaboration network of prominent authors. It reveals that Brian J. Cole and Brian C.

Werner, who rank first and second in publication volume, have a close collaboration. However, overall, there is limited cooperation among authors in this field, indicating a relatively disconnected network. To advance research in this area, enhancing collaboration among scholars is recommended.

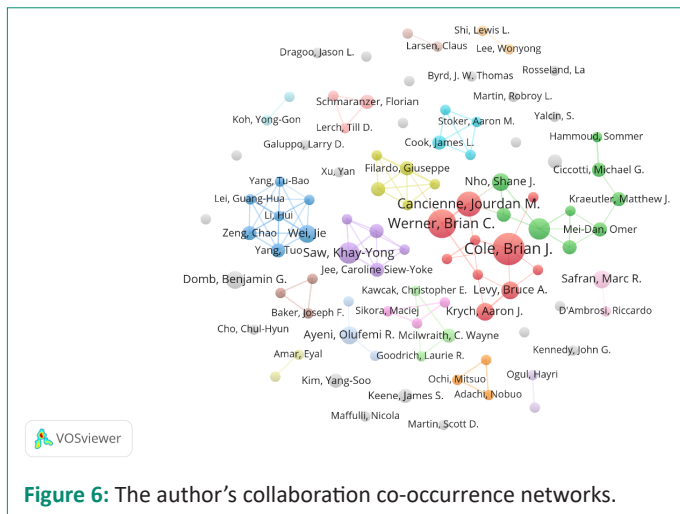


Figure 6: The author's collaboration co-occurrence networks.

Discussion on research hotspots and trends

Discussion on disciplinary hotspots

Based on the results generated by Cite Space, an analysis of the frequency, centrality, and temporal development of relevant disciplines provides insight into the application of adjunct injections in arthroscopic treatment. Figure 7 illustrates the interdisciplinary co-occurrence diagram, with the following observations:

Orthopedics (485 occurrences, centrality 0.16): Orthopedics is a primary discipline investigating the use of intra-articular injections in arthroscopic treatment. High research activity in this field was observed in 2000, indicating early and substantial interest. The sustained high centrality of Orthopedics suggests its fundamental role in the study of arthroscopic procedures involving intra-articular injections.

Surgery (288 occurrences, centrality 0.36): As a central discipline in arthroscopic surgery and associated treatments, Surgery exhibited significant research activity in 2000. The elevated centrality underscores its pivotal role in developing and applying intra-articular injections within arthroscopic treatments.

Sport Sciences (275 occurrences, centrality 0.17): Sport Sciences, focusing on sports and related injuries, saw a relatively high research frequency in 2000. This reflects the relevance of intra-articular injections in managing sports injuries. Despite a decline in research frequency over time, sports sciences continue to maintain notable centrality.

Rheumatology (86 occurrences, centrality 0.05): This discipline, which explores arthritis and rheumatic diseases, had a lower frequency of research in 2000 but demonstrated some centrality. This indicates an emerging recognition of the role of intra-articular injections in treating rheumatic conditions.

Medicine, General & Internal (73 occurrences, centrality 0.23): Encompassing a broad range of internal medicine research, this discipline showed increased activity from 2003 onward. This trend reflects growing attention to the clinical applications and efficacy of intra-articular injections in broader medical contexts.

The analysis indicates that Orthopedics, Surgery, and Sport Sciences play significant roles in the research on intra-articular injections in arthroscopic treatment. The temporal emergence and centrality of these disciplines align with key research trends and hotspots. Initially focused on surgical applications and efficacy evaluations, research has progressively shifted toward clinical applications and evaluations.

Overall, research on intra-articular injections in arthroscopic treatment has evolved from a focus on surgical aspects to a broader clinical perspective. Future investigations may further delve into these disciplines to enhance the understanding and application of intra-articular injections in arthroscopic therapy.

