ISSN 2618-1584 Vol. 4, Issue 4: 16-25, DOI: 10.25236/FMSR.2022.040404

Global Research Trends in Post-Traumatic Osteoarthritis: A Bibliometric and Visualized Study

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Abstract: *Aim: Post-Traumatic osteoarthritis (PTOA) is a prevalent cause of joint pain and limited movement, significantly lowering people's quality of life. In recent years, with the increase of traffic accidents and accidental injuries, the incidence of articular cartilage injury has increased, and the incidence of traumatic arthritis has greatly increased. This research aims to look into the current worldwide status and trends in this subject. Method: On the Science Citation Index-Expanded Web of Science, the publications about PTOA were searched from 1994 to 2021. The data sources were studied and indexed by the method of bibliometrics. The data sources were studied and indexed by bibliometrics. To visualise, VOS viewer and GraphPadPrism7 software conducted bibliographic coupling analysis, co-authorship analysis, co-citation analysis, co-occurrence analysis, and the analysis of publication trends in PTOA research. Result: A total of 2239 related publications were collected. Globally, the number of papers published each year and the relative research interests are increasing. The cumulative published number of PTOA research accords with Logistic growth model: f(x) =a/(1+eb-cx). The United States contributes the most to worldwide research, receives the most citations, has the highest H index, and has the highest total link strength(TLS). Most papers have been published in the journal Osteoarthritis and Cartilage. The University of Calgary is the institution that makes the greatest contribution. Studies can be divided into four clusters: Mechanism Research, Tissue Engineering, Clinical Study, and Epidemiology. The investment in clinical research is relatively small. Conclusion: The number of publications on PTOA is expected to rise in the coming years, based on current global trends. In this field, the USA Is the biggest contributor. Noteworthy are the latest hot spots, including "Inflammation", "Anterior Cruciate Ligament Reconstruction", "Mesenchymal Stem Cell" and "differentiation". Therefore, there will be more and more studies on the mechanism of PTOA, which may inspire new clinical treatments for osteoarthritis caused by trauma.*

Keywords: *bibliometrics, post-traumatic osteoarthritis, global trend, osteoarthritis, visualized study*

1. Introduction

Post-Traumatic osteoarthritis refers to osteoarthritis that usually occurs after joint trauma, which generally leads to long-term joint pain and dysfunction. According to statistics, 12% of osteoarthritis patients have had joint injuries in the past[1]. In the USA, the number of patients with knee, hip or ankle PTOA disease is close to 6 million, accounting for an annual social expenditure's about $3 billion [2]. About 50% of patients with joint trauma develop osteoarthritis[3]. If left uncontrolled, osteoarthritis can develop to a complete loss of the articular surface, leading to osteoporosis, subchondral sclerosis, osteophyte formation and cyst formation at the bone junction[4]. Joint trauma's most significant effect is articular cartilage injury. Due to the inherent characteristics of a scarcity of chondrocytes and lack of blood vessels in the tissue, the self-repair ability of the tissue is extremely limited[5]. Therefore, the degeneration process after the injury cannot be changed to a large extent. At present, there are many conservative treatments for osteoarthritis after joint injury, including painkillers, physiotherapy, unloaded bracing, intra-articular injection and so on. In order to restore joint function and relieve pain, many scholars have adopted surgery to restore joint stability, but some studies have shown that surgery cannot reduce the risk of PTOA[6]. Many researchers speculate that this is because surgery cannot reverse the molecular and cellular changes in joint tissue caused by injury[7]. However, the global research on the qualitative and quantitative characteristics of PTOA is limited. It is more necessary to evaluate the current

ISSN 2618-1584 Vol. 4, Issue 4: 16-25, DOI: 10.25236/FMSR.2022.040404

situation and trend of PTOA research and predict the promising hot topics and directions in this field. Therefore, it is essential to summarize PTOA research's current situation and predict trends and promising keywords.

