

A Worldwide Bibliometric Analysis of Published Literature on Osteoporosis Vertebral Compression Fracture

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Background: With the aging population growth in the world, the prevalence of osteoporotic vertebral compression fracture (OVCF) is rapidly increasing and receiving widespread attention. Although there are numerous articles on the topic, the research status and hotspot analysis are unclear.

Objective: The goal of this study is to identify trends in the OVCF field and to analyze the most highly cited original articles published in the Web of Science Index on OVCF using bibliometric analysis.

Methods: All OVCF data were obtained from the Web of Science Core Collection, and the number of citations, institutions, journals, countries, and years of publication in this field were visually analyzed using VOSviewer, the bibliometrics online analysis platform, and Excel software. Simultaneously, the top 100 most cited articles were extracted and analyzed.

Results: A total of 756 publications were related to OVCF were included from 1900 to 2022. In recent years, the number of articles on OVCF significantly increased. They are mainly from 41 countries/regions and 202 journals, led by China and the United States. Among all countries, China had the most significant contribution on OVCF ($n = 363$), and it also was cited most often ($n = 3337$). The institution with the most articles was Soochow University ($n = 40$). *Osteoporosis International* was the journal with most studies and has published 50 on this field. The journal of *Spine* was cited most often ($n = 1968$). The most productive periods were from 2016 to 2020, which received 294 articles and 4868 citations. After the analysis, the “vertebroplasty” and “kyphoplasty” of OVCF have been the most common research hotspots.

Conclusion: This study represents an updated bibliometric analysis of OVCF. The aim is to identify current research hotspots and future trends to guide clinicians and researchers in this field.

Keywords: osteoporotic vertebral compression fracture, OVCF, bibliometric analysis, VOSviewer, Web of Science, research trends

Introduction

Osteoporosis, which is characterized by reduced bone mass and deterioration of bone architecture, has become a serious clinical problem in the elderly.^{1–3} At the same time, osteoporosis significantly increases the risk of brittle fracture, of which vertebral fracture is one of the most severe fracture types.^{4–6} The vertebral fractures secondary to osteoporosis are commonly regarded as osteoporotic vertebral compression fracture (OVCF), and spinal bone loss caused by osteoporosis and history of fall and fracture are considered to be the main risk factors.^{7,8} This type of fracture has become the third most common fragility fracture worldwide and the starting point of a lasting, severely painful, disabling condition and even death.^{2,9–12} Approximately 1.4 million of the elderly population regarding OVCF are diagnosed annually, and 16%

of postmenopausal women worldwide suffering from it.^{10,13,14} The main clinical features of OVCF are described as the collapse/compression/wedging of a vertebral body and commonly showing lumbago and backache.^{10,15} Moreover, there are studies indicating that vertebral fracture caused by osteoporosis is associated with a decreased quality of life, as well as an increase in the disability rate and mortality.^{16,17} Therefore, the OVCF has seriously damaged human health and quality of life and brought heavy burden to family and society with the increase in social population aging.

Given the heightened attention in the OVCF, a large number of related articles have been published in academic journals in recent years. Nevertheless, the trend of OVCF research is unclear, and it is also a challenge to gain a comprehensive analysis of the research in OVCF. Bibliometric analysis has become a widely applied scientific research methodology due to its reliability and efficiency.^{18,19} Based on the quantitative analysis of published articles, it can measure the contribution of an individual, journal, institution or country by relevant parameters.^{20–22} This analysis can also roughly evaluate the trend of one specific topic and has been frequently conducted in various areas.^{23–25} Besides, another advantage of bibliometric analysis is the mining of valuable information and displaying it intuitively by the visualization.²⁶ However, to our knowledge, no bibliometric studies on OVCF have been published to date. Therefore, the purpose of this bibliometric analysis is to identify the most influential publications, explore the research directions, analyze the research status and trends regarding OVCF, and provide related researchers with valuable information to facilitate collaboration.

Materials and Methods

Search Strategy

All the data of this study were obtained from articles retrieved from the core collection database of Web of Science on April 9, 2022. The following search strategy was used in this study: Title = (osteoporotic vertebral compression fracture) OR Title = OVCF AND Document type (article OR review) AND Language = English AND Time span = 1900 to 2022.