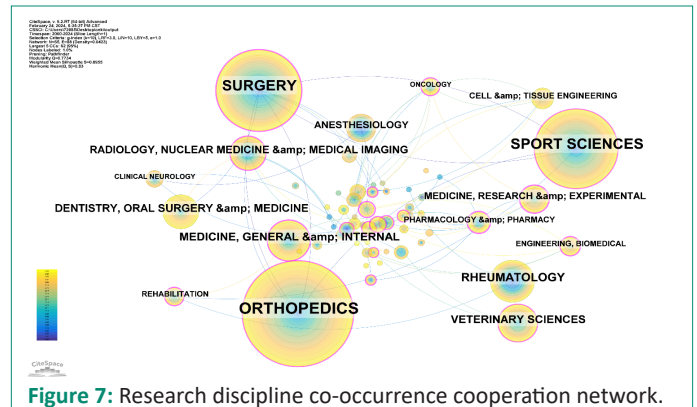


Figure 7: Research discipline co-occurrence cooperation network.

Analysis of keyword

Keywords serve as the fundamental topics of published research articles, and their co-occurrence analysis provides insights into the relationships between different research topics within a field [38]. The co-occurrence network of keywords, depicted in Figure 8, consists of 457 nodes and 1,537 lines, where the lines represent co-occurrence relationships between keywords, with line thickness indicating the frequency of co-occurrences. The analysis reveals that high-frequency keywords include "mesenchymal stem cell" (649), "in vitro" (304), "differentiation" (295), "stem cell" (234), "bone marrow" (213), "expression" (211), "stromal cell" (208), "repair" (176), "bone" (136), and "marrow stromal cell" (134). Keywords with the highest centrality are "tissue engineering" (0.09), "collagen" (0.08), "transplantation" (0.07), "defect" (0.07), "marrow" (0.07), "bone marrow" (0.06), "cell" (0.06), "bone morphogenetic protein 2" (0.06), "injury" (0.06), and "expression" (0.05).

Keyword clustering analysis further simplifies these keywords into clusters based on their co-occurrence network, as shown in Figure 9. The clusters, each containing more than 15 nodes and with silhouettes greater than 0.8, represent distinct research topics. The structural features between clusters highlight key nodes and reflect the primary research hotspots and trends in the field.

In the context of intra-articular injections for knee Osteoarthritis (OA), a systematic review assessed the long-term safety of common treatments. Findings indicated that lifestyle modifications, including weight loss and exercise, presented a low risk of harm and offered beneficial long-term outcomes [39]. Intra-articular hyaluronic acid and corticosteroids also demonstrated low risk and positive long-term outcomes [40], whereas nonsteroidal anti-inflammatory drugs were associated with an increased risk of medical complications [41].

For postoperative pain management following shoulder arthroscopy, a systematic review identified interscalene nerve

Cluster 6: Focusing on 2008, this cluster involves keywords related to intra-articular injection, local anesthesia, arthroscopic partial meniscectomy, and toxicity. The association of these keywords with intra-articular injections underscores their potential applications in these areas.

Cluster 7: Concentrated in 2016, this cluster includes keywords related to mesenchymal stem cells, regenerative medicine, cell therapy, amniotic tissue, and tissue matrix. The presence of these keywords indicates the significance of intra-articular injections in regenerative medicine and related fields.

Cluster 8: Highlighting 2013, this cluster involves keywords related to mesenchymal stem cells, hyaluronic acid, articular cartilage, arthroscopic drilling, and hyaline cartilage. The connection of these keywords with intra-articular injections suggests their importance in cartilage repair and related treatments.

Cluster 9: Focusing on 2011, this cluster includes keywords related to pain management, hip arthroscopic surgery, peri-iliac injection, preoperative analgesia, and intra-articular analgesia. The presence of these keywords indicates the critical role of intra-articular injections in pain management for hip arthroscopic surgery.

Cluster 10: Concentrated in 2008, this cluster involves keywords related to joint activity, anesthesia, primary frozen shoulder, corticosteroid injection, and double-blind. The association of these keywords with intra-articular injections underscores their significance in treating primary frozen shoulder and similar conditions.

Cluster 11: Highlighting 2013, this cluster includes keywords related to the rotator cuff, knee, joint pain, and nonsteroidal anti-inflammatory drugs. The presence of these keywords indicates the importance of intra-articular injections in managing these conditions.

Cluster 12: Focusing on 2005, this cluster involves keywords related to intra-articular injection, magnesium sulfate, anti-inflammatory effects, hyaluronic acid, and analgesic effects. The connection of these keywords with intra-articular injections underscores their potential in managing inflammation and pain.