The publication is a crucial index to quantify the contribution of scientific research because it is a fundamental component of it. The information and metrological qualities from literature databases are studied using bibliometric analysis, which may be used to quantify and qualitatively evaluate the research community's trend during the period[8]. In addition, bibliometric analysis has become increasingly popular in recent years[9]. Bibliometrics, on the other hand, aids researchers in obtaining a vast amount of data and using it for scientific research performance evaluation[10]. This feasible method has been successfully used to evaluate the research trends of the spine[11], stem cells in osteoarthritis[12], coronavirus[13] and cervical spondylosis[14]. However, the amount and quality of PTAOA study results have not been documented as far as we know. As a result, the goal of this research is to assess the present state and trends in PTOA research.

2. Materials and methods

2.1. Data source

The full text of the article must be typeset in a single column. The Science Citation Index-Expanded of the Web of Science (WOS), widely regarded as the best resource for bibliometrics, is used for bibliometric analysis[12]. Since human and animal subjects are not recruited, ethical approval is not required.

2.2. Search strategy

From establishing the database to June 30, 2021, all papers were retrieved in Web of Science. The search terms used in this study are (TS= (Traumatic osteoarthritis) OR TS= (Post-Traumatic Osteoarthritis) OR TS= (Traumatic OA)) AND (Language=English) AND (Document type=All document types). The data in WOS is used to improve information on publications in certain countries or regions.

2.3. Data collection

We obtained and analyzed complete details from the WOS database (including title, year of publication, authors' names, countries, names of publishing journals, affiliations, keywords, and abstracts), and uploaded them into Microsoft Excel2019. The two authors (YS and WYP) independently filter and extract, enter and collect data. Any differences are resolved through discussion and consensus. Finally, the two writers manually cleaned and analyzed the data in Microsoft Excel2019 and GraphPadPrism7.

2.4. Bibliometric analysis

Bibliometric analysis has become an important tool for global analysis and investigation in various scientific fields and analyzed a large number of literature or research trend using mathematical and statistical methodologies[15]. The WOS function has been used to characterize the basic characteristics of qualified articles listed above. The H-Index is offered as a replacement for existing measuring indicators as the best approach to quantify the impact of scientific research[16]. The H-Index indicates that a scientist or country has published H articles, each cited by other publications at least H times[17]. The logistic growth model: $f(x) = a/(1+eb-cx)$ has stable applicability and the ability to predict future trends[18, 19]. Create a graph of the number of publications over time using GraphPadprism7. The independent variable x denotes the year, and the dependent variable f(x) denotes the total number of publications. The annual number of publications, the top 20 countries globally, authors, institutions, funding agencies, research orientations, total citation frequency, journals, average citation frequency, and H-Index were all examined using Excel2019. For visual analysis of publications, the VOS viewer (Leiden University, Leiden, Netherlands) can be utilized[20], which was previously used for bibliographic coupling, co-citation, co-occurrence analysis and co-authorship.

