

## Research Article

# Surgical Procedures for Hip Joint Preservation for Osteonecrosis of the Femoral Head: A Bibliometric Analysis

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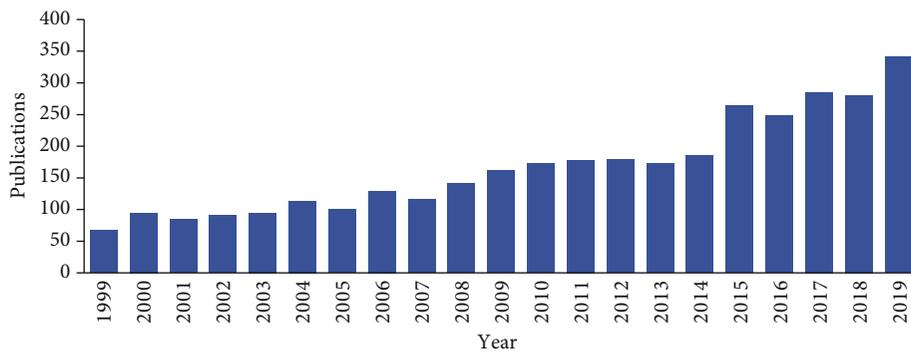
**Background and Objective.** Studies have concentrated on the surgical procedures for hip joint preservation for osteonecrosis of the femoral head (ONFH). This study is aimed at presenting a bibliometric analysis of the relevant articles published from 1999 to 2019. **Method.** Articles which concentrated on surgical procedures for hip joint preservation for ONFH were searched using Web of Science database. The data were analyzed by using bibliometric analysis. Additionally, VOS viewer software was used for bibliographic coupling, coauthorship, cocitation, and cooccurrence analyses and to investigate the publication trends of the mentioned field. **Results.** A total of 3467 articles were included. China had the highest number of relevant published articles. However, the USA made the highest contributions to the global research with the highest citations and *h*-index. The journal of *Clinical Orthopaedics and Related Research* published the highest number of relevant articles. Studies could be classified into four clusters: “process and clinical treatment,” “risk factors and diagnosis,” “pathophysiology,” and “basic research.” “Pathophysiology” and “basic research” clusters were predicted as the next hot topics of surgical procedures for hip joint preservation for ONFH. **Conclusion.** Based on the current global trends, the number of published articles related to surgical procedures for hip joint preservation for ONFH has increased. The USA was noted as the leading country in global research in the target field. “Pathophysiology” and “basic research” clusters may be the next hot spots, and scholars need to further concentrate on the target topic.

## 1. Background

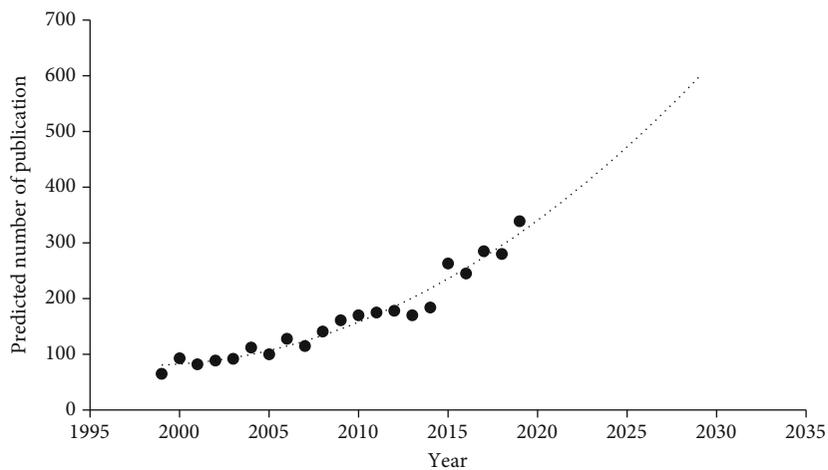
Osteonecrosis of the femoral head (ONFH) is a devastating condition, mainly influencing patients in their third to fifth decades of life that typically progresses to cell death, fracture, and collapse of femoral head [1, 2]. The processes could be the result of trauma, corticosteroids, alcohol, blood dyscrasias, idiopathic, and miscellaneous factors [3]. However, the underlying pathogenesis has still remained elusive. The incidence of ONFH in the UK (1.4 per 100,000) is comparable with Japan (1.9 per 100,000) [4, 5], and 20,000-30,000 new cases are annually diagnosed in the USA [6]. Although ONFH has a low incidence compared with primary hip osteoarthritis, it negatively influences individuals' quality of life. Besides, spontaneous regression of ONFH is extremely rare. In case of late treatment, it may lead to complete collapse of the femoral head within 2-3 years, and the vast

majority of untreated patients undergo total hip arthroplasty (THA) [7]. Hence, early intervention is highly essential to stop or reverse the progression of the disease, ultimately preserving joint and preventing the need for THA. The surgical treatment of ONFH can be divided into two major branches: FH sparing procedures (FHSP) and FH replacement procedures (FHRP). In general, FHSP are indicated at precollapse stages with minimal symptoms, whereas FHRP are preferred at postcollapse symptomatic stages [8]. However, the global research trends related to surgical procedures for hip joint preservation for ONFH have not been reported yet. Therefore, it is urgent to investigate the global status of surgical procedures for hip joint preservation for ONFH.

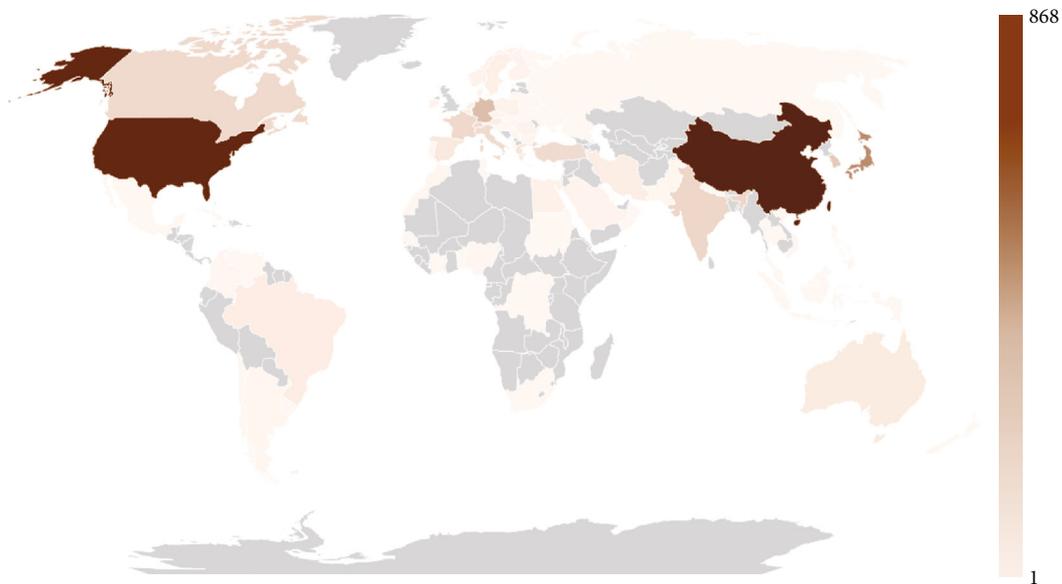
Bibliometrics is quantitative analysis of scientific publications and their citations [9]. It is developed for a wide range and can serve as an important tool for monitoring research trends, determining the impact of research funding, as well



(a)



(b)



(c)

FIGURE 1: Continued.