Cluster 13: Concentrated in 2002, this cluster includes keywords related to the knee, radio assimilation, synovectomy, and arthroscopic synovectomy. The association of these keywords with intra-articular injections highlights their relevance in treating these conditions.

Through the analysis of these clusters, it is evident that research on intra-articular injections in arthroscopic treatment primarily focuses on pain management, osteoarthritis, cartilage repair, and regeneration. These research directions are crucial for improving the effectiveness of arthroscopic treatments and enhancing patient quality of life. Continued research on intra-articular injections in arthroscopic treatment is essential to advance this field further.

Evolutionary trends in hot topic research

The keyword timeline visualization map is pivotal in illustrating the relationships between clusters and the historical span of keywords within each cluster [49]. The research timeline for the application of adjuvant injection in arthroscopic treatment, depicted in Figure 11, arranges nodes in the same cluster in chronological order on a horizontal line, with time indicated at the

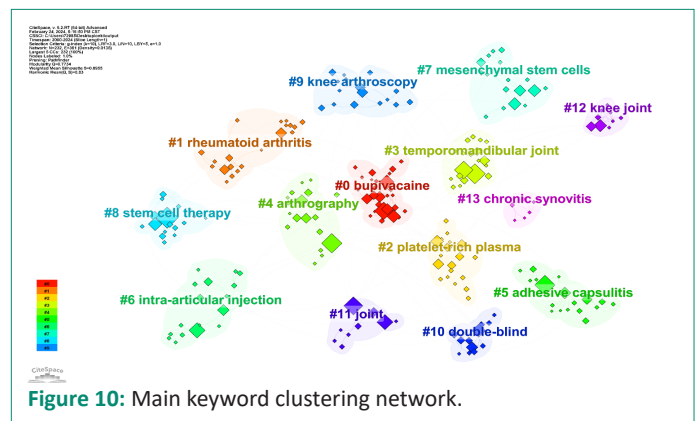


Figure 10: Main keyword clustering network.

top of the view. Nodes positioned further to the right denote more recent research [50]. This timeline visualization allows for a clear understanding of the historical development and trends in the application of adjuvant injections in arthroscopic treatment.

In 2004, the keyword “Osteoarthritis” appeared 126 times with a high centrality (0.13), highlighting the significant attention given to intra-articular injection research in treating osteoarthritis during that year. Similarly, “Arthroscopy” emerged 112 times in 2001 with high centrality (0.23), indicating that the application of intra-articular injection in arthroscopic surgery began garnering substantial interest in 2001. Additionally, “Pain” demonstrated high centrality in 2003, and “Hyaluronic acid” in 2007, reflecting the focus on pain management and cartilage protection through intra-articular injections during these years.

Between 2000 and 2002, keywords such as “Injection,” “Knee,” “Joint,” and “Bupivacaine” were notably frequent, indicating heightened research interest in injection methods for intra-articular injections, knee joint conditions, joint diseases, and local anesthetics. From 2003 to 2005, keywords like “Double-blind,” “Outcome,” and “Intra-articular injection” became more prominent, signifying attention to double-blind studies, efficacy evaluations, and studies on intra-articular injections in arthroscopic treatment during this period.

From 2000 to 2004, research on intra-articular injections in arthroscopic treatment primarily focused on osteoarthritis, arthroscopic surgery, pain management, and cartilage protection. These research directions are crucial for enhancing the effectiveness of arthroscopic treatments and improving patients’ quality of life. Future research should continue to delve into these areas and foster collaboration among different themes to further advance the field of intra-articular injections in arthroscopic treatment.

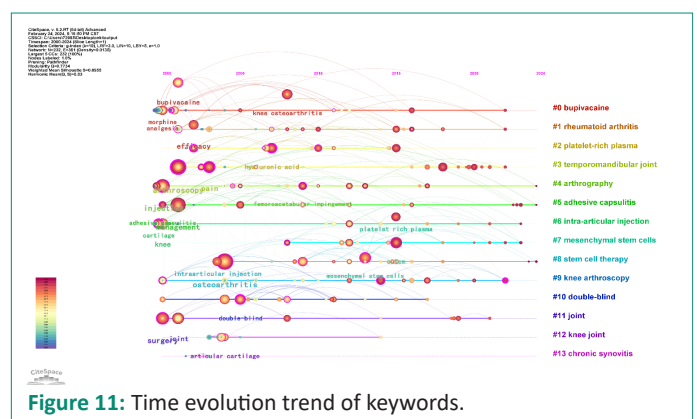


Figure 11: Time evolution trend of keywords.