ISSN 2618-1584 Vol. 4, Issue 4: 16-25, DOI: 10.25236/FMSR.2022.040404

3. Results

3.1. Trends in global publications

3.1.1. Total number of publications worldwide

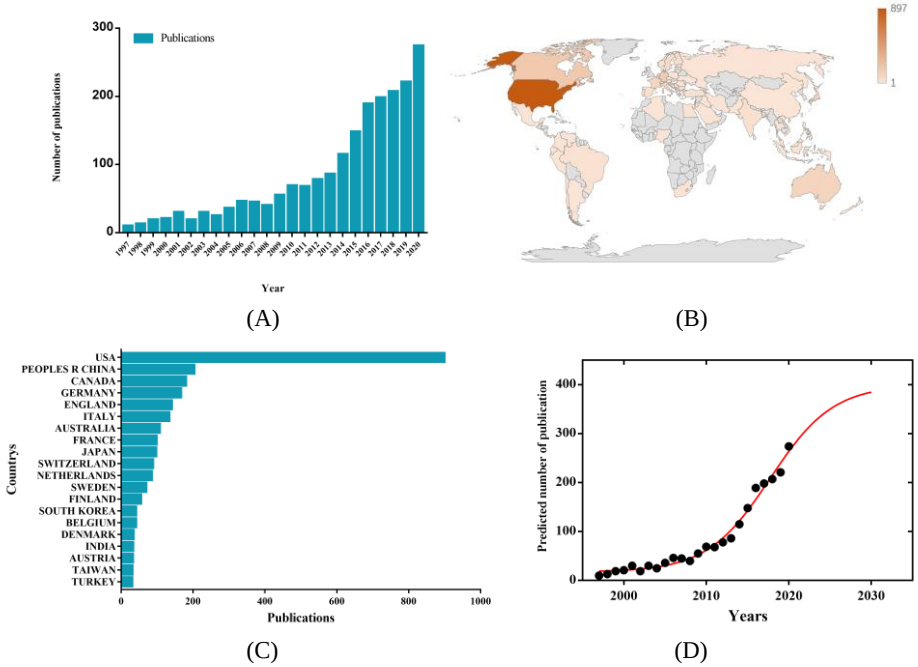
A total of 2239 publications met the search criteria between the database's inception and 2021. In the last five years, the majority of the research has been published (2016-2020, 1089, 48.6%). A substantial trend in annual global publications was discovered from 1997 to 2020. This demonstrates that PTOA research is becoming increasingly concerned (Fig 1A).

3.1.2. Countries' contributions

This field has received grants from 53 nations and regions. The United States published the most related articles (898, 40.11%), followed by China (202, 9.02%), Canada (179, 8.00%), Germany (165, 7.37%), and the United Kingdom (139, 6.21%) among these countries (Fig 1B, C).

3.1.3. Global publication trends

In order to predict the number of future publications, we used the Logistic Regression model to create the time curve. Figure 1D depicts a model fitting curve that forecasts the number of worldwide publications will increase in the following years.



(A) The total number of publications on PTOA and their associated research interests. (B) A world map depicting the spread of PTOA research. (C) The total number of PTOA-related publications in the top 20 nations. (D) Forecasting the number of publications in the future using model fitting curves of worldwide publishing growth patterns on applications.

Figure 1: PTOA contributes to global trends and countries.

3.2. Quality of publications of different countries

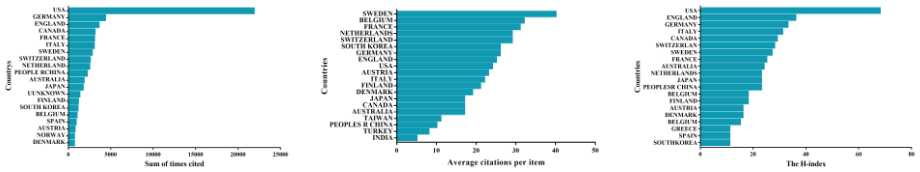
3.2.1. The total number of citations

The United States has the highest full frequency of publication citations (21 860). The United Kingdom (3562), Canada (3100), and France (3025) ranked second, third, and fourth, respectively, in terms of overall citation frequency (Fig 2A). The average citation frequency in Sweden is the highest (40.75). In terms of intermediate citation frequency, Belgium came in second (32.43), followed by France (31.19), the Netherlands (29.39), and Switzerland (29.14). (Fig 2B).

3.2.2. H-index

The highest H-index was found in related papers from the USA (68), followed by the United Kingdom (36), France (33), Italy (33) and Switzerland (29) (Fig 2C).

ISSN 2618-1584 Vol. 4, Issue 4: 16-25, DOI: 10.25236/FMSR.2022.040404



(A) (B) (C)

(A) The total number of citations received by PTOA research publications from various nations. (B) The average number of citations per publication for studies published in various nations. (C) The H-index of different countries' publications.

Figure 2: Different countries' citation frequency and H-index levels.