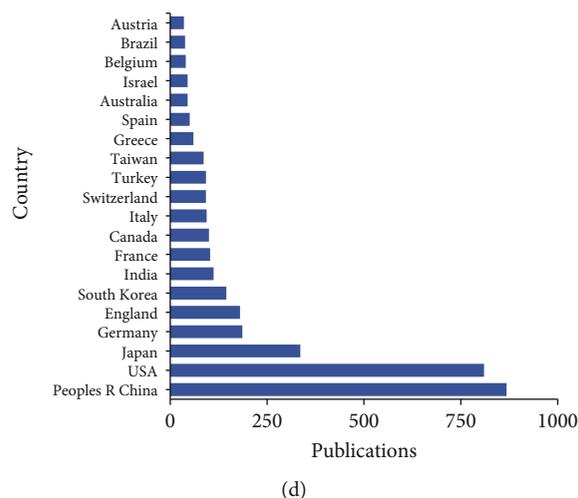


FIGURE 1: Global trends and authors' countries of origin contributing to surgical procedures for hip joint preservation for osteonecrosis of the femoral head (ONFH). (a) The number of articles published in the past 21 years related to surgical procedures for hip joint preservation for ONFH. (b) Model fitting curves related to global publishing trends. (c) World map showing the distribution of surgical procedures for hip joint preservation for ONFH. (d) The total number of published articles related to surgical procedures for hip joint preservation for ONFH in the top 20 countries.

as comparing research progress among different countries, institutions, etc. [10]. Furthermore, bibliometric analysis is valuable in formulating policy and clinical guideline of various diseases [11]. However, the analysis of bibliometric variables regarding surgical procedures for hip joint preservation for ONFH remains elusive. Thus, the present study is aimed at providing a full-scale insight into the status and global trends of surgical procedures for hip joint preservation for ONFH. Meanwhile, in order to carry out a deeper analysis on the bibliometric information, we used graphical mapping of the bibliographic data with the purpose of determining how the leading actors of the publication were connected with each other.

## 2. Materials and Methods

**2.1. Search Strategy.** It has been extensively accepted that Web of Science (WoS) is the most appropriate database for performing bibliometric analysis [12]. In the current research, a comprehensive search was undertaken from 1999 to 2019 using WoS database with document types restricted to articles and reviews. Besides, only English-language articles were included.

**2.2. Data Collection.** Two reviewers independently checked and extracted the following information from eligible articles: year of publication, authors' full name, title, name of journal, authors' affiliation, authors' nationality, keywords, sum of citations, *h*-index. Any disagreement was resolved by consensus-based discussion.

**2.3. Bibliometric Analysis.** The index of *h* means that an author or country has published *h* articles, and each of which has been cited in other publications at least *h* times [11]. Therefore, it is an author/country-level metric, implied both the productivity and citation impact of the publications of a scientist or a country [13]. We used the Microsoft Excel

2016 to generate a prediction model formulated as follows:  $f(x) = ax^3 + bx^2 + cx + d$  where *x* refers to year of publication, and  $f(x)$  represents the cumulative number of articles published in a certain year; besides, we analyzed the time trend of the publications, as well as tendency in the future based on the cumulative number of articles published [14].

**2.4. Visualized Analysis.** Herein, VOS viewer (Leiden University, Leiden, The Netherlands) was used for mapping and visualizing bibliometric networks of the publications [15]. It offers text mining functionality that can be used to construct and visualize cooccurrence networks of important terms extracted from a body of scientific literature. The following settings were chosen during the import: "Create a map based on bibliographic data," "read data from bibliographic database files," "type of analysis: bibliographic coupling," "unit of analysis: sources, organizations, countries," and "counting method: full counting"; "create a map based on bibliographic data," "read data from bibliographic database files," "type of analysis: coauthorship," "unit of analysis: authors, organizations, countries," and "counting method: full counting"; "create a map based on bibliographic data," "read data from bibliographic database files," "type of analysis: cocitation," "unit of analysis: cited references, cited sources," and "counting method: full counting"; "create a map based on bibliographic data," "read data from bibliographic database files," "type of analysis: cooccurrence," "unit of analysis: all keywords," "counting method: full counting," "network visualization," and "overlay visualization"; through these options, the VOS viewer analyzes and visualizes them in the form of bubble maps.

## 3. Results

**3.1. Global Publishing Trends.** There was a total of 3,467 articles published from 1999 to 2019 that met the inclusion

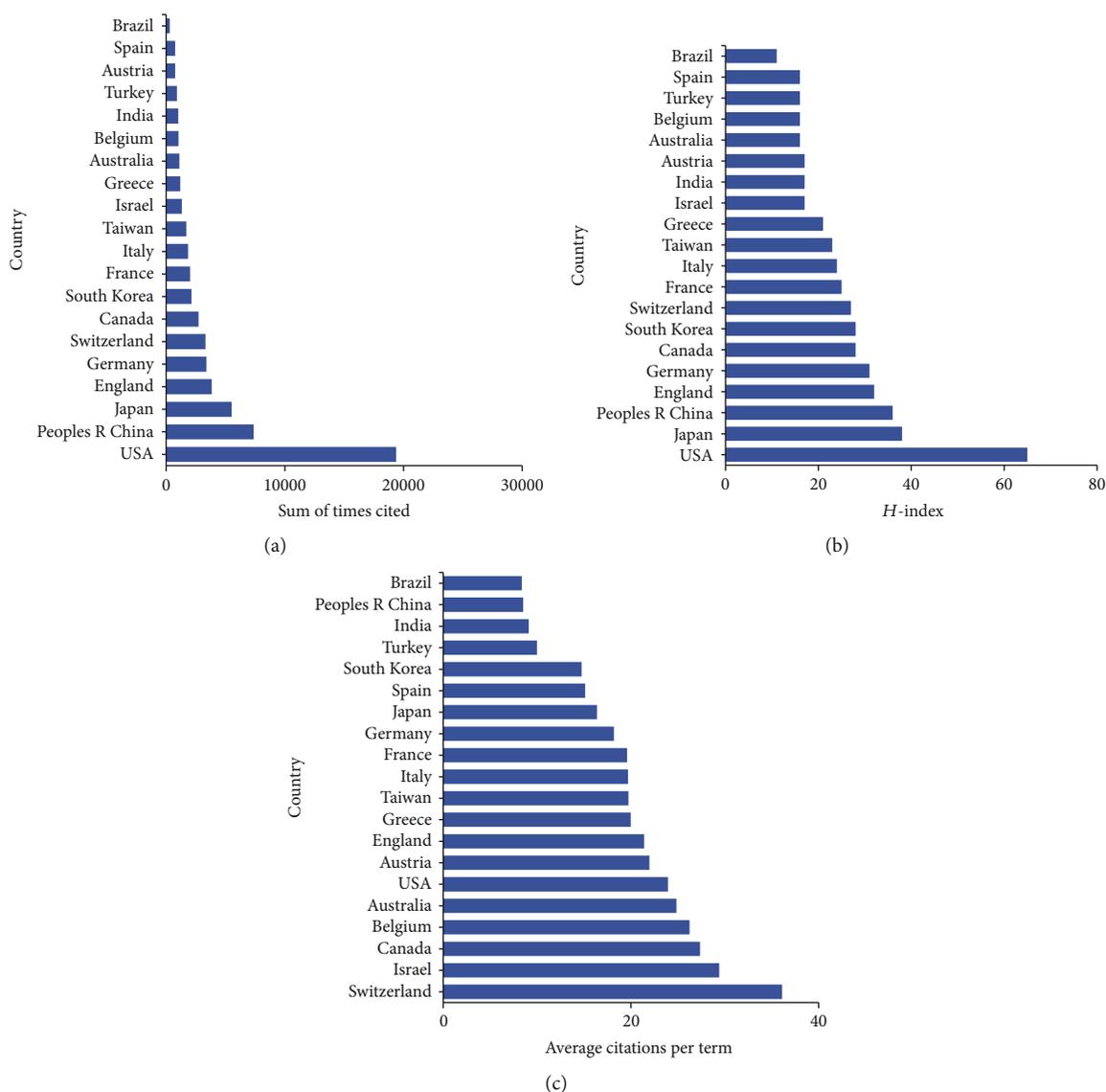


FIGURE 2: Frequency of citation of articles and *h*-index in different countries. (a) The frequency of citation of articles related to surgical procedures for hip joint preservation for osteonecrosis of the femoral head (ONFH) in the top 20 countries. (b) The *h*-index in the top 20 countries. (c) The average frequency of citation of articles in top 20 countries.