Research hotspots and emerging topics

Citespace's keyword emergence analysis is a powerful method for identifying the frequency and correlation of keyword appearances in literature, revealing hotspots and trends in the research field of adjuvant injection in arthroscopic treatment [52]. Through this analysis, researchers can discern which keywords appear more frequently, indicating the areas of greatest interest and activity within the field. Figure 12 highlights the key research keywords for adjuvant injection in arthroscopic treatment, showing the year and intensity of their emergence, as well as their importance to the research topic.

Keywords with strong citation bursts were identified using Citespace's analysis of strong citation bursts to explore the frontier field of Mesenchymal Stem Cells (MSCs) in orthopedic diseases. As shown in Figure 12, the keywords with the strongest citation bursts included "expression" (2002-2003), "culture" (2002-2003), and "progenitor cell" (2008-2012). More recent burst keywords included "knee" (2014-2021), "platelet-rich plasma" (2015-2021), "osteoarthritis" (2015-2021), and "scaffold" (2018-2021). This highlights the evolving focus in the field, with newer research concentrating on advanced therapies and technologies.

Various therapies aim to reduce symptoms of knee Osteoarthritis (OA), but a cure for the disease remains elusive. A review article evaluated current practices for managing knee OA and discussed emerging therapies, underscoring the importance of a multi-faceted treatment approach and the need for continued research to develop new strategies [53]. A systematic review investigating predictors of outcomes after hip arthroscopic surgery for patients with Femoroacetabular Impingement (FAI) found that younger age, male sex, lower body mass index, absence of preoperative pain, and positive response to preoperative intra-articular hip injections were associated with positive outcomes. Conversely, older age, female sex, higher body mass index, osteoarthritic changes, and undergoing labral debridement alone were predictors of negative outcomes [54,55].

Citespace's analysis calculated the year, intensity, and importance of keyword emergence, offering insights into the development trends and hotspots in intra-articular injection for arthroscopic treatment [56]. Below, we analyze the year and intensity of emergence, the importance of these keywords, and the cooperative relationships between research topics during corresponding years.

The emergence of intra-articular injection in arthroscopic treatment is primarily concentrated between 2000 and 2004. During this period, keywords like "morphine" and "intra-articular morphine" emerged with high intensity, signaling the beginning of explorations into using intra-articular morphine for pain relief in arthroscopic treatment. Concurrently, other related keywords such as "surgery," "postoperative pain," and "knee arthroscopy" appeared, reflecting the clinical emphasis on arthroscopic surgery and postoperative pain management at that time. Additionally, "rheumatoid arthritis" began to emerge in 2001, indicating growing research interest in arthroscopic treatment for rheumatoid arthritis.

Hot areas related to intra-articular injection and arthroscopic treatment include "bupivacaine," "postoperative surgery," "pain relief," and "arthroscopic knee surgery," all of which emerged with high intensity between 2001 and 2004. These keywords indicate that research during this period focused on pain man-

agement, postoperative analgesia, and joint cartilage repair in arthroscopic treatment. Later years saw the emergence of important keywords such as "hyaluronic acid," "mesenchymal stem cells," and "platelet-rich plasma," reflecting the growing interest in these emerging treatment methods.

The development trends and hotspots for intra-articular injection in arthroscopic treatment were predominantly concentrated between 2000 and 2004. The emerging keywords from this period highlight the importance of pain management, postoperative pain, joint cartilage repair, and new treatment methods in arthroscopic treatment. The collaborative relationships between these research fields likely stem from their inter-related roles in clinical practice aimed at improving the effectiveness of arthroscopic treatment and patient quality of life. Future research should continue to explore these areas to further advance the field of intra-articular injection in arthroscopic treatment.