3.3. Assessing global publications

3.3.1. Journal analysis

The top 1 journal, which published the most studies about PTOA, is Osteoarthritis and Cartilage (impact factor [IF] = 6.58, 2020) with 259 publications. The following journal is the Journal Of Orthopaedic Research (IF = 3.49, 2020) having 118 articles. And 59 articles/45 articles had published in Knee Surgery Sports Traumatology Arthroscopy (IF = 4.34, 2020)/ Journal Of Shoulder And Elbow Surgery (IF = 3.02, 2020). Fig 3a lists the top 20 journals with the most published studies. The top 20 journals with the most published papers are listed in Figure 3A.

3.3.2. Funding source

Figure 3B depicts the top 20 funding sources. The United States Department of Health and Human Services (HHS) supported 322 studies (ranked first), while the National Institutes of Health (NIH) funded 315(ranked second).

3.3.3. Authors

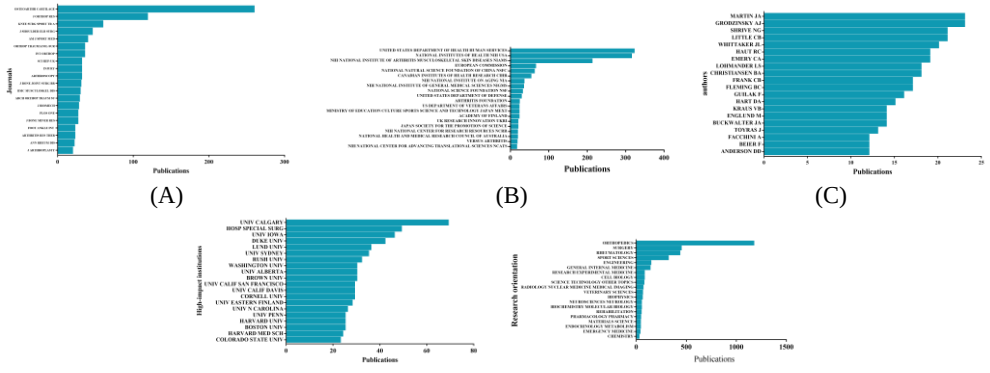
The top 20 authors were responsible for 338 publications, and 15.01 % of all publications in this discipline (Figure 3C). Martin J A and Grodzinsky A J, who each published 23 publications about PTOA, were followed by Shrive N G and Little C B, who published 22 articles about PTOA.

3.3.4. Institution output

The distribution of research orientations connected to PTOA is shown in Fig 3D. Orthopedics, surgery, rheumatology, and sports sciences are the most popular research fields.

3.3.5. Research orientations

The top 20 authors were responsible for 338 publications, and 15.01 % of all publications in this discipline (Figure 3E). Martin J A and Grodzinsky A J, who each published 23 publications about PTOA, were followed by Shrive N G and Little C B, who published 22 articles about PTOA.



(A) (B) (C)

(D) (E)

(A) The world's most prestigious scientific publications. (B) The world's biggest PTOA-related contribution funds. (C) The world's most influential authors. (D) The world's high-impact institutions. (E) The whole of the world's research orientations.

Figure 3: Global research on PTOA: high-contribution journals, research orientations, high-impact institutions, authors and funds.