Tools

VOSviewer, the online bibliometric analysis platform (<https://bibliometric.com>), and Excel software were used to collect and analyze the data. VOSviewer and bibliometrics online analysis platform broadly recognized as the important tools were usually used to visually analyze the collaborative network of authors, institutions, countries and co-citation of keyword clusters to explore research trends and hotspots. The role of Excel software was used to identify various details of the publication, including title, author, journal, institution, country, year of publication, journal impact factors, citation reports and the number of published articles.

Data Extraction

According to the search strategy, the relevant parameters of articles were independently extracted by the two authors (YLL and TXZ), which discussed the vital information until they achieved a consensus. All data were obtained from the core collection database of Web of Science, and the useful information on OVCF was extracted and analyzed by using VOSviewer, online bibliometric analysis, and Excel software.

Result

Publication Trend

A total of 756 publications regarding OVCF were retrieved in the core collection database of Web of Science from 1900 to 2022. The number of annual publications showed a relatively stable growth trend between 1991 and 2022 in general (Figure 1A). According to the quantitative analysis of the chart, a growing trend was revealed in the past few decades in global research on OVCF, from 6 articles from 1991 to 1995 to 294 articles from 2016 to 2020. In addition, the research results indicate that OVCF is getting more and more attention and predicting a continual growth in the future. Some articles published between 2016 and 2020 attracted extensive research interest and were cited frequently as the basis, thus producing an important impact in the field.