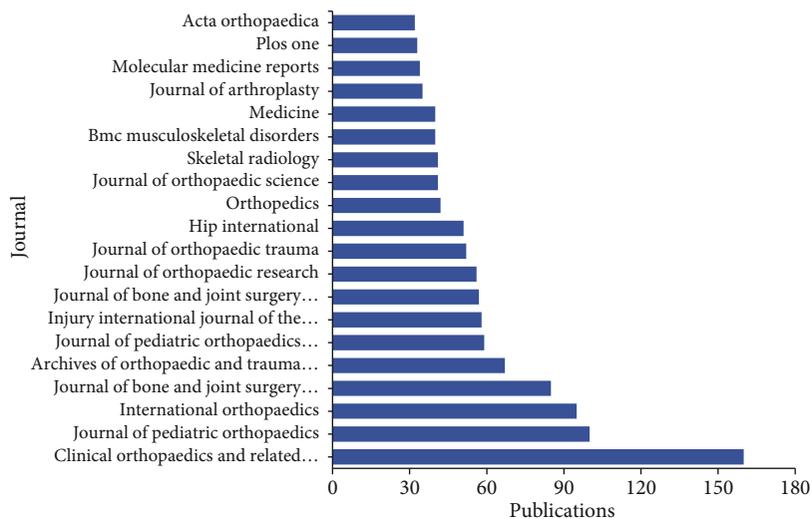
criteria. It was found that the number of articles published per year about surgical procedures for hip joint preservation for ONFH steadily increased in the past two decades, from 65 in 1999 to 339 in 2019 (Figure 1(a)). On the basis of the model fitting curves of publication growth, the cumulative number of global publications is shown in Figure 1(b). The number of articles published in this field was estimated to increase by nearly 2 times from 339 in 2019 to approximately 600 in 2030.

**3.1.1. Contribution of Authors' Country of Origin.** There were a total of 84 countries and regions involved in the item of authors' country of origin. Chinese scholars published the greatest number of articles (868, 25.04%), followed by the USA (816, 23.36%), Japan (336, 9.69%), Germany (186, 5.37%), and the UK (180, 5.19%) (Figures 1(c) and 1(d)).

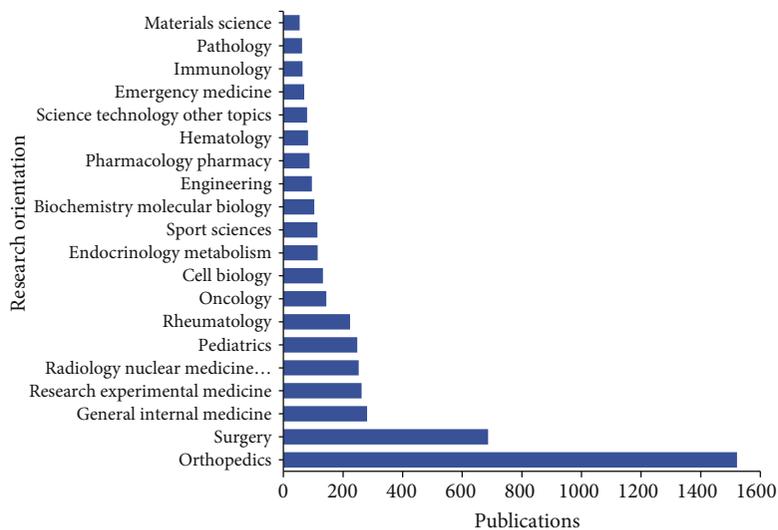
**3.2. Quality of Published Articles in Different Countries.** As illustrated in Figure 2(a), the USA had the highest proportion of citations (19,393), followed by China (7,384), Japan (5,507), the UK (3,850), and Germany (3,385). The involved articles from the USA had the highest proportion of *h*-index (65), followed by Japan (38), China (36), the UK (32), and Germany (31) (Figure 2(b)). The average frequency of citation of articles is displayed in Figure 2(c). Switzerland had the highest average frequency of citation of articles (36.1), followed by Israel (29.40), Canada (27.37), Belgium (26.25), and Australia (24.84) (Figure 2(c)).

### 3.3. Analysis of Global Publications

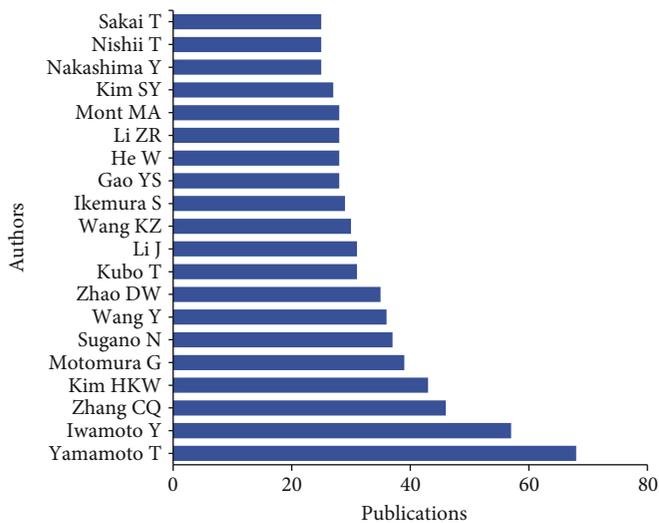
**3.3.1. Journals.** The *Clinical Orthopaedics and Related Research* (impact factor [IF] = 4.154, 2018) published the majority of articles (160 articles). Besides, 100 articles were



(a)