ISSN 2618-1584 Vol. 4, Issue 4: 16-25, DOI: 10.25236/FMSR.2022.040404

3.4. Analysis of bibliographic coupling

3.4.1. Journal

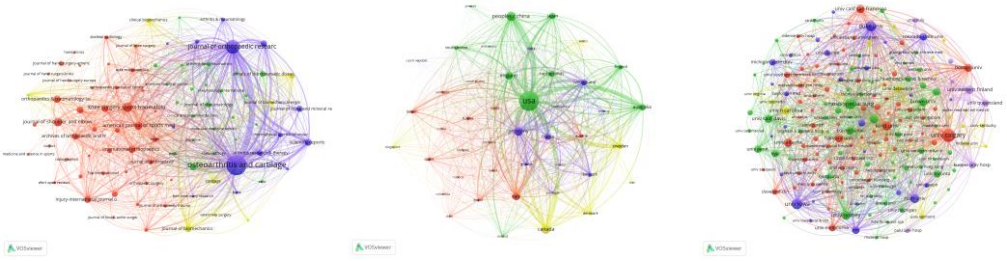
In PTOA research, bibliographic coupling analysis is used to determine the relatedness of things based on the number of references they share and to produce a knowledge domain map to show the collaboration network between them. Each of these sections represents a magazine, with the size of the sphere indicating its level of influence. The spheres are represented by links, with the more robust the bond (the closer the collaboration). Analyze journal names in all articles using the VOS viewer. As illustrated in figure 4A, the overall link strength has 88 elements. Osteoarthritis And Cartilage (TLS =27,914), Journal Of Orthopaedic Research (TLS =25016), Knee Surgery Sports Traumatology Arthroscopy (TLS =6581) were the top five journals with the highest total link strength.

3.4.2. Country

VOS viewer was used to analyze papers published in 44 countries (the minimum number of documents required for a country with more than five) (figure 4C). The United States (TLS =147,718), Germany (TLS =44,215), Canada (TLS =34,993), Australia (TLS =32,938), and China (TLS =31,668) were the top five countries with the highest total link strength.

3.4.3. Institution

Papers published in 186 institutions (the minimum number of documents required for institutions with more than five) were analyzed using the VOS viewer (Figure 4B). Duke University (TLS =23,680), University of Calgary (TLS =20,421), Lund University (TLS =19,599), Hospital Special Surgery (TLS =24,760), and Washington University (TLS =21,654) are the highest total link strength institutions all over the world.



(A) (B) (C)

(A) A map depicting the 88 journals available on PTOA. (B) A map of the 44 countries that make up the PTOA. (C) A map of the 186 PTOA-related institutions. A similarity link between two journals/institutions/countries is established by drawing a line between two points in the figure. The closer the two journals/institutions/countries are linked, the thicker the line.

Figure 4: A bibliographic coupling study of PTOA research from all over the world.

3.5. Analysis of co-authorship

3.5.1. Author

The goal of the co-author analysis is to determine the project's relevance based on the number of co-authors, as well as to generate a knowledge domain map of the main research authors to show their cooperative network in PTOA research, which can provide valuable information for individual researchers looking for partners, research organizations and development cooperation groups, and countries to achieve the goal of academic exchange. The VOS viewer was used to assess 124 authors (the minimum number of documents required for a country with more than five) (figure 5A). Shrive N G (TLS = 54), Hart D A (TLS = 46), Frank C B (TLS = 42), Martin J A (TLS = 36), and Shekarforoush M (TLS = 34) are the top five total link strength writers.

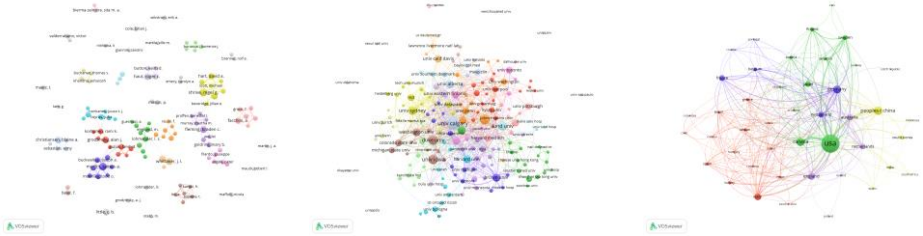
3.5.2. Institution

Studies identified in 184 institutions (the minimum number of documents required for an institution with more than five) were analyzed using VOS viewer (figure 5B). University Calgary (TLS = 72), University Eastern Finland (TLS = 67), Lund University (TLS = 66), Boston University (TLS = 65), and Duke University (TLS = 54) are the top five institutions with the highest total link strength.

ISSN 2618-1584 Vol. 4, Issue 4: 16-25, DOI: 10.25236/FMSR.2022.040404

3.5.3. Country

Analyze publications in 44 countries using VOS reader (the minimum number of documents required for a country with more than five) (figure 5C). USA (TLS = 324), Germany (TLS = 151), England (TLS = 117), Canada (TLS = 100), and Switzerland (TLS = 100) are the top five countries in terms of total link strength.



