

# Mapping Research in Joint Preserving Procedures of Osteonecrosis of the Femoral Head: A Bibliometric Analysis

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## Research article

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# Abstract

**Background:** There have been increased interests in the joint preserving procedures of osteonecrosis of the femoral head (ONFH). This study aims to present a bibliometric analysis of the publications of this field during this period (1999–2019).

**Method:** Publications related to joint preserving procedures of ONFH were searched from the Science Citation Index-Expanded Web of Science. The data were analyzed by using bibliometric methodology. Additionally, the work made a graphical mapping by using the VOS viewer software. This was used for bibliographic coupling, co-authorship, co-citation, co-occurrence analysis and to investigate the publication trends in this field.

**Results:** A total of 3467 articles were included. The number of publications were increasing globally every year. China made the most publications. But the USA made the highest contributions to the global research with the most citations and the highest H-index. CLINICAL ORTHOPAEDICS AND RELATED RESEARCH had the highest publication number. Studies could be classified into four clusters: process and clinical treatment, risk factors and diagnosis, pathophysiology, and basic research. Pathophysiology and basic research were predicted as the next hot topics in joint preserving procedures of ONFH.

**Conclusion:** Base on the current global trends, it has been growing in a number of publications of joint preserving procedures of ONFH since 1999. The USA was the leading country in global research in this field. Pathophysiology and basic research may be the next hot spots, which need more attention in the future.

## Background

Osteonecrosis of the femoral head (ONFH) is a devastating condition affecting patients mainly in their third to fifth decades of life that usually progresses to cellular death, fracture, and femoral head collapse [1,2]. The processes could be the result of trauma, corticosteroids, alcohol, blood dyscrasias, idiopathic, and miscellaneous factors [3]. But underlying pathogenesis still remains unclear. The incidence of ONFH in UK (1.4 per 100,000) is comparable with Japan (Japan: 1.9 per 100,000) [4,5]. And 20,000 to 30,000 new case were diagnosed each year in the USA [6]. Although ONFH has a low incidence compared with primary hip osteoarthritis, it has a significant disease burden impact because it greatly affects people in the prime of life (33 to 38 years). Besides, spontaneous regression of ONFH is rare. If left untreated, it will lead to complete collapse of the femoral head within 2-3 years, and the vast majority of untreated patients will progress to total hip arthroplasty (THA) [7]. For these reasons, early intervention is critical to stop or reverse the progression of the disease, ultimately preserving joint and preventing the need for THA. The joint preserving procedures of ONFH can be divided into two major branches: Conservative treatment includes pharmacologic agents, biophysical treatments; surgical treatment includes core decompression, vascularized and non-vascularized bone grafting, and proximal femoral osteotomies [8]. However, the global research trends and impact in the joint preserving procedures of ONFH has not been

reported yet. Therefore, there is a need to investigate the global status of the joint preserving procedures of ONFH.

Bibliometrics is a research area of library and information sciences that studies the bibliographic material by using quantitative approaches [9]. It is developed for a wide range and served as an important tool for monitoring research trends, determining the impact of research funding, and comparing research progress in different countries, institutions and so forth [10]. Furthermore, bibliometric analysis is valuable in formulating policy and clinical guideline of various diseases [11]. However, the analysis of bibliometric variables regarding the joint preserving procedures of ONFH remains unclear. Thus, the aim of this study was to provide a full-scale insight into the status quo and global trends of the joint preserving procedures of ONFH. Meanwhile, in order to take a deeper analysis of the bibliometric information, this paper used graphical mapping of the bibliographic data with the purpose of conforming how the leading actors of the publication were connected with each other.

## Materials And Methods

### Data source and search Strategy

It has been consistently accepted that the Science Citation Index-Expanded (SCI-E) of Thomson Reuters' Web of Science (WoS) is the most appropriate database for performing bibliometric analysis [12]. We did a comprehensive search online from 1999 to 2019 by WoS database with document types restricted to articles and reviews. for the sake of avoiding bias resulting from rapidly database renewal, all data were obtained on April 10, 2020. The search strategies were presented as follows: theme = (osteonecrosis of the femoral head OR (femoral head necrosis)) Not theme = (hip replacement OR (hip arthroplasty)) AND Document types = (ARTICLE OR REVIEW). All publications identified were English language.

### Data Collection

Two reviewers independently checked and extracted the entire records of these publications, including the year of publication, authors' names, title, name of publishing journal, affiliations, nationalities, keywords, sum of citations, H-index, and so on. All these were saved as TXT files from the WoS database and then read by Microsoft Excel 2017. Any disagreement was resolved by discussion or turn to help from experts to reach a consensus.

### Bibliometric Analysis

The index of H implied that a scholar or country has published H papers and each of which has been cited in other publications at least H times. Thus, the H-index reflects both the number of publications and the number of citations per publication [13]. We used the Microsoft Excel 2016 to generate prediction model:  $f(x) = ax^3+bx^2+cx+d$  and analyzed the time trend of the publications as well as the tendency in the future based on the cumulative number of publications. In this formula, the symbol x refers to the year, and f(x) represents the cumulative amount of papers by the year.