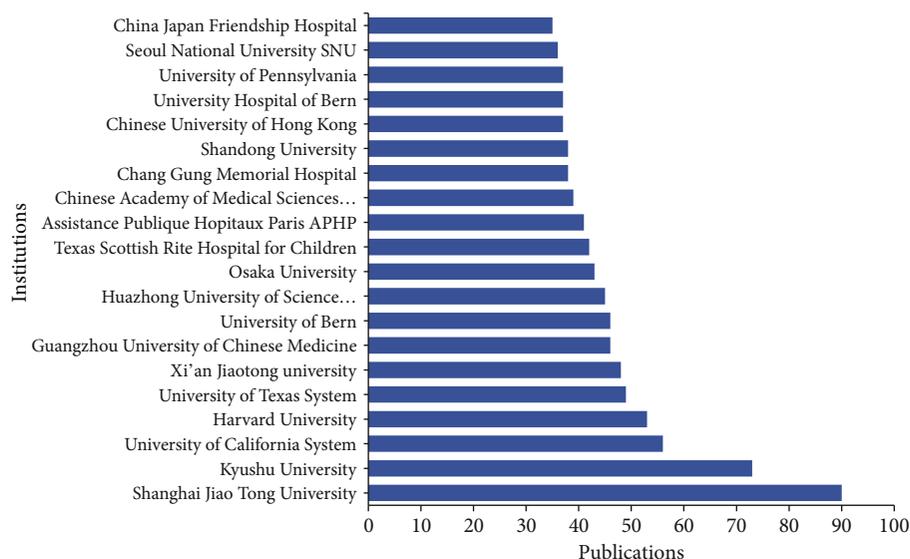


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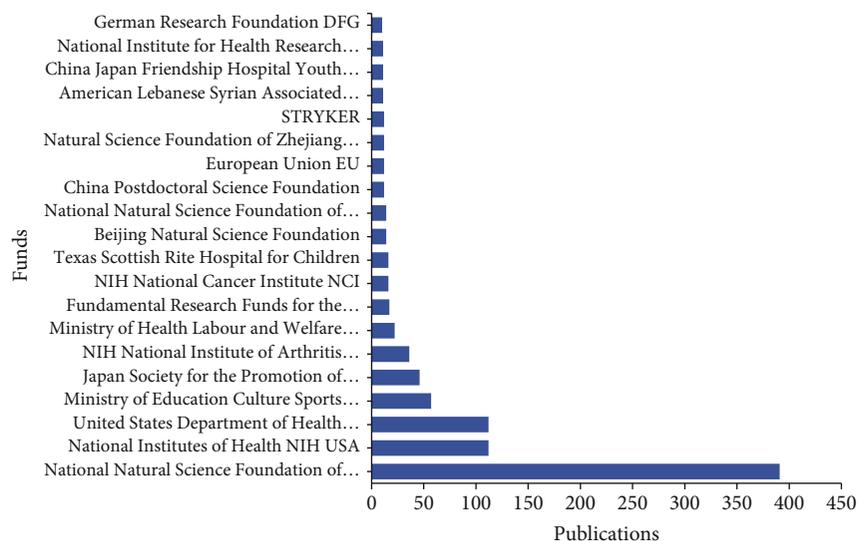


(c)

FIGURE 3: Continued.



(d)



(e)

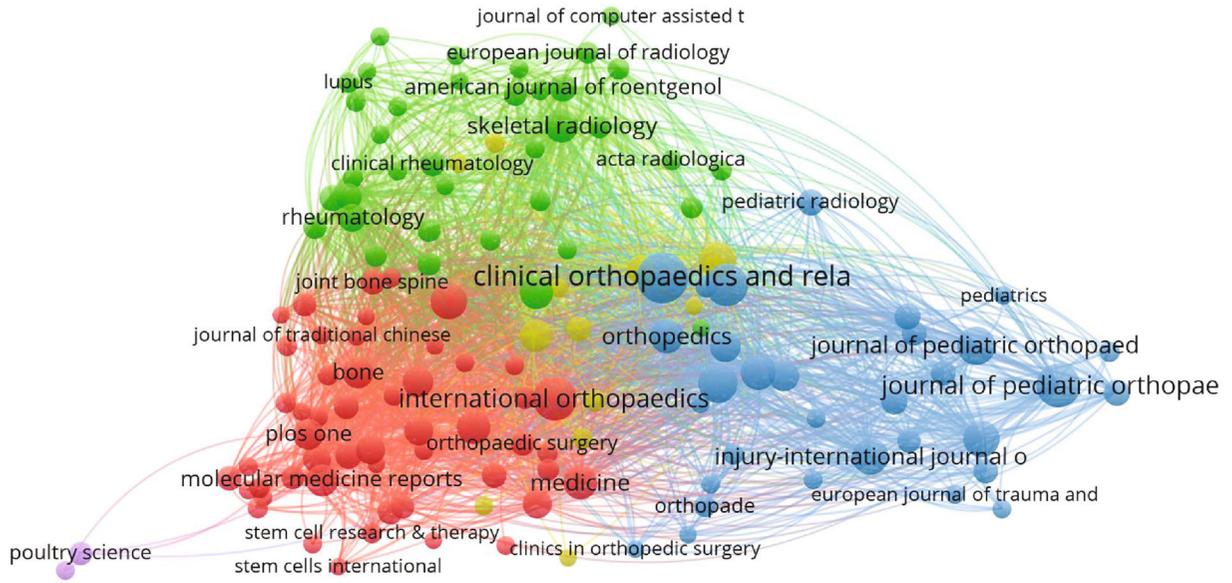
FIGURE 3: Top 20 journals (a), research orientations (b), authors' name (c), authors' affiliation (d), and grants (e) related to surgical procedures for hip joint preservation for osteonecrosis of the femoral head (ONFH).

published at *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) regarding surgical procedures for hip joint preservation for ONFH. The top 20 journals that published the majority of articles are listed in Figure 3(a).

**3.3.2. Research Orientations.** As depicted in Figure 3(b), orthopedics is the most popular research field (1522, 43.90%), followed by surgery (687, 19.82%), general internal medicine (281, 8.11%), experimental medicine (262, 7.56%), and medical imaging (253, 7.30%).

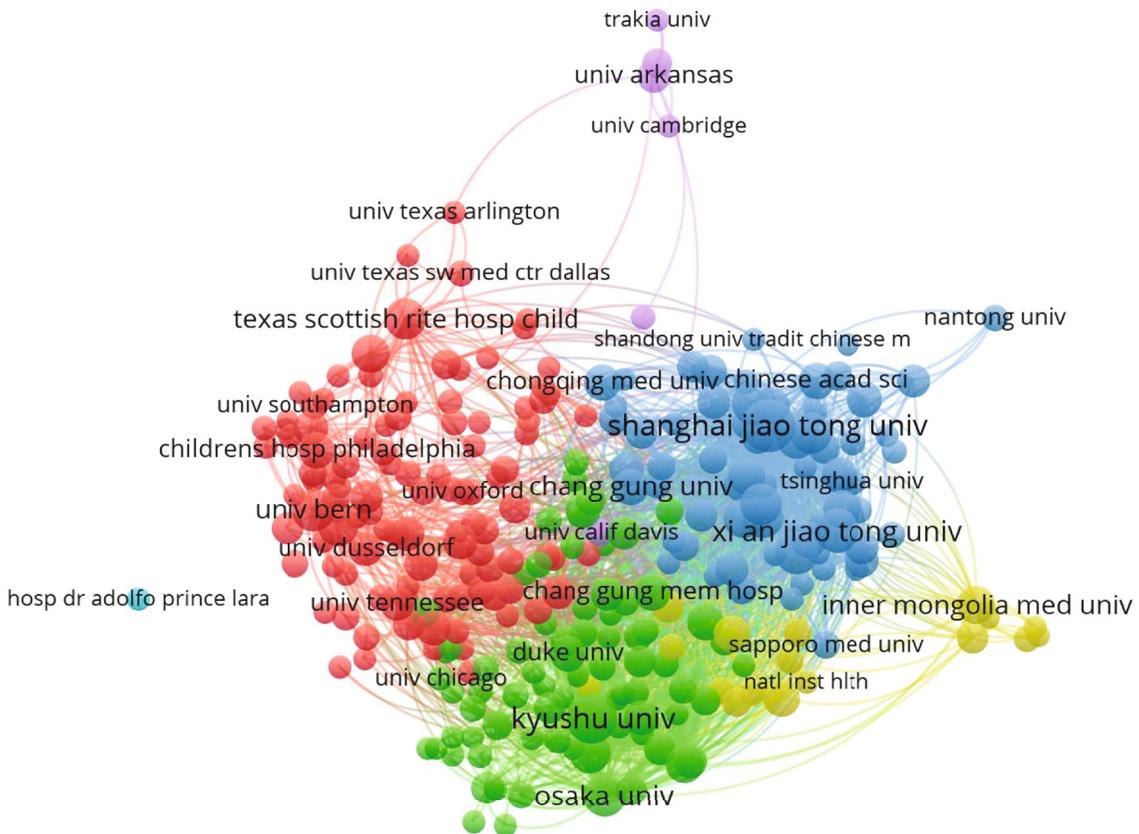
**3.3.3. Authors.** Figure 3(c) shows the top 20 authors who concentrated on surgical procedures for hip joint preservation for ONFH. Yamamoto published the highest number of articles in this field with 68 papers, followed by Iwamoto with 57 papers, Zhang with 46 papers, Kim with 43 papers, and Motomura with 39 papers.

**3.3.4. Institutions.** The Shanghai Jiao Tong University accounted for the highest number of articles published among different institutions worldwide (90 papers). Figure 3(d) illustrates the top 20 institutions that published the greatest number of articles in this field; there were 9 institutions in China, followed by 5 in the USA, 2 in Japan, 2 in Switzerland, 1 in France, and 1 in South Korea.



VOSviewer

(a)



VOSviewer

(b)

FIGURE 4: Continued.

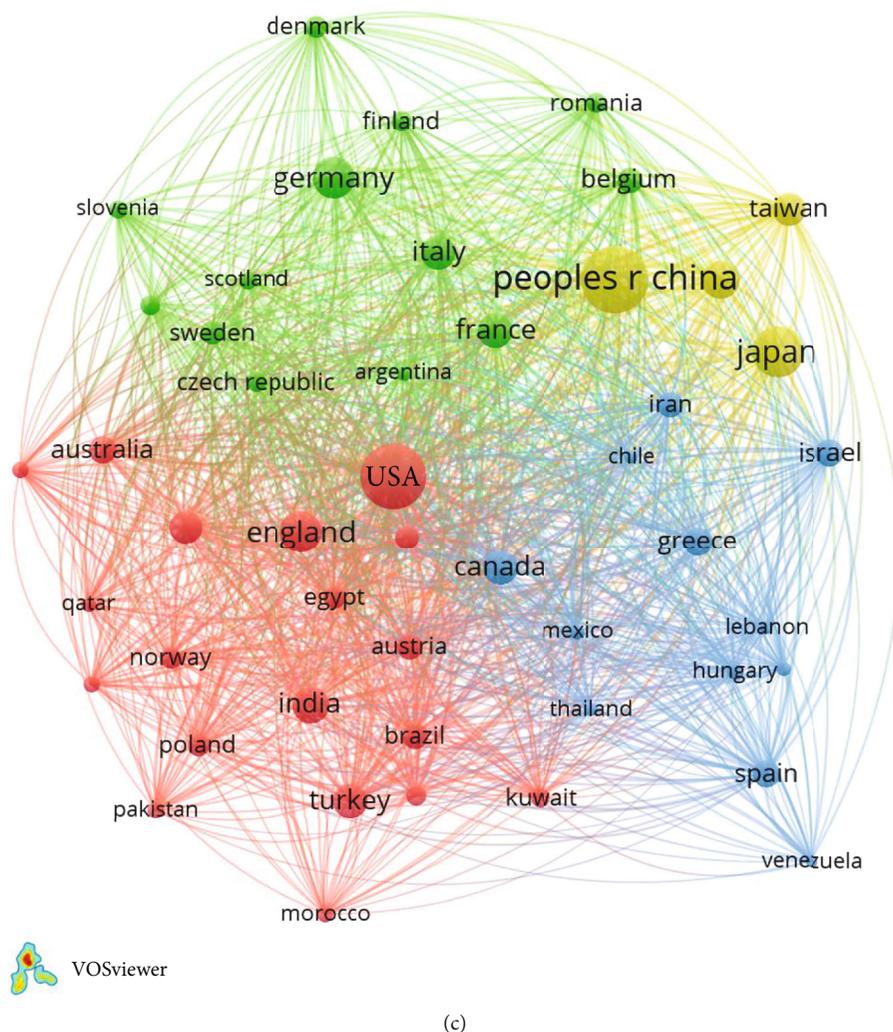


FIGURE 4: Bibliographic coupling analysis of published articles related to surgical procedures for hip joint preservation for osteonecrosis of the femoral head (ONFH). (a) Mapping of the 134 identified journals focused on surgical procedures for hip joint preservation for ONFH. (b) Mapping of the 274 institutions contributed to surgical procedures for hip joint preservation for ONFH. (c) Mapping of the 48 countries hosted in surgical procedures for hip joint preservation for 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.

**3.3.5. Funding Agencies.** The top 20 funding agencies are presented in Figure 3(e). The National Natural Science Foundation of China supported the highest number of articles (391 articles), followed by National Institutes of Health (NIH; Bethesda, MD, USA) (112 articles), and the United States Department of Health Human Services (Washington, D.C., USA) (112 papers).

### 3.4. Bibliographic Coupling Analysis

**3.4.1. Journals.** Bibliographic coupling is a well-established measure that uses citation analysis to establish a similarity relationship between documents. The VOS viewer was used to analyze the name of journals. There were 134 journals in total link strength (TLS) (Figure 4(a)). The top 5 journals with the greatest TLS were as follows: *Clinical Orthopaedics and Related Research* (TLS = 78,284), *Journal of Bone and Joint Surgery American Volume* (TLS = 47,929), *International Orthopaedics* (TLS = 38,065), *Journal of Bone and Joint Surgery British Volume* (TLS = 28,449), and *Journal of Pediatric Orthopaedics* (TLS = 26,102).

**3.4.2. Institutions.** All the eligible articles were published by 274 institutions and were analyzed via VOS viewer. The top 5 institutions with the highest TLS were as follows: Kyushu University (TLS = 54,422), Shanghai Jiaotong University (TLS = 43,162), Chinese University of Hong Kong (TLS = 30,624), Xi'an Jiaotong University (TLS = 30,036), and Seoul National University (TLS = 29,609) (Figure 4(b)).

**3.4.3. Countries.** The eligible articles were published by authors from 48 countries and were analyzed using VOS viewer. The top 5 countries with large TLS were as follows: USA (TLS = 383,754), China (TLS = 292,399), Japan (TLS = 168,467), Germany (TLS = 102,548), and South Korea (TLS = 90,846) (Figure 4(c)).

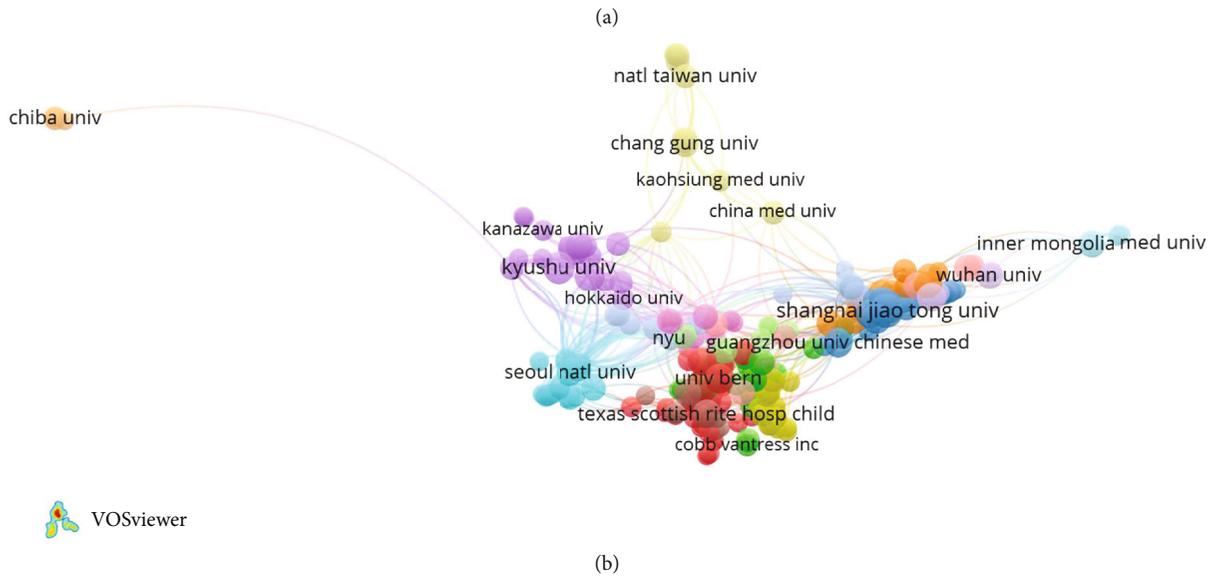
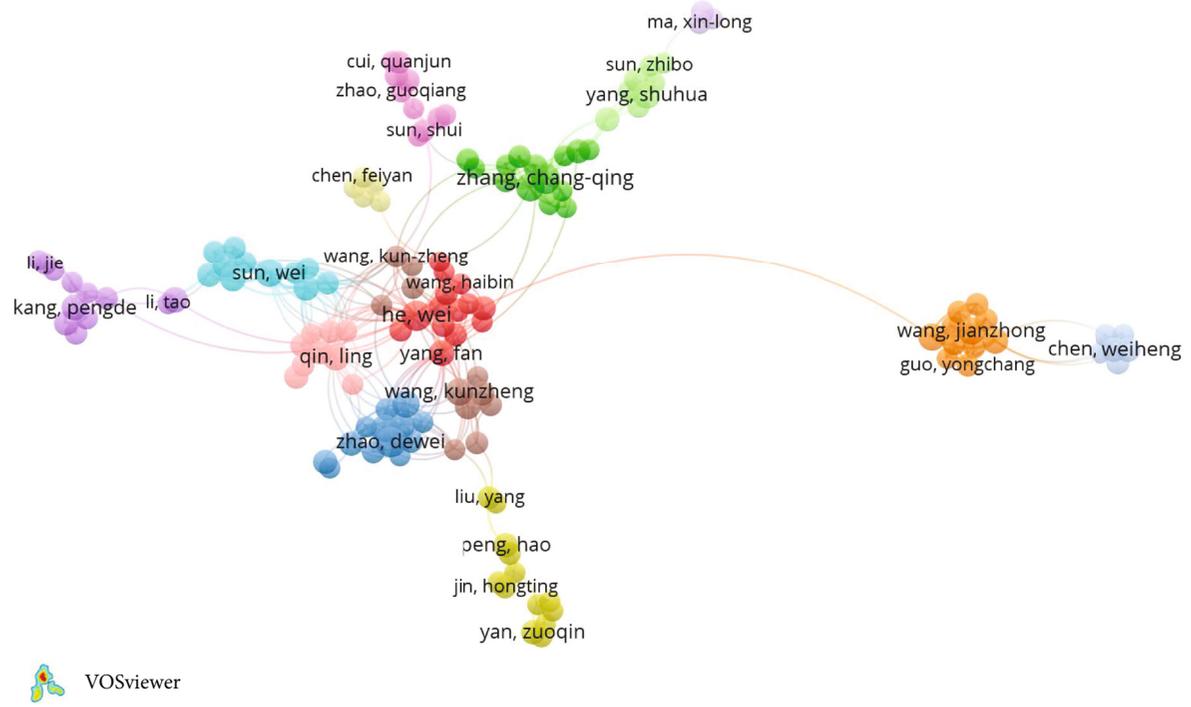


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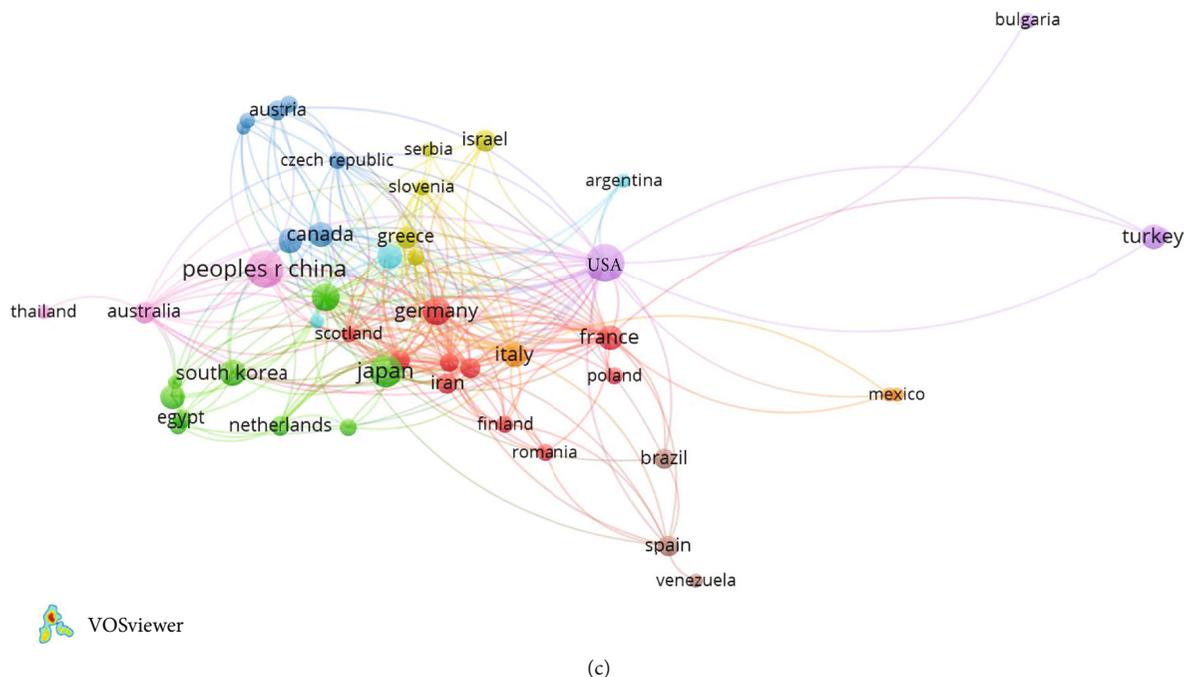


FIGURE 5: Coauthorship analysis of researches on surgical procedures for hip joint preservation for osteonecrosis of the femoral head (ONFH). (a) Mapping of the 140 authors identified by coauthorship analysis regarding surgical procedures for hip joint preservation for ONFH. (b) Mapping of the 249 institutions explored by coauthorship analysis regarding surgical procedures for hip joint preservation for ONFH. (c) Mapping of the 47 countries detected by coauthorship analysis regarding surgical procedures for hip joint preservation for ONFH. The size of the points represents the coauthorship frequency. The line between two points in the figure represents that two authors/institutions/countries had a collaboration. The thicker the line, the closer the collaboration between the two authors/institutions/countries.

### 3.5. Coauthorship Analysis

**3.5.1. Authors.** Coauthorship is a measure of the relationship between authors, but compared to other measures of relationship, it indicates a stronger social connection between collaborating authors. For instance, if an author can cooperatively publish an article with 10 authors, each of the 10 coauthorship links had a weight of 1/10. A total of 140 authors were identified and were analyzed through VOS viewer. The top 5 authors with large TLS were as follows: Yamamoto (TLS = 172), Moyomura (TLS = 165), Iwamoto (TLS = 155), Ikemura (TLS = 104), and Sugano (TLS = 81) (Figure 5(a)).

**3.5.2. Institutions.** Studies conducted at 249 institutions were analyzed using VOS viewer. The top 5 institutions with large TLS were as follows: Kyungpook National University (TLS = 65), Chinese University of Hong Kong (TLS = 61), Seoul National University (TLS = 60), Chinese Academy of Sciences (TLS = 51), and Stanford University (TLS = 51) (Figure 5(b)).

**3.5.3. Countries.** The eligible articles were published by authors from 47 countries and were analyzed using VOS viewer (Figure 5(c)). The top 5 countries with large TLS were as follows: the USA (TLS = 247), the UK (TLS = 113), Germany (TLS = 108), China (TLS = 92), and France (TLS = 76).

**3.6. Cocitation Analysis.** Cocitation analysis provides a forward-looking assessment on document similarity in contrast to bibliographic coupling, which is retrospective. There were 612 references that were analyzed by using VOS viewer (Figure 6(a)). The top 5 articles with large TLS were as follows: Mont and Hungerford [16] (TLS = 4,082), Ficat [17] (TLS = 3,254), Mankin [18] (TLS = 2,573), Assouline et al. [19] (TLS = 2,557), and Steinberg et al. [20] (TLS = 2,539).

**3.6.1. Journals.** A total of 630 journals were analyzed using VOS viewer. The top 5 journals with large TLS were as follows: *Clinical Orthopaedics and Related Research* (TLS = 314,286), *Journal of Bone and Joint Surgery American Volume* (TLS = 295,588), *Journal of Bone and Joint Surgery British Volume* (TLS = 224,238), *Journal of Pediatric Orthopaedics* (TLS = 94,528), and *Radiology* (TLS = 61,601) (Figure 6(b)).

**3.7. Cooccurrence Analysis.** Cooccurrence analysis is a technique often applied in text mining, comparative genomics, and promoter analysis. The trends and current topics of the research area were assessed by the keyword network map, which was created by VOS viewer. As depicted in Figure 7(a), a total of 1,002 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 were core decompression, necrosis, expression, natural-history, and risk. In the “risk factors

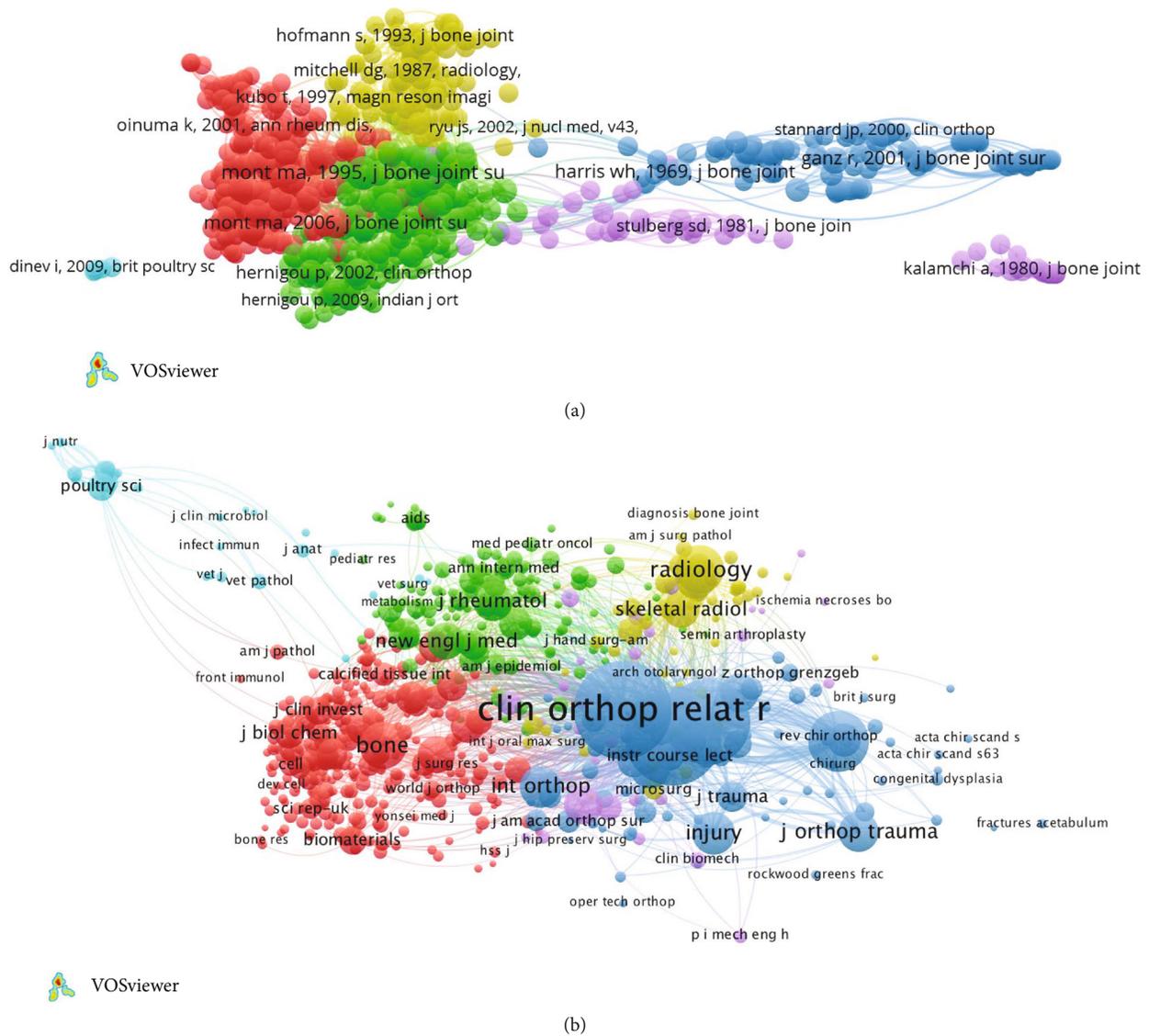


FIGURE 6: Mapping of cocited references related to surgical procedures for hip joint preservation for osteonecrosis of the femoral head (ONFH). (a) Mapping of cocited references related to the mentioned field. The size of the points represents the frequency of citation of articles. A line between two points means that both were cited in one article. A shorter line indicates a closer link between two articles. Points in the same color belong to the same research direction. (b) Mapping of cocited journals related to the mentioned field (630 points with different colors represent the 630 identified journals). The size of the points represents the frequency of citation of articles. A line between two points illustrates that both were cited in one journal. A shorter line indicates a closer link between two journals. Points in the same color belong to the same research direction.

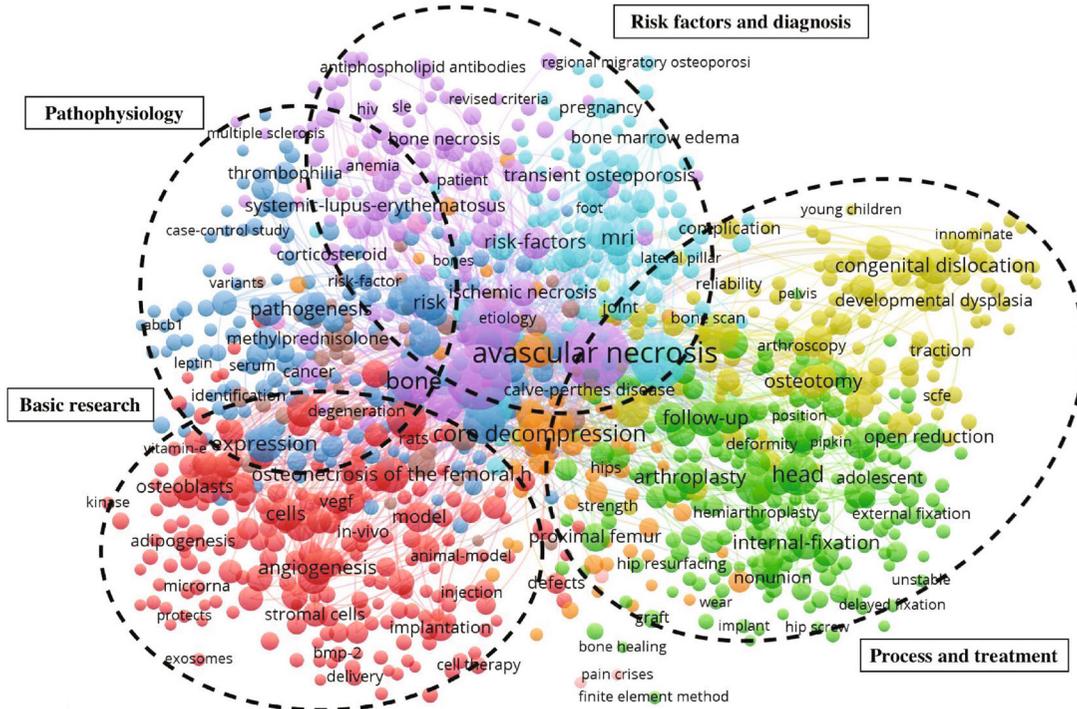
and diagnosis” cluster, the relevant keywords were avascular necrosis, osteonecrosis, femoral head, hip, and bone. In the “pathophysiology” cluster, the main keywords were necrosis, expression, risk, pathogenesis, and osteoporosis. In the “basic research” cluster, primary keywords were nontraumatic osteonecrosis, osteonecrosis of the femoral head, apoptosis, steroid-induced osteonecrosis, and differentiation. These clusters covered the most fundamental themes related to surgical procedures for hip joint preservation for ONFH.

In VOS viewer, blue color means that a keyword appeared early and yellow-colored keywords appeared later. Figure 7(b) shows that during the early stage of surgical pro-

cedures for hip joint preservation for ONFH, “process and clinical treatment” and “risk factors and diagnosis” clusters are the major topics. However, the recently developed trends showed that “pathophysiology” and “basic research” clusters will be extensively concerned in the future.

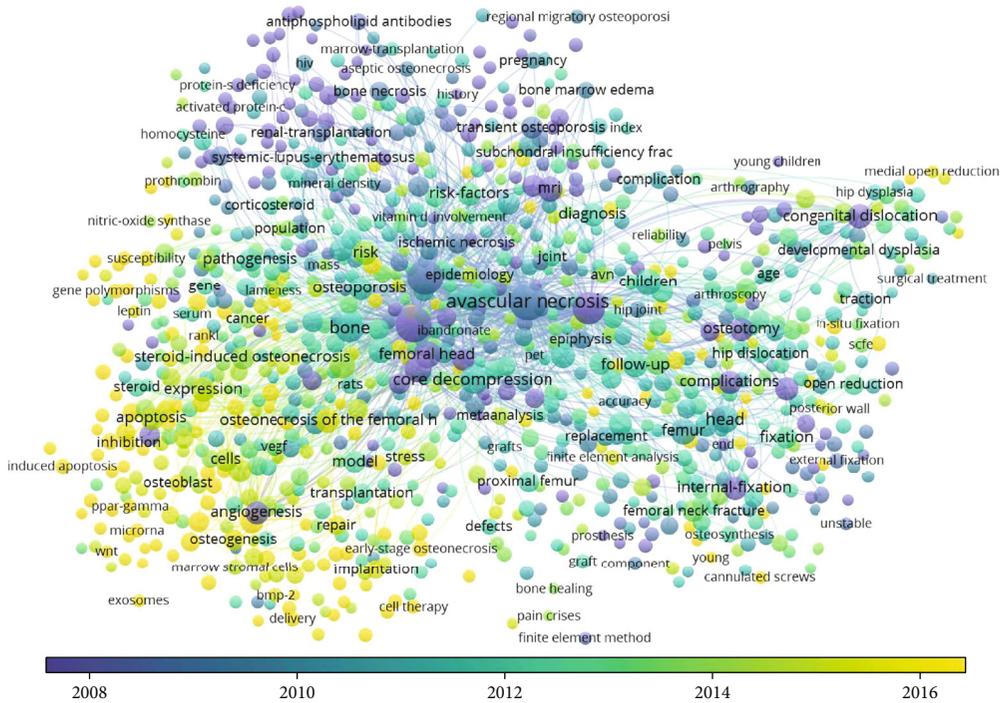
#### 4. Discussion

4.1. Global Research Trends Related to Surgical Procedures for Hip Joint Preservation for ONFH. The bibliometric analysis of surgical procedures for hip joint preservation for ONFH revealed some significant outcomes. In recent years, several scholars have concentrated on surgical procedures for hip



VOSviewer

(a)



VOSviewer

(b)

FIGURE 7: Cooccurrence analysis of global research about surgical procedures for hip joint preservation for osteonecrosis of the femoral head (ONFH). (a) Mapping of keywords in the research; the size of the points represents the frequency, and the keywords are divided into 4 clusters as follows: “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 that appeared later.

joint preservation for ONFH, according to statistics extracted from WoS. In the current study, the authors from 84 countries participated in publication of relevant articles. Additionally, China and the United States stood at the first and second places in the total number of published articles, respectively. However, the USA had the highest proportion of contributions to surgical procedures for hip joint preservation for ONFH in terms of the total number of citations and *h*-index. To our knowledge, the *h*-index and the total number of citations represent the academic impact and quality of a nation's publication. Therefore, the USA was found as the leading country in this field, because the USA has markedly concentrated on ONFH via diverse financial and nonfinancial resources. It is noteworthy that the National Natural Science Foundation of China stood in the first place in this domain. The contradiction between the quantity and quality of publications in China might attribute to several reasons. Firstly, Chinese academic evaluation system is based on quantity of publications rather than the quality, indicating an urgent need for Chinese investigators to improve the quality of research articles in the future. Secondly, in China, the number of publications in the relevant field remained relatively small before 2010. Hence, Chinese scholars need to dedicate more effort to dramatically increase average frequency of citation of articles.

*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 highest number of articles about studies on surgical procedures for hip joint preservation for ONFH. Figure 1(c) lists the top 20 authors who have published the highest number of articles about surgical procedures for hip joint preservation for ONFH, and they were pioneers in this area. Of the top 20 institutions, there were 9 institutions from China, and 5 from the USA. At the same time, China has invested millions of Chinese Yuan on surgical procedures for hip joint preservation for ONFH. Thus, the quality of researches should be greatly improved in China in the future.

According to bibliographic coupling analysis, *Clinical Orthopaedics and Related Research* is the most appropriate journal, and the USA is the leading country in this field. Coauthorship analysis indicated that the country/institution/author, with the highest TLS, would be more likely to cooperate with others. We employed cocitation analysis to assess the influence of the number of citations. *Clinical Orthopaedics and Related Research* had the highest average frequency of citation of articles related to surgical procedures for hip joint preservation for ONFH.

**4.2. Researches on Surgical Procedures for Hip Joint Preservation for ONFH.** The cooccurrence analysis revealed the possible research orientation to be helpful in the future. Therefore, we used this method to identify future trends and hot spots about surgical procedures for hip joint preservation for ONFH. The cooccurrence network was created by the keywords of the included studies. As revealed in the current study, four research-based clusters were dis-

covered, including "process and clinical treatment," "risk factors and diagnosis," "pathophysiology," and "basic research" (Figure 7(a)).

Overlay visualization map is a significant analysis to predict the research direction. As illustrated in Figure 7(b), the color bar indicates how the scores are drawn, in which "pathophysiology" and "basic research" clusters (yellow color) will be the next hot topics in this field. Further concentration on pathophysiology may assist scholars to better understand ONFH and develop more effective diagnostic and therapeutic approaches. Several scholars have concentrated on traumatic or nontraumatic causes of risk factors for ONFH [21]. Therefore, further attention needs to be paid to pathophysiology in the future. Research that utilized stem cells and growth factors has shown promising outcomes in terms of clarifying both the etiology and treatment of ONFH [22, 23].

**4.3. Strengths and Limitations.** This study, for the first time, assessed the status and trends of studies which concentrated on surgical procedures for hip joint preservation for ONFH through bibliometric and visualized analyses. However, this study contains a number of limitations. Firstly, only English-language articles were included, leading to language bias. Secondly, differences may exist between the real world and the present results. For instance, other databases (PubMed and Google Scholar) were not analyzed, which could increase the number of published articles.

## 5. Conclusions

In summary, the current status and global trends of surgical procedures for hip joint preservation for ONFH could be studied. Although China made the highest contribution to the total number of published articles, the USA was globally found as the leading country in this field. *Clinical Orthopaedics and Related Research* published the highest number of relevant articles. According to bibliometric and visualized analyses, we could predict that further studies related to surgical procedures for hip joint preservation for ONFH will be published in the coming years. Pathophysiology and basic research will significantly attract scholars' attention and will be the next hot spot in the future.

## Data Availability

The first author can provide all data.

## Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

## Authors' Contributions

Qingxi Zhang and Hui Li contributed equally to this work.

## Acknowledgments

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