(A) (B) (C)

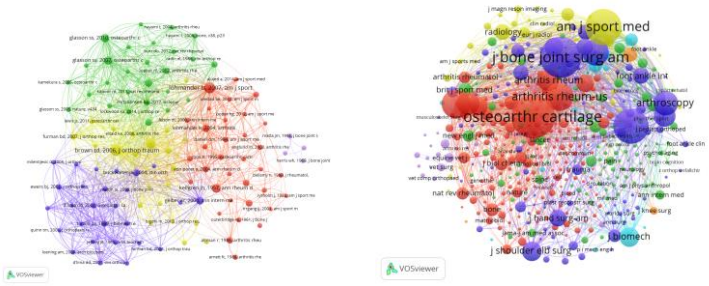
(A) On PTOA, a mapping of the 124 authors' co-authorship analysis. (B) Mapping of the 184 institutions co-authorship analysis on PTOA. (C) Co-authorship study on PTOA mapping for 44 nations. The size of the dots represents the frequency of co-authorship. The line connecting two points in the diagram denotes the establishment of a partnership between two authors/institutions/countries. The thicker the line, the closer the two authors/institutions/countries collaborate.

Figure 5: Co-authorship analysis of PTOA studies from around the world.

3.6. Co-citation analysis

3.6.1. Publication

According to co-citation analysis, the correlation of things is based on the number of times they are co-cited. VOS viewer is used to analyzing 435 references (defined as the minimum number of citations of a cited reference that were utilized more than 20) (figure 6A). The following are the first five studies with high total connection strength: Journal of orthopaedic trauma Nov-Dec 2006;20(10):739-44[2](TLS = 934); Lancet 2007 Dec 22;370(9605):2082-4[21](TLS = 719); Journal of orthopaedic research 2011 Jun;29(6):802-9[22](TLS = 719); Annals of internal medicine 2000 Sep 5;133(5):321-8[23](TLS = 408)and Osteoarthritis Cartilage 2010 Oct;18 Suppl 3:S17-23[24](TLS = 384) are the top studies with high total connection strength.



(A) (B)

(A) A mapping of the field's co-cited references (The 435 points in various colours indicate the 435 references listed). The size of the points represents the citation frequency. A line connecting two places indicates that they were both mentioned in the same paper. A shorter line between the two publications suggests a stronger connection. The same colour points all relate to the same research direction. (B) A mapping of the field's co-cited journals. (The 416 points in various colours reflect the 416 journals recognized). The size of the points represents the citation frequency. A line connecting two locations indicates that they were both mentioned in the same journal. A shorter line between the two journals suggests a closer connection. The same colour points all relate to the same research direction).

Figure 6: Co-citation mapping about PTOA.

3.6.2. Journal

Using the VOS viewer, analyze the names of co-citation journals. A journal is a publication in which a source is cited at least 20 times. There are 416 identified journals, as shown in figure 6B, that surfaced in the overall link strength. Osteoarthritis And Cartilage (total link strength = 219,461 times), Journal of Bone and Joint Surgery (American Volume) (total link strength = 151,215 times), American Journal Of

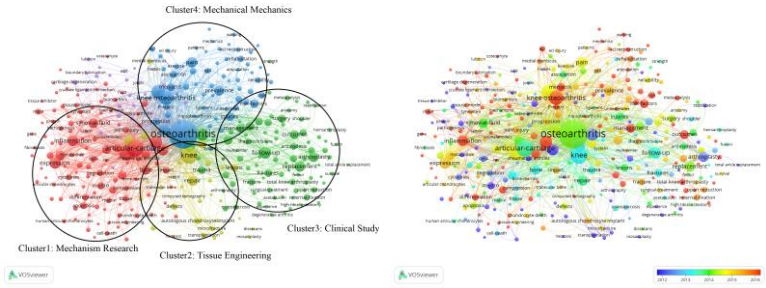
ISSN 2618-1584 Vol. 4, Issue 4: 16-25, DOI: 10.25236/FMSR.2022.040404

Sports Medicine (total link strength = 149,397 times), Clinical Orthopaedics And Related Research (total link strength = 116,846 times), Arthritis And Rheumatism (total link strength = 101,121 times) are the top five journals.