## Visualized Analysis

As a software tool, VOS viewer (Leiden University, Leiden, The Netherlands) was used for constructing and visualizing bibliometric networks of the publications [14]. Furthermore, it is an optimal method for analyzing the correlation of highly cited references with productive authors. We used VOS viewer for bibliographic coupling, co-authorship, co-citation and co-occurrence analyses.

## Results

### Trends in global publications

#### *Number and trends of Global publications*

A total of 3467 articles from 1999 to 2019 match the research inclusion criteria. We found that the number of publications per year about joint preserving procedures of ONFH demonstrated a steadily increasing trend in the past two decades, from 65 in 1999 to 339 in 2019 (Fig.1A). On the basis of the model fitting curves of publication growth, the cumulative publication number of global is shown in Fig. 1B. The number of publications in this field was estimated to grow by nearly 2 times from 339 in 2019 to approximately 600 by 2030.

#### *Contribution of countries*

There were total of 84 countries and regions published articles in this domain. China published the most papers (868, 25.04%), followed by United States (816, 23.36 %), Japan (336, 9.69%), Germany (186, 5.37%), and England (180, 5.19%). (Fig. 1C and D).

### Quality of publications of different countries

As is shown in Fig. 2A, USA had the highest total citation frequencies (19,393). Then is China, ranked second (7,384), followed by Japan (5,507), England (3,850), and Germany (3,385). The involved articles from the USA had the highest H-index (65), followed by Japan (38), China (36), England (32), and Germany (31) (Fig. 2B). The average citation frequencies of top 20 countries are shown in Fig. 2c. Switzerland had the highest average citation frequencies (36.1). While Israel ranked second (29.40), followed by Canada (27.37), Belgium (26.25), and Australia (24.84) (Fig. 2C).

### Analysis of global publications

#### *Journal analysis*

The CLINICAL ORTHOPAEDICS AND RELATED RESEARCH (impact factor [IF] = 4.154, 2018) published the most studies with 160 articles. There were 100 articles in JOURNAL OF PEDIATRIC ORTHOPAEDICS (IF = 2.046, 2018), 95 articles in INTERNATIONAL ORTHOPAEDICS (IF = 2.384, 2018), 85 articles in JOURNAL OF BONE AND JOINT SURGERY AMERICAN VOLUME (IF = 4.716, 2018), and 67 articles in ARCHIVES OF

ORTHOPAEDIC AND TRAUMA SURGERY (IF = 1.973, 2018) on joint preserving procedures of ONFH. The top 20 journals that published the most articles are listed in Fig. 3A.

### *Research orientations*

As is shown in the Fig. 3B, orthopedics is the most popular research fields (1522, 43.90%), and the surgery ranked second (687, 19.82%), followed by general internal medicine (281, 8.11%), research experimental medicine (262, 7.56%) and radiology nuclear medicine medical imaging (253, 7.30%).

### *Authors*

The fig. 3C shows the top 20 authors relate to the joint preserving procedures of ONFH. YAMAMOTO T published the most research on this field with 68 papers, followed by IWAMOTO Y with 57 papers, ZHANG CQ with 46 papers, KIM HKW with 43 papers, and MOTOMURA G with 39 papers.

### *Institution output*

The Shanghai Jiao Tong University had the highest number of papers among institutions worldwide (90 papers). Fig. 3D shows the top 20 contributive institution distribution of publications in this field. There were 9 China institutions followed by 5 United States institutions, 2 Japan institutions, 2 Switzerland institutions, 1 France as well as 1 South Korea institution.

### *Funding source*

The top 20 funding bodies are shown in Fig. 3E. National Nature Science Foundation of China provides financial support for 391 papers ranked the first, followed by National Institutes of Health NIH USA (112 papers) and United States Department of Health Human Services (112 papers).

## **Bibliographic coupling analysis**

### *Journals*

Bibliographic coupling is a well-established measure that uses citation analysis to establish a similarity relationship between documents. it was constructed on the shared references among publications, providing deeper insights into the journal, institution, and country. We use the VOS viewer to analyze the journal names in total publications. There were 134 journals appeared in total link strength (TLS) (Fig. 4A). The top five journals with greatest total link strengths are as follows: CLINICAL ORTHOPAEDICS AND RELATED RESEARCH (TSL=78,284), JOURNAL OF BONE AND JOINT SURGERY AMERICAN VOLUME (TSL=47,929), INTERNATIONAL ORTHOPAEDICS (TSL=38,065), JOURNAL OF BONE AND JOINT SURGERY BRITISH VOLUME (TSL=28,449), JOURNAL OF PEDIATRIC ORTHOPAEDICS (TSL=26,102).

### *Institutions*

All the papers were reported in 274 institutions and were analyzed via VOS viewer (the minimum number of publications of an institution was over five). The top five institutions with large total link strength are the following: Kyushu University (TSL=54,422), Shanghai Jiao Tong University (TSL=43,162), Chinese University Hongkong (TSL=30,624), Xi An Jiao Tong University (TSL=30,036), and Seoul National University (TSL=29,609) (Fig. 4B).