Top 25 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	2000 - 2024
intraarticular morphine	2000	7.53	2000	2005	
surgery	2000	6.83	2000	2005	
postoperative pain	2000	6.1	2000	2008	
knee arthroscopy	2000	4.84	2000	2012	
morphine	2000	4.31	2000	2006	
rheumatoid arthritis	2001	10.51	2001	2011	
bupivacaine	2001	6.09	2001	2010	
knee joint	2003	5	2003	2005	
postoperative analgesia	2004	5.08	2004	2006	
pain relief	2004	4.75	2004	2014	
arthroscopic knee surgery	2001	6.09	2011	2014	
articular cartilage	2004	4.26	2012	2014	
therapy	2004	6.41	2013	2018	
repair	2009	5.36	2013	2016	
hyaluronic-acid	2015	4.34	2015	2019	
pain management	2016	4.64	2016	2017	
mesenchymal stem cells	2013	6.27	2017	2022	
prevalence	2017	5.05	2017	2020	
outcm	2015	7.73	2018	2024	
total knee arthroplasty	2010	4.84	2018	2022	
hip arthroscopy	2014	7.02	2019	2024	
arthrocentesis	2020	6.78	2020	2024	
platelet-rich plasma	2015	5.6	2020	2024	
temporomandibular joint	2018	8.57	2021	2024	
management	2001	6.42	2022	2024	

Figure 12: Keyword hotspot year emergence.

Conclusion

In conclusion, this bibliometric study provides a comprehensive analysis of dynamic structures and emerging trends in major trauma research using the visualization software, CiteSpace. Based on our findings, the leading countries are the United States, Germany, and England, while Asian countries need more investment in the research field. The comprehensive performance of publication volume, citation frequency, and link strength highlights the significant contributions of institutions such as Rush University, which excels in all three aspects. Hospitals such as the Hospital for Special Surgery and the Mayo Clinic also demonstrate importance and contributions in terms of publication volume and citation frequency. Notably, Yonsei Sarang Hospital has a high influence in terms of citation frequency.

In terms of leading researchers, Brian J. Cole leads in publication volume, indicating their high research activity in the field of intra-articular injection. Yun Jin Choi and Yong Gon Koh show outstanding performance in citation frequency, reflecting the high impact of their research. Wei Jie ranks first in link strength, indicating close research collaboration with other authors. Regarding publishing journals, "Arthroscopy: The Journal of Arthroscopy and Related Surgery" ranks first in terms of publication volume, citation frequency, and link strength, underscoring its important position in the field of intra-articular injection.

“Knee Surgery, Sports Traumatology, Arthroscopy” also performs well in terms of article volume and link strength.

Key disciplines such as surgery, orthopedics, and sports sciences play crucial roles in the research of intra-articular injection in arthroscopic treatment. The development trends and hotspots in this field primarily focus on arthroscopy, osteoarthritis, pain management, research on drugs and treatment methods, and the repair and protection of articular cartilage.

To enhance care and guide future research in intra-articular injection therapies, the following recommendations are proposed:

Foster Interdisciplinary Collaboration: Encourage cooperation between different medical and scientific disciplines to integrate diverse perspectives and expertise.

Develop Personalized Treatment Strategies: Tailor treatments based on individual patient characteristics to improve outcomes.

Innovate in Biomaterials and Pharmaceuticals: Continue developing new materials and drugs to enhance treatment efficacy and safety.

Conduct Longitudinal Studies: Perform long-term research to understand the lasting effects and potential risks of intra-articular injections.

Update Clinical Guidelines: Regularly revise treatment protocols to reflect the latest research findings and clinical practices.

Enhance Patient Education and Engagement: Inform patients about treatment options and involve them in decision-making processes.

Explore Emerging Technologies: Investigate new technologies, such as regenerative medicine and advanced imaging techniques, to improve treatment outcomes.

Establish Global Research Networks: Create international collaborations to share knowledge, resources, and best practices across different regions.

These strategies aim to advance the field of intra-articular injection in arthroscopic treatment, ultimately improving patient care and outcomes.

Limitations

This study had the following limitations. According to a study, it is acknowledged that WOSCC is the recommended database for bibliometric analysis. Consequently, data were collected from the WOSCC database, whereas data from other sources such as PubMed, Google Scholar, and Embase were not included. As several newly published and potentially high-impact studies may not have been included in our study, the emerging hotspots and trends in major trauma research may vary with bibliometric data updates.

Declarations

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