3.7. Analysis of co-occurrence

Co-occurrence analysis describes the internal content and structure of an academic area based on the cluster's relevancy, as well as the field's research boundaries. Popular themes and directions are determined through analysis, which aids in the monitoring and follow-up of scientific research and programs[25, 26]. VOS viewer was used to creating a network map, and keywords used more than 10 times in the titles and abstracts of all papers were analyzed. There are a total of 327 keywords, which were roughly divided into four clusters: "mechanism research", "tissue engineering", "clinical research" and " Mechanical mechanics" (Figure 7A). In the "mechanism research" cluster, the frequently used keywords are: articular-cartilage, cartilage, Post-traumatic Osteoarthritis, Expression, Rheumatoid Arthritis, Synovial-fluid and Inflammation. For the "tissue engineering" cluster, the main keywords are: Repair、Autologous Chondrocyte Implantation、Subchondral Bone、MRI, and Lesions. For the "clinical research" cluster, the main keywords are Joint、Arthritis、Follow-up、Replacement and Arthroplasty. In the " Mechanical mechanics" cluster, the frequently used keywords are Osteoarthritis, Knee Osteoarthritis, Anterior cruciate ligament, Injury, Pain and Prevalence. These results show that the above four directions are the most prominent areas of PTOA in osteoarthritis research.

The VOS viewer colour-codes keywords based on how frequently they appear in all of the publications included (figure 7B). The colour blue denotes that the keyword appears sooner, whereas red indicates that the keyword appears later. Before 2014, most studies concentrated on "mechanism research" and "tissue engineering" in the early stages of the research. According to current trends, "mechanics research" and "mechanical mechanics" will attract a lot of attention in the future.



(A) (B)

(A) Keyword mapping in PTOA research; point size represents frequency, and keywords are divided into four clusters: mechanism research (left in red), tissue engineering (lower in yellow), clinical research (right in green), and epidemiology (upper in blue). (B) Keyword distribution by mean frequency of appearance; blue-coloured keywords appeared earlier than yellow-coloured keywords, while red-coloured keywords appeared later.

Figure 7: Co-occurrence analysis of PTOA studies from around the world.

4. Discussion

4.1. Global publication status and quality

Bibliometrics and visual analysis can present and anticipate the current state of the search field. We can witness the quick development in the field of PTOA research based on the evaluation of contributor countries, institutions, funding institutions, and research focus of PTOA research in this study[27]. The number of papers published each year has increased dramatically, as seen in this study. In addition, in recent years, there has been a rise in interest in related studies. In this topic, 53 countries have published significant research. We forecast the number of publications in the future based on current data. As a result, more comprehensive studies on PTOA will be released in the coming years. Researchers are now encouraged to perform further high-quality studies due to the current optimistic outcomes.

4.2. The trends of PTOA

According to the national contribution analysis findings, the United States has the most publications

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and contributes the most. Orthopedics and the United States Department of Health and Human Services scored top and second regarding the number of papers published in the research direction and funding institutions, respectively. The United States has made the most significant contribution to PTOA research globally in terms of a total number of published papers, total citation frequency, and H index, and may be considered a pioneer and leader in this subject. China is second in terms of overall publications. On the other hand, China is ranked 10th in overall citation frequency and 11th in H-index. The fact that Chinese academic grading systems tend to focus on quantity rather than quality may explain why there are variations in the number and quality of publications[28], causing researchers and doctors to rush to submit articles while ignoring the quality of their work With China's gradual expansion in scientific research funding, the quality of study will improve dramatically, keeping up with global publications in this sector.