### *Countries*

There are 48 countries identified by the papers and were analyzed using VOS viewer (the minimum number of publications from a country was over five). The top five countries with large total link strength are the following: USA (TSL=383,754), China (TSL=292,399), Japan (TSL=168,467), Germany (TSL=102,548) and South Korea (TSL=90,846) (Fig. 4C).

## **Co-authorship analysis**

### *Authors*

Coauthor analysis refers to the establishment of the relationship between items according to the number of coauthors. For instance, if an author coauthors an article with ten other authors, each of the 10 co-authorship links has a weight of 1/10. A total of 140 authors were identified were analyzed through VOS viewer (the minimum number of documents from an author was over five). The top five authors with large total link strengths are as follows: YAMAMOTO T (TSL=172), MOYOMURA G (TSL=165), IWAMOTO Y (TSL=155), IKEMURA S (TSL=104), and SUGANO N (TSL=81) (Fig. 5A).

### *Institutions*

Studies identified in the 249 institutions were analyzed using VOS viewer (the minimum number of publications from an institution was over five). The top five institutions with large TLS are as follows: Kyungpook National University (TSL=65), Chinese University Hongkong (TSL=61), Seoul National University (TSL=60), Chinese Academy of Sciences (TSL=51), and Stanford University (TSL=51) (Fig. 5B).

### *Countries*

Publications (the minimum number of studies from a country was over five) identified in the 47 countries were analyzed using VOS viewer (Fig. 5C). The top five countries with large TSL are the following: USA (TSL=247), Englan (TSL=113), Germany (TSL=108), China (TSL=92), and France (TSL=76).

## **Co-citation analysis**

### *Publications*

Co-citation analysis implied that the relatedness of items based on the number of times they were cited together. There were 612 references (the minimum number of citations of a reference was over 20 times) were analyzed by using VOS viewer (Fig. 6A). The top five papers with large TLS are as follows: Mont et

al. [15] (TSL=4,082), Ficat et al. [16] (TSL=3,254), Mankin et al. [17] (TSL=2,573), Assouline et al. [18] (TSL=2,557), and Steinberget al. [19] (TSL=2,539).

### *Journals*

A total of 630 journals of co-citation analysis were analyzed using VOS viewer (the minimum number of citations from a source was over 20 times). The top five journals with large total link strengths are as follows: CLINICAL ORTHOPAEDICS AND RELATED RESEARCH (TSL=314,286), JOURNAL OF BONE AND JOINT SURGERY AMERICAN VOLUME (TSL=295,588), JOURNAL OF BONE AND JOINT SURGERY BRITISH VOLUME (TSL=224,238), JOURNAL OF PEDIATRIC ORTHOPAEDICS (TSL=94,528), and Radiology (TSL=61,601) (Fig. 6B).

### **Co-occurrence analysis**

Co-occurrence analysis is a method to build the relationship of items base on the number of publications in which they occur together. The trends and current topics of the research area were established by the keyword network map, which was created by VOS viewer (the minimum number of occurrences of a keyword was over five). As is shown in Fig. 7A, total 1,002 included keywords were grouped into approximately 4 clusters: "Process and clinical treatment", "Risk factors and diagnosis", "Pathophysiology", and "Basic research". In the "Process and clinical treatment" cluster, the main keywords are core decompression, necrosis, expression, natural-history, and risk. Within cluster of "Risk factors and diagnosis", the relevant keywords are avascular necrosis, osteonecrosis, femoral-head, hip, and bone. In "Pathophysiology" cluster, the main keywords are necrosis, expression, risk, pathogenesis, and osteoporosis. As with the cluster of "Basic research", primary keywords are also listed, including nontraumatic osteonecrosis, osteonecrosis of the femoral head, apoptosis, steroid-induced osteonecrosis, and differentiation. These results demonstrate the most core theme of joint preserving procedures of ONFH up till now.

VOS viewer can quantify and color-coded the relative novelty of a keyword through defining the average appearing year. The blue color means the keyword appeared early and yellow-colored keywords appeared later. The fig. 7B shows that during the early stage of joint preserving procedures of ONFH, "Process and clinical treatment", and "Risk factors and diagnosis" are the major topics in this field (before 2014). However, the recent development trends show that the clusters of "Pathophysiology", and "Basic research" will be extensively concerned in the future.

## **Discussion**

### **Global research trends in joint preserving procedures of ONFH**

This bibliometric analysis of joint preserving procedures of ONFH reveals some interesting and valuable facts. In recent years, the related research of joint preserving procedures of ONFH has been continuously developing, as was reflected in the increasing number of publications every year. From the current study, a

total of 84 countries were shown to have published articles in this field. China and United States ranked the first and the second respectively in total number of publications. However, the USA made the largest contributions to global joint preserving procedures of ONFH research in terms of total number of citations and value of H-index. As we all know, the h-index and the total number of citations represent the academic impact and quality of a nation's publication. Therefore, the USA was the leading country in this field, which was not surprising, because the USA focused on this issue earlier and had advanced equipment, experts, and sufficient funding. It is worth noting that the National Nature Science Foundation of China has ranked the first in this domain. The contradiction between the quantity and quality of publications in China might attribute to several reasons. Firstly, Chinese academic evaluation system has been focusing more on the quantity rather than the quality of publications. This indicates the urgent need for Chinese investigators to improve the quality of papers in the future. Secondly, the number of publications in the related field remained relatively small before 2010 in China. Hence, China need more time to catch up with other countries with citation frequency.

CLINICAL ORTHOPAEDICS AND RELATED RESEARCH, JOURNAL OF PEDIATRIC ORTHOPAEDICS, INTERNATIONAL ORTHOPAEDICS, JOURNAL OF BONE AND JOINT SURGERY AMERICAN VOLUME, and ARCHIVES OF ORTHOPAEDIC AND TRAUMA SURGERY published the most studies on joint preserving procedures of ONFH. The journals in the list (Fig. 3A) might be the main publishing channels for the future findings. Most of research orientations focus on orthopedics and surgery. Fig. 1C lists the top 20 authors who have published the most articles about joint preserving procedures of ONFH, and they were considered to be pioneers in this area. Their findings deserve constant attention. Of the top 20 institutions, there were 9 institutions from China, and 5 from the USA. That means Chinese scholars were very interested in this field. At the same time, China has invested loads of funds in joint preserving procedures of ONFH. Thus, the quality of research could be greatly improved in China in the future.

Through bibliographic coupling analysis, CLINICAL ORTHOPAEDICS AND RELATED RESEARCH is the most related journal, and the USA is the leading country in this field. Co-authorship analysis indicates that the country/institution/author, with the highest total link strengths, would be more likely to cooperate with others. We used co-citation analysis to investigate the impact of article by counting the number of citations. CLINICAL ORTHOPAEDICS AND RELATED RESEARC is the journal with the highest citation frequency in joint preserving procedures of ONFH field. The top 5 articles, which as footing stone studies, have the greatest total frequency of co-citation.

### **Research focus on joint preserving procedures of ONFH**

The co-occurrence analysis could indicate the possible research orientation in the future. Therefore, we used this method to identify future trends and hot spots about joint preserving procedures of ONFH. The map of the co-occurrence network was created by the keywords of all titles and abstracts of the included studies. As is shown in our study, four research clusters were discovered, including "Process and clinical treatment", "Risk factors and diagnosis", "Pathophysiology", and "Basic research" (Fig. 7A). It is

consistent with our common sense in this field. Therefore, more investment and high-quality work are still required in these four trends.

Overlay visualization map is a significant analysis to predict the research direction. As is shown in Fig. 7B, the color bar indicates how the scores are drawn to the color, "Pathophysiology" and "Basic research" (yellow color) might be the next hot topics in this field. This conforms to the current research situation. Studying on pathophysiology could help scholars to have a better understanding of ONFH, and to intervene and treat it more efficiently. Most researchers pointed towards traumatic or non-traumatic causes that have been identified as risk factors for ONFH [20]. But the precipitating mechanism which will lead to this pathway is still unclear. Therefore, pathophysiology research should be a hot spot in the future. Basic research provided a new idea and method for the treatment of ONFH. Research involving stem cells and growth factors shows promise in clarifying both the etiology and treatment of this devastating disease, and an increasing number of recent studies have focused on this topic [21,22]. However, the optimal stem cell selection protocol, the ideal injection number, and the safety of stem cell therapy must be further explored in the future. In addition, the fact of mechanism study lagging behind the clinical application has motivated more scholars to do basic research.

## Conclusion

Based on our study, it shows the current status and global trends in joint preserving procedures of ONFH. Although China made the highest contributions to the total number of publications, the USA was the leading country in global research in this field. CLINICAL ORTHOPAEDICS AND RELATED RESEARCH had the most publications and highest correlation to this domain. Through the bibliometric and visualized analyses, we can predict that more studies about joint preserving procedures of ONFH will be published in the coming years. Pathophysiology and basic research will get more attention and be the next hot spot in the future.

## Declarations

**Ethics approval and consent to participate:** Not applicable.

**Consent for publication:** Not applicable.

**Availability of data and material:** All data generated or analysed during this study are included in this published article.

**Competing interests:** The authors declared that they have no conflict of interests.

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## Author contributions

Study design: Qingxi Zhang.

Data collection/validation: Qingxi Zhang and Yu Zhao.

Data analysis: Qingxi Zhang and Hui Li.

Result interpretation: Qingxi Zhang and Dan Xing.

Reporting & editing: Qingxi Zhang and Jianhao Lin.

Final approval of the version to be submitted: Qingxi Zhang, Yu Zhao, Hui Li, Dan Xing, and Jianhao Lin.

Project guarantor: Jianhao Lin.

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## Figures

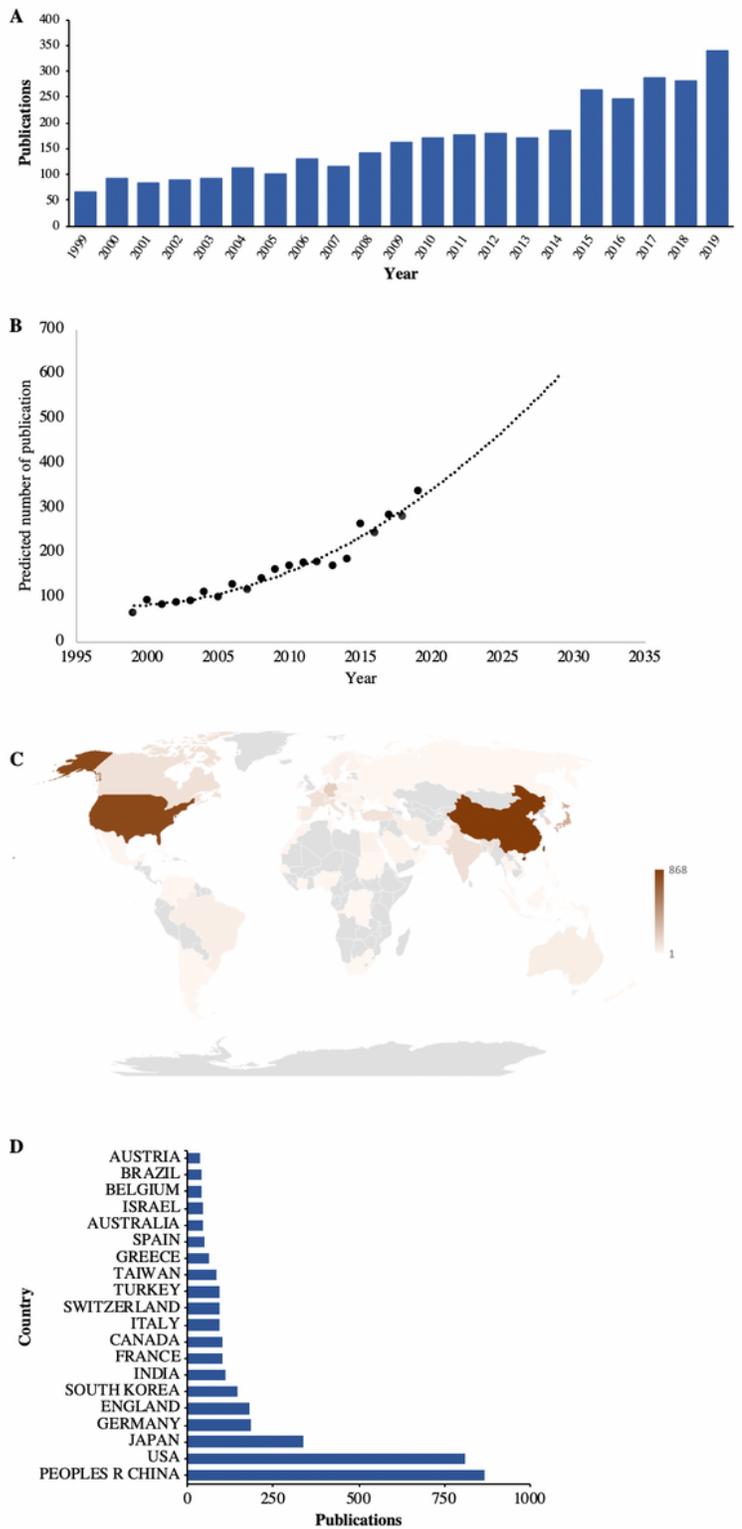


Figure 1

Global trends and country contributing to joint preserving procedures of osteonecrosis of the femoral head (ONFH). (A) The single-year publication numbers in the past 21 years related to joint preserving procedures of ONFH. (B) Model fitting curves of trends in global publications. (C) World map showing the distribution of joint preserving procedures of ONFH. (D) The sum of joint preserving procedures of ONFH research related articles from the top 20 countries.

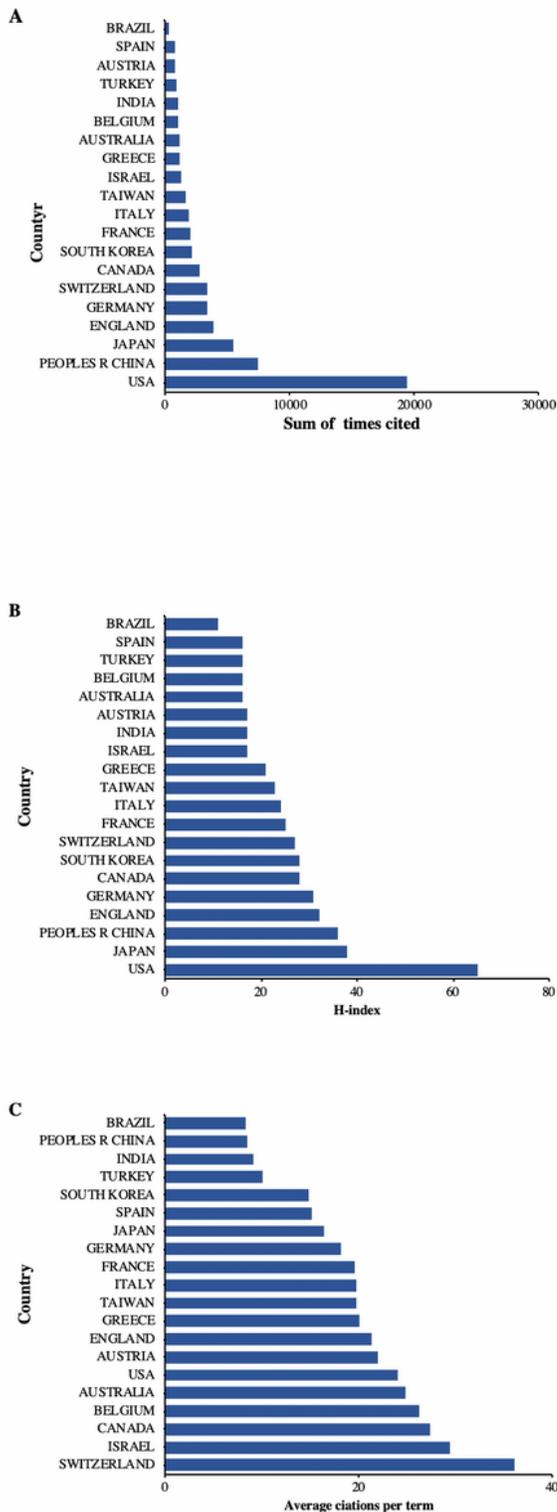


Figure 2

Citation frequency and H-index levels of different countries. (A) The sum citations for joint preserving procedures of osteonecrosis of the femoral head (ONFH) articles from top 20 countries. (B) The H-index of publications from top 20 countries. (C) The average citations per paper for articles from top 20 countries.

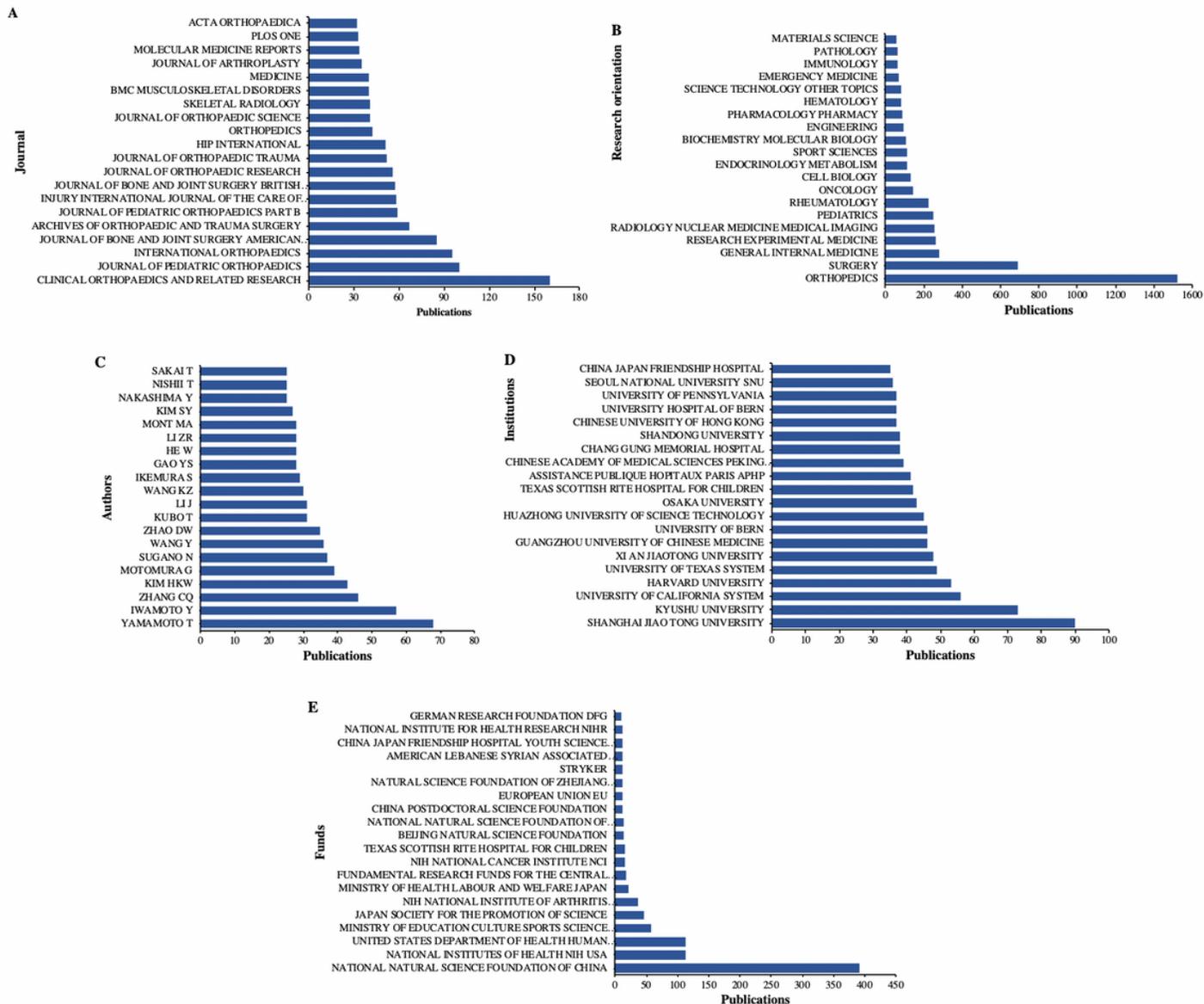
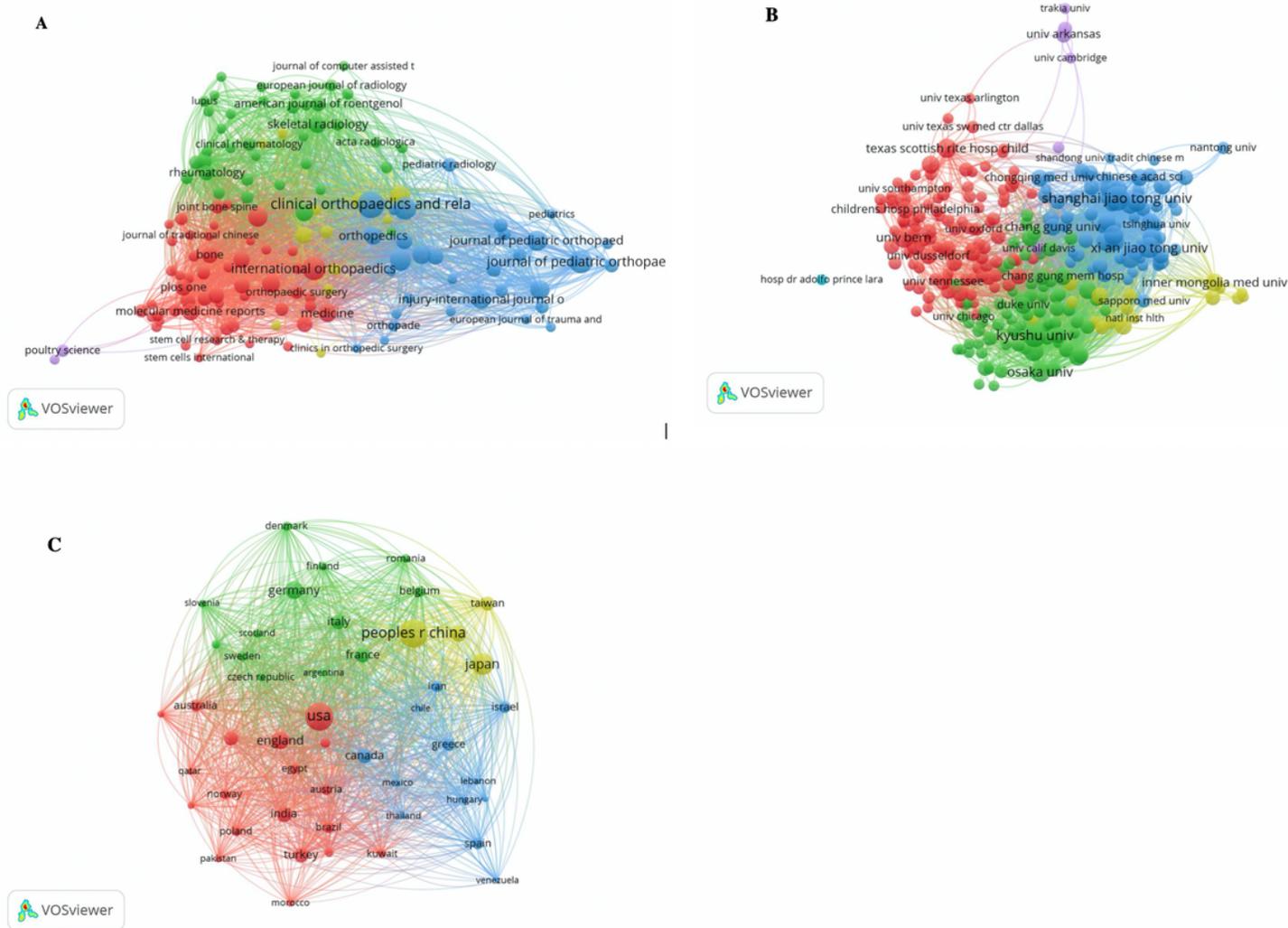


Figure 3

Top 20 journals (A), research orientations (B), authors (C), institutions (D), and funds (E) of global research about joint preserving procedures of osteonecrosis of the femoral head (ONFH).



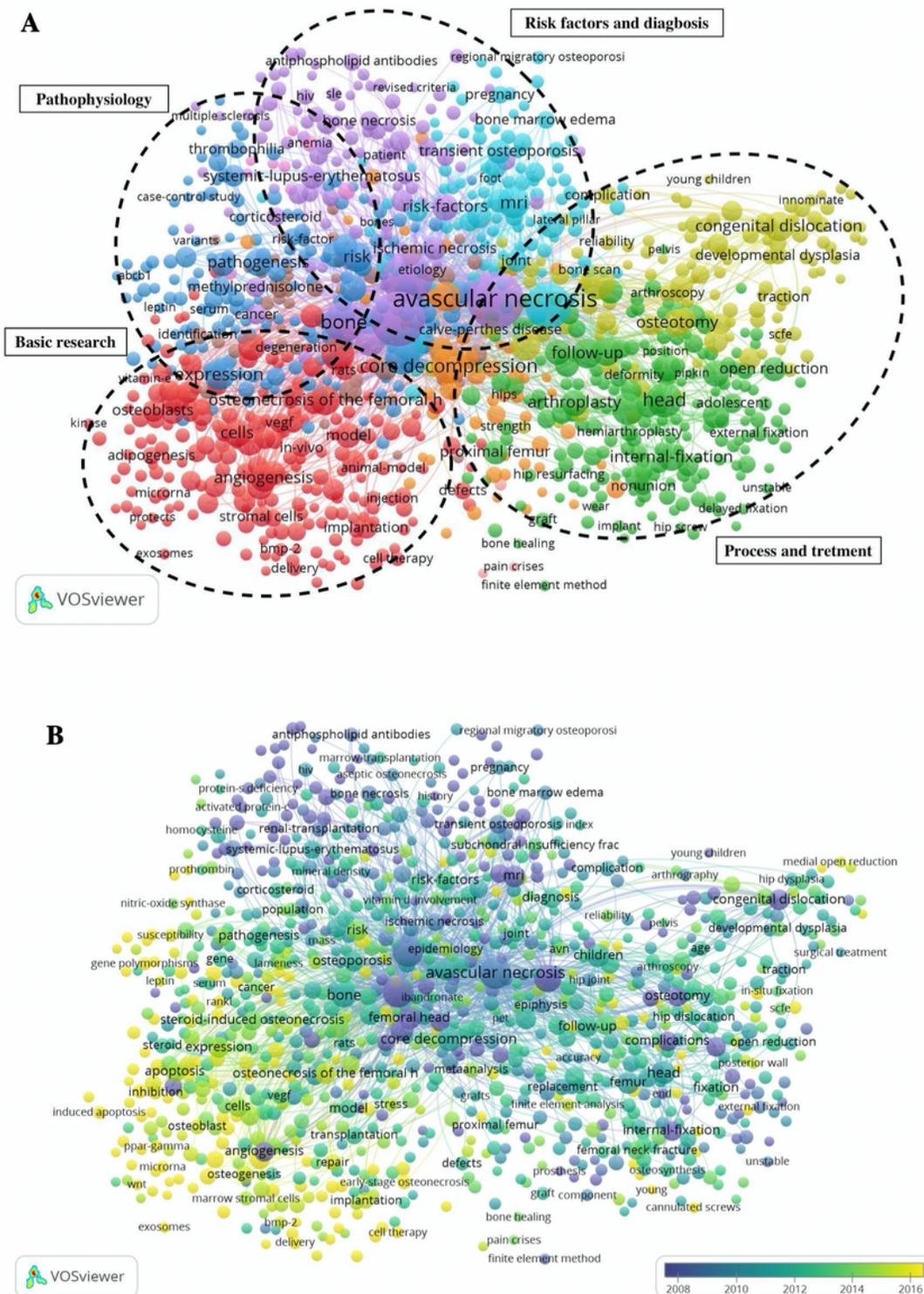
**Figure 4**

Bibliographic coupling analysis of global research about joint preserving procedures of osteonecrosis of the femoral head (ONFH). (A) Mapping of the 134 identified journals on joint preserving procedures of ONFH (B) Mapping of the 274 institutions on joint preserving procedures of ONFH. (c) Mapping of the 48 countries on joint preserving procedures of ONFH. The line between two points in the figure represents that two journals/institutions/countries had establish a similarity relationship. The thicker the line, the closer the link between the two journals/ institutions/countries.





countries on joint preserving procedures of ONFH. The line between two points in the figure represents that two journals/institutions/countries had established a similarity relationship. The thicker the line, the closer the link between the two journals/ institutions/countries.



**Figure 7**

Co-occurrence analysis of global research about joint preserving procedures of osteonecrosis of the femoral head (ONFH). (A) Mapping of keywords in the research on it; the size of the points represents the

frequency, and the keywords are divided into 4 clusters: "Process and clinical treatment", "Risk factors and diagnosis", "Pathophysiology", and "Basic research". (B) Distribution of keywords according to the mean frequency of appearance; keywords in purple appeared earlier than those in green and yellow colored keywords appeared later.