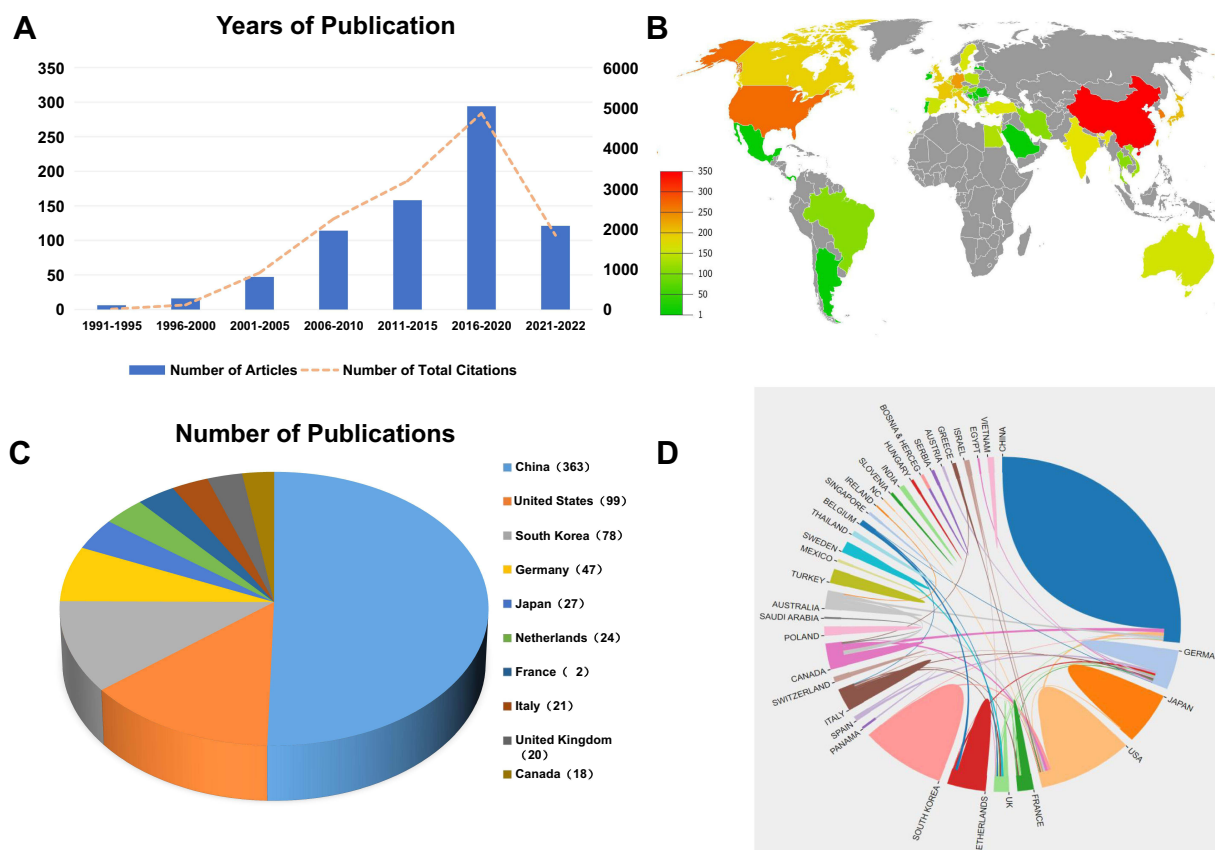


Figure 1 Overview of publications. **(A)** Trends in the number of publications and citations on OVCF research from 1991 to 2022. **(B)** Distribution of publications. **(C)** The top 10 most active countries. **(D)** Network map of international cooperation.

Country Distribution

These articles are from at least 41 different countries and regions. The global contribution of OVCF is visually analyzed and displayed by value in the world map (Figure 1B). The number of publications in diverse countries/regions was intuitively displayed (only the top 10 countries/regions) (Figure 1C). Among the top 10 countries, China published the largest number of publications ($n = 363$), which accounted for more than half of article counts, followed by the United States ($n = 99$), South Korea ($n = 78$). From Figure 1C, it can be seen that China has become the major contributor to OVCF research. Next, we analyzed the importance of countries in the collaboration network visualization by using online bibliometric analysis platform. The visual network map showed that China was the most active country far beyond the impact of any other countries/regions, followed by the United States, South Korea, Japan, Germany, and the Netherlands, which were potential power on OVCF research (Figure 1D). Furthermore, the cooperation between China and Canada as well as China and the United States occurred frequently.

Analysis of Institution

The research of the published papers covers at least 828 diverse professional agencies. In terms of research institutions, the top 10 were Soochow University ($n = 40$), Capital Medical University ($n = 18$), Xi An Jiao Tong University ($n = 15$), Nanjing Medical University ($n = 15$), Guangzhou University of Chinese Medicine ($n = 14$), Zhejiang University ($n = 13$), Chang Gung University ($n = 13$), Shandong University ($n = 12$), Leiden University ($n = 11$), and Sichuan University ($n = 11$) (Figure 2A). In addition, the other 9 of the top 10 most prolific organizations were from China, except Leiden University. According to the citation report, studies from Saint Elizabeth Hospital had the highest number of citations ($n = 1080$), and

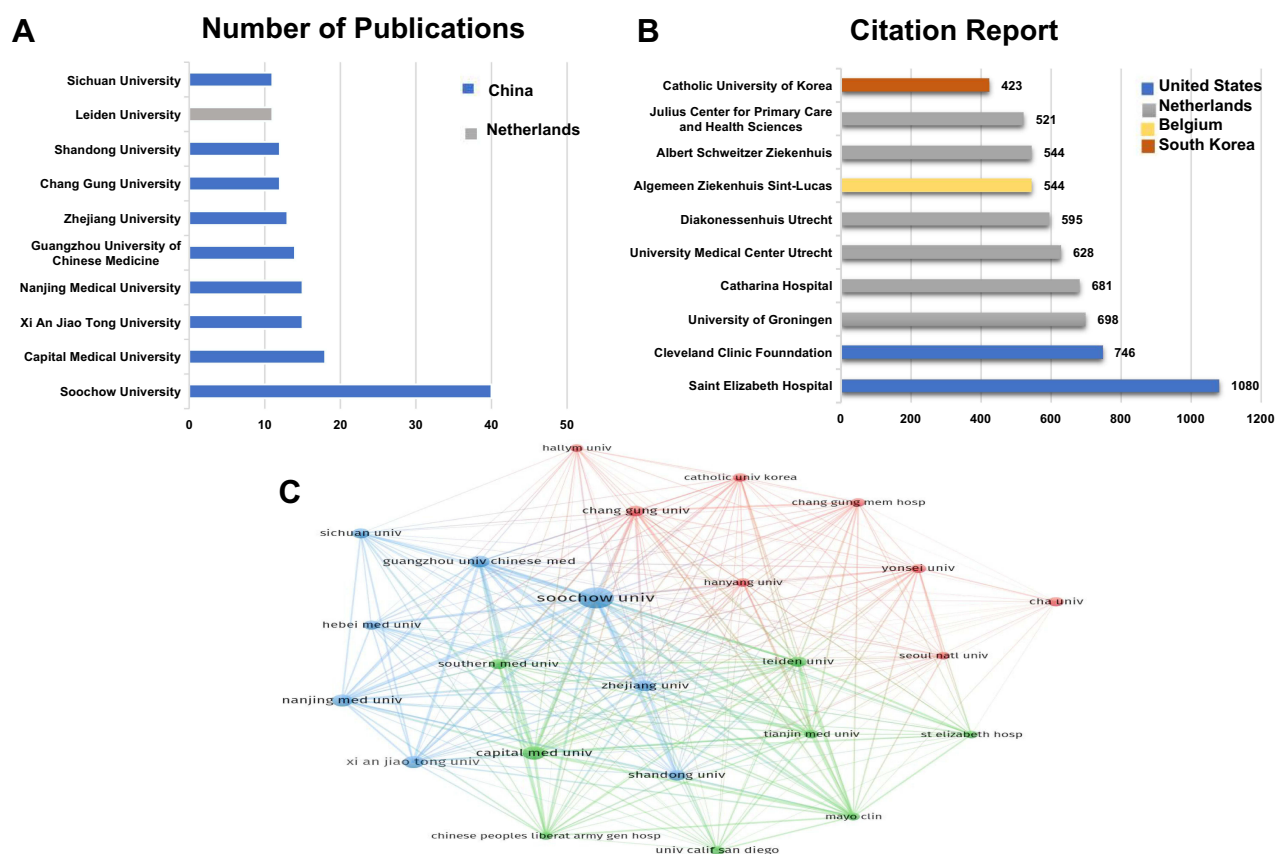


Figure 2 Highest impact institutions on OVCF. (A) The top 10 institutions in publications. Different colors indicated diverse countries, blue for China, gray for Netherlands. (B) The top 10 institutions in citations. Different colors indicated diverse countries, blue for United States, gray for Netherlands, yellow for Belgium, red for South Korea. (C) Network map of bibliometric coupling between institutions with more than seven publications. The thickness of the lines indicates the strength of the relationship, and the size of the node represents the number of published articles.

the next two high-citation agencies were Cleveland Clinic Foundation ($n = 746$) and University of Groningen ($n = 698$) (Figure 2B).

We by using VOSviewer software identified the network map of bibliometric coupling between institutions beyond seven publications. The result revealed the collaboration status of 24 institutions on the network map, which indicated the strength of the coupling relationship via the thickness of the lines, and represented the number of published articles by the size of the node (Figure 2C). In this visual analysis, Soochow University had the highest total link strength ($n = 4178$), followed by Capital Medical University ($n = 3150$), Guangzhou University of Chinese Medicine ($n=2810$), and Zhejiang University ($n = 2799$). Furthermore, the strongest coupling relationship between Soochow University and Nanjing Medical University indicated their direction of studies is more similar and have most of the same reference documents.

Journal of Publication

In the past few decades, a total of 212 academic journals appeared in the research field of OVCF. The result showed the top 10 most active journals for publishing articles on the research field of OVCF, most of which are located in the United States (Table 1). Among all the journals, *Osteoporosis International* ($n = 50$) had the most contribution, followed by *Spine* ($n = 35$), *World Neurosurgery* ($n = 34$), *European Spine Journal* ($n = 32$), *Medicine* ($n = 28$), *Journal of Orthopaedic Surgery and Research* ($n = 27$), *Pain Physician* ($n = 26$), *Journal of Spinal Disorders & Techniques* ($n = 16$), *Spine Journal* ($n=14$), and *BMC Musculoskeletal Disorders* ($n = 14$). Moreover, *Spine* and *Osteoporosis International* had the highest citation counts, which received 1968 and 802 citations, respectively.

Table 1 Journals Publishing Most on Osteoporotic Vertebral Compression Fracture

Source	Articles	Total Citations	Mean Citations	Impact Factor	JCR Partition	Country
<i>Osteoporosis International</i>	50	802	16	4.507	Q2	United Kingdom
<i>Spine</i>	35	1968	56.2	4.166	Q2	United States
<i>World Neurosurgery</i>	34	169	5	2.104	Q4	United States
<i>European Spine Journal</i>	32	689	21.5	3.134	Q3	United States
<i>Medicine</i>	28	225	8	1.889	Q2	United States
<i>Journal of Orthopaedic Surgery and Research</i>	27	190	7	2.359	Q2	United Kingdom
<i>Pain Physician</i>	26	279	10.7	4.965	Q2	United States
<i>Journal of Spinal Disorders & Techniques</i>	16	497	31.1	NA	NA	United States
<i>Spine Journal</i>	14	285	20.4	3.134	Q3	United States
<i>BMC Musculoskeletal Disorders</i>	14	98	7	2.362	Q2	United Kingdom

Analysis of Author

Using online bibliometric platform to analyze the contribution of authors, we identified the top 10 active authors in the field of OVCF research (Table 2). Among them, Yang, H.L. from Soochow University in China was on the top of the list, with 27 articles and counted 5 as first author, 11 as the corresponding author, and the next two high-production authors were Hao, D. J. (n = 13) from the Xi An Jiao Tong University in China and Zhang, L. from Beijing Hospital (n = 12).

Keyword Analysis and Research Hotspot

Keywords are the core of the research field of a paper. The accuracy and frequency of keywords are two important factors that affect the research focus of co-occurrence recognition. In the co-occurrence network analysis, a total of 1418 keywords were obtained in OVCF research by using VOSviewer software, and 90 keywords met the threshold that

Table 2 Top 10 Prolific Authors on Osteoporotic Vertebral Compression Fracture

Author	Article Counts	Total Citations	Average Citations	First Author Counts	First Author Citation Counts	Average First Author Citation Counts	Corresponding Author	Corresponding Author Citation Counts
Yang, H.L.	27	133	4.93	5	24	4.8	11	67
Hao, D.J.	13	33	2.54	0	0	0	10	33
Zhang, L.	12	65	5.42	5	49	9.8	3	2
Li, Y.	11	22	2	5	6	1.2	1	0
Liang, D.	10	49	4.9	1	10	10	0	0
Li, J.	10	4	0.4	1	0	0	1	0
Nieuwenhuijse, M.J.	9	107	11.89	8	93	11.63	7	81
Wang, H.	9	32	3.56	3	10	3.33	2	1
Chen, H.	9	27	3	3	9	3	0	0
Juttmann, J.R.	9	152	16.89	0	0	0	0	0

occurred at least 10 times (Figure 3A). The size of the node represents the number of the occurrences of terms in the literature (Author Keywords + Keywords Plus). The thickness of the connecting line indicates the link strength of two keywords. We used a visual approach to analyze the important keywords from the literature and classified into 3 clusters (diagnosis, treatment, and complications). As shown in Figure 3A, we can identify the clusters of red, green, and blue, which, respectively, represent three different research directions of OVCF. The main keywords of diagnosis cluster of red were “osteoporosis”, “vertebral compression fracture”, “spine”, “kyphoplasty” and “vertebroplasty”. While the keywords of treatment cluster of blue included “percutaneous vertebroplasty”, “balloon kyphoplasty”, “randomized trial”, “efficacy” and “augmentation”, and complications cluster of green mainly included “cement leakage”, “OVCF”, “leak”, “risk factors” “and meta analysis.”

According to the timeline viewer analysis of clustering, the colors represented the average year of publication of the identified keywords, as well as found the dynamic trend of research hotspot evolution in this field. In the early stage, “osteoporosis”, “vertebral compression fracture”, “spine”, “cement”, and “women” were the main research directions regarding OVCF (Figure 3B). Now the newest topics have turned into “osteoporotic vertebral compression fractures”, “risk factors”, “conservative treatment”, “percutaneous kyphoplasty”, and “meta analysis.” Through the analysis of the keywords, we can obtain research topics in a specific field, explore the research focus and the research direction.

Top 100 Cited Articles

During the study period, we identified the top 100 cited articles on OVCF in the core collection database of Web of Science (Table 3). These articles were published between 1993 and 2018. The period in which the most frequently cited articles were published was 2006 through 2010, received 40 articles and 3086 citations (Figure 4A).

The 100 most-cited publications were abstracted from 77 institutions. Among these articles, Saint Elisabeth Hospital from the Netherlands contributed 6 of the top 100 articles, and the Leiden University Medical Center, Soochow University and Tianjin Medical University each contributed 4 articles (Figure 4B). The analysis results have shown that the number of papers published by scientific institutions can roughly reflect their scientific research ability in related fields. Hence, the top 10 institutions, which account for 31% of total publications, have become the most representative institutions in this field of OVCF research.

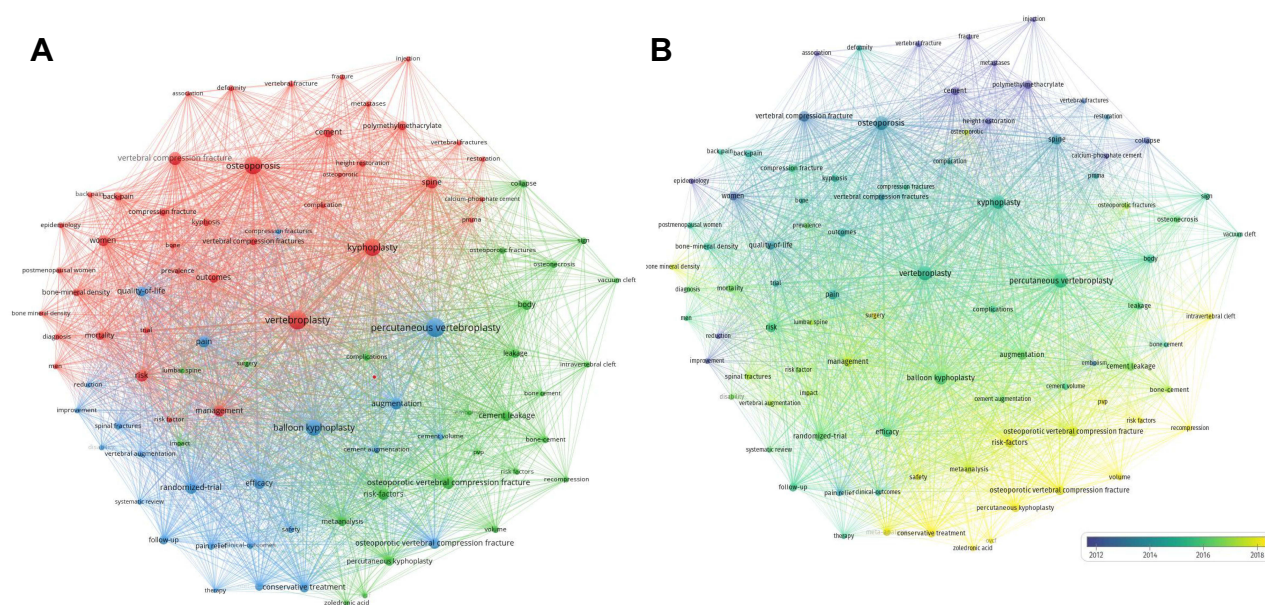


Figure 3 Co-occurrence analysis of keywords. **(A)** Keyword co-occurrence clustering network of OVCF. Each node in this map represents a keyword that occurred at least 10 times. Different colors indicated diverse research clusters, red for diagnosis cluster, green for complications cluster and blue for treatment cluster. **(B)** Distribution of keywords according to average publication year. Colors showed evolution of keyword over time (purple: earlier, yellow: later).

Table 3 Top 100 Most-Cited Articles on Osteoporotic Vertebral Compression Fracture

Rank	Author	Title	Journal	Year	Citations	Citations/ Year
1	Jensen, M. E.	Percutaneous polymethylmethacrylate vertebroplasty in the treatment of osteoporotic vertebral body compression fractures: technical aspects	<i>American Journal of Neuroradiology</i>	1997	758	29.15
2	Lieberman, I.H.	Initial outcome and efficacy of kyphoplasty in the treatment of painful osteoporotic vertebral compression fractures	<i>Spine</i>	2001	665	30.23
3	Klazen, C. A.	Vertebroplasty versus conservative treatment in acute osteoporotic vertebral compression fractures (VERTOS II): an open-label randomised trial	<i>Lancet</i>	2010	544	41.85
4	Cortet, B.	Percutaneous vertebroplasty in the treatment of osteoporotic vertebral compression fractures: an open prospective study	<i>Journal of Rheumatology</i>	1999	356	14.83
5	Lyles, K. W.	Association of osteoporotic vertebral compression fractures with impaired functional status	<i>American Journal of Medicine</i>	1993	287	9.57
6	Voormolen, M. H.	Percutaneous vertebroplasty compared with optimal pain medication treatment: short-term clinical outcome of patients with subacute or chronic painful osteoporotic vertebral compression fractures. The VERTOS study	<i>American Journal of Neuroradiology</i>	2007	266	16.63
7	Phillips, F. M.	Early radiographic and clinical results of balloon kyphoplasty for the treatment of osteoporotic vertebral compression fractures	<i>Spine</i>	2003	192	9.6
8	Peh, W. C.	Percutaneous vertebroplasty for severe osteoporotic vertebral body compression fractures	<i>Radiology</i>	2002	183	8.71
9	Liu, J. T.	Balloon kyphoplasty versus vertebroplasty for treatment of osteoporotic vertebral compression fracture: a prospective, comparative, and randomized clinical study	<i>Osteoporosis International</i>	2010	177	13.62
10	Farrokhi, M. R.	Randomized controlled trial of percutaneous vertebroplasty versus optimal medical management for the relief of pain and disability in acute osteoporotic vertebral compression fractures	<i>Journal of Neurosurgery-Spine</i>	2011	170	14.17
11	Ryu, K. S.	Dose-dependent epidural leakage of polymethylmethacrylate after percutaneous vertebroplasty in patients with osteoporotic vertebral compression fractures	<i>Journal of Neurosurgery</i>	2002	169	8.05
12	Voggenreiter, G.	Balloon kyphoplasty is effective in deformity correction of osteoporotic vertebral compression fractures	<i>Spine</i>	2005	168	9.33
13	Bai, B.	The use of an injectable, biodegradable calcium phosphate bone substitute for the prophylactic augmentation of osteoporotic vertebrae and the management of vertebral compression fractures	<i>Spine</i>	1999	155	6.46

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Table 3 (Continued).

Rank	Author	Title	Journal	Year	Citations	Citations/ Year
14	Phillips, F. M.	Minimally invasive treatments of osteoporotic vertebral compression fractures	<i>Spine</i>	2003	145	7.25
15	Voormolen, M. H.	The risk of new osteoporotic vertebral compression fractures in the year after percutaneous vertebroplasty	<i>Journal of Vascular and Interventional Radiology</i>	2006	143	8.41
16	Baur, A.	Acute osteoporotic and neoplastic vertebral compression fractures: fluid sign at MR imaging	<i>Radiology</i>	2002	140	6.67
17	Kim, Y. J.	Pulmonary cement embolism after percutaneous vertebroplasty in osteoporotic vertebral compression fractures: incidence, characteristics, and risk factors	<i>Radiology</i>	2009	133	9.5
18	Komemushi, A.	Percutaneous vertebroplasty for osteoporotic compression fracture: multivariate study of predictors of new vertebral body fracture	<i>Cardiovascular and Interventional Radiology</i>	2006	126	7.41
19	Nieuwenhuijse, M. J.	Cement leakage in percutaneous vertebroplasty for osteoporotic vertebral compression fractures: identification of risk factors	<i>Spine Journal</i>	2011	115	9.58
20	Hadjipavlou, A. G.	Percutaneous vertebroplasty and balloon kyphoplasty for the treatment of osteoporotic vertebral compression fractures and osteolytic tumours	<i>Journal of Bone and Joint Surgery-British Volume</i>	2005	114	6.33
21	McKiernan, F.	Intravertebral clefts in osteoporotic vertebral compression fractures	<i>Arthritis and Rheumatism</i>	2003	108	5.4
22	Ploeg, W. T.	Percutaneous vertebroplasty as a treatment for osteoporotic vertebral compression fractures: a systematic review	<i>European Spine Journal</i>	2006	103	6.06
23	Yang, E. Z.	Percutaneous vertebroplasty versus conservative treatment in aged patients with acute osteoporotic vertebral compression fractures: a prospective randomized controlled clinical study	<i>Spine</i>	2016	93	13.29
24	Kobayashi, K.	Percutaneous vertebroplasty immediately relieves pain of osteoporotic vertebral compression fractures and prevents prolonged immobilization of patients	<i>European Radiology</i>	2005	91	5.06
25	Kaup, M.	Dual-energy ct-based display of bone marrow edema in osteoporotic vertebral compression fractures: impact on diagnostic accuracy of radiologists with varying levels of experience in correlation to MR imaging	<i>Radiology</i>	2016	90	12.86
26	Nakano, M.	Percutaneous transpedicular vertebroplasty with calcium phosphate cement in the treatment of osteoporotic vertebral compression and burst fractures	<i>Journal of Neurosurgery</i>	2002	88	4.19
27	Knopp, J. A.	Calcitonin for treating acute pain of osteoporotic vertebral compression fractures: a systematic review of randomized, controlled trials	<i>Osteoporosis International</i>	2005	87	4.83

(Continued)

Table 3 (Continued).

Rank	Author	Title	Journal	Year	Citations	Citations/ Year
28	Firanesu, C. E.	Vertebroplasty versus sham procedure for painful acute osteoporotic vertebral compression fractures (VERTOS IV): randomised sham controlled clinical trial	<i>BMJ-British Medical Journal</i>	2018	86	17.2
29	Pradhan, B. B.	Kyphoplasty reduction of osteoporotic vertebral compression fractures: correction of local kyphosis versus overall sagittal alignment	<i>Spine</i>	2006	86	5.06
30	Ma, X. L.	Balloon kyphoplasty versus percutaneous vertebroplasty in treating osteoporotic vertebral compression fracture: grading the evidence through a systematic review and meta-analysis	<i>European Spine Journal</i>	2012	85	7.73
31	Baur, A.	Diagnostic value of increased diffusion weighting of a steady-state free precession sequence for differentiating acute benign osteoporotic fractures from pathologic vertebral compression fractures	<i>American Journal of Neuroradiology</i>	2001	82	3.73
32	Han, S.	Percutaneous vertebroplasty versus balloon kyphoplasty for treatment of osteoporotic vertebral compression fracture: a meta-analysis of randomised and non-randomised controlled trials	<i>International Orthopaedics</i>	2011	76	6.33
33	Kim, Y. Y.	Recompression of vertebral body after balloon kyphoplasty for osteoporotic vertebral compression fracture	<i>European Spine Journal</i>	2010	76	5.85
34	De Negri, P.	Treatment of painful osteoporotic or traumatic vertebral compression fractures by percutaneous vertebral augmentation procedures - a nonrandomized comparison between vertebroplasty and kyphoplasty	<i>Clinical Journal of Pain</i>	2007	75	4.69
35	Lin, W. C.	New vertebral osteoporotic compression fractures after percutaneous vertebroplasty: retrospective analysis of risk factors	<i>Journal of Vascular and Interventional Radiology</i>	2008	69	4.6
36	Hochmuth, K.	Percutaneous vertebroplasty in the therapy of osteoporotic vertebral compression fractures: a critical review	<i>European Radiology</i>	2006	69	4.06
37	Voormolen, M. H.	Prospective clinical follow-up after percutaneous vertebroplasty in patients with painful osteoporotic vertebral compression fractures	<i>Journal of Vascular and Interventional Radiology</i>	2006	68	4
38	Syed, M. I.	New symptomatic vertebral compression fractures within a year following vertebroplasty in osteoporotic women	<i>American Journal of Neuroradiology</i>	2005	68	3.78
39	Movrin, I.	Adjacent vertebral fractures after percutaneous vertebral augmentation of osteoporotic vertebral compression fracture: a comparison of balloon kyphoplasty and vertebroplasty	<i>Archives of Orthopaedic and Trauma Surgery</i>	2010	66	5.08

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Table 3 (Continued).

Rank	Author	Title	Journal	Year	Citations	Citations/ Year
40	Zhang, H.	Does percutaneous vertebroplasty or balloon kyphoplasty for osteoporotic vertebral compression fractures increase the incidence of new vertebral fractures? A meta-analysis	<i>Pain Physician</i>	2017	65	10.83
41	Lee, H. M.	Comparative analysis of clinical outcomes in patients with osteoporotic vertebral compression fractures (OVCFs): conservative treatment versus