When two books have citations from the third book in their references, this is known as bibliographic coupling. We establish the similarity link between diverse articles in this work using bibliographic coupling analysis from three perspectives: journals, institutions, and nations. The core journals of PTOA research may be Osteoarthritis and Cartilage, Clinical Orthopaedics And Related Research, American Journal Of Sports Medicine and Journal of Bone and Joint Surgery (American Volume) (Fig 4A), and the latest research progress in this field is more likely to be reported by the above journals. At the same time, Osteoarthritis And Cartilage is the journal with the most papers, indicating that the journal is at the forefront of international PTOA research.

The University of Calgary, which has the most significant number of total link strengths, is considered the leading institution in PTOA research. The top three institutions with the most published articles in the world are all from the USA, which is consistent with the leading position of the USA in this field. Almost all of the top 20 institutions come from the top five countries. Thus, it can be seen that first-class research institutions' establishment plays an integral part in improving a country's academic level. As shown in Figure 3D, Martin J A and Grodzinsky A J are probably the most significant contributors in this field; we should closely monitor their further research and newly published articles for the latest progress in PTOA research. Cooperative publication of papers is of great significance for promoting scientific research innovation and knowledge sharing and improving scientific research quality. The co-author analysis method assesses collaboration between different countries, institutions, and authors. The higher the total link strength score, the more willing authors, institutions, and countries are to collaborate. For example, Shrive N G, University Calgary and the USA are the best choices for us to work together. The purpose of co-citation analysis is to determine the study's influence based on the number of times it has been cited. The current results show that the iconic research on PTOA has a large total citation frequency and provides a lot of meaningful references. The journal Osteoarthritis and Cartilage is the most widely mentioned in this topic and is well-known.

4.3. Research focus on PTOA

We discovered the research direction and hot issue in this field using co-occurrence analysis. A co-occurrence network map was created using all of the terms found in the study's title and abstract. Figure 7a shows four study directions, including clusters for "mechanism research," "tissue engineering," "clinical research," and "mechanical mechanics." Although this outcome is in line with common sense in this subject, this research can help to clarify future research directions. Keywords like articular-cartilage, cartilage, and Post-traumatic Osteoarthritis are more prevalent with greater weights in the center of the co-occurrence graph. As a result, additional high-quality research on PTOA in these four directions is still required.

The overlay visualization map is similar to the co-occurrence map, but the color of the items is different, corresponding to the time of occurrence; this method is very useful for tracking the research direction. The color denotes the year of publication in Figure 7B's overlay depiction. According to the findings, mechanism research and epidemiology (red) may be the next hot issue in this sector. Based on the results, "Inflammation", "Anterior Cruciate Ligament Reconstruction", "mesenchymal stem cell" and "differentiation" may become popular directions in the study of PTOA, especially those involving Anterior Cruciate Ligament Reconstruction and Inflammation have sprung up widely in recent years[29–31]. Therefore, the research on the mechanism of PTOA and the treatment of osteoarthritis may be the main focus in this field.

ISSN 2618-1584 Vol. 4, Issue 4: 16-25, DOI: 10.25236/FMSR.2022.040404

4.4. Strengths and limitations

The state and trends of PTOA research were analyzed using bibliometric and graphical analysis, which was considered to be relatively objective and complete. However, since non-English publications have been excluded, our study has some limitations, resulting in language bias. Furthermore, due to the low frequency of citations so far, research published in 2021 is not fully included in this analysis, and recently released high-quality articles may not be highlighted. As a result, future studies should concentrate on the most recent findings and non-English publications.

5. Conclusions

The global trend of PTOA is depicted in this study. The United States is the most significant contributor to research and a global leader in this sector. The journal Osteoarthritis and Cartilage has the most articles connected to this topic. More research on PTOA is expected to be released in the coming years. Research into the mechanism of PTOA, in particular, will attract increased focus and become a research hotspot in the future.

Acknowledgement

Grants from Chang Zhi Medical College's 2020 Doctoral Starting Fund helped fund this research. (No. BS2020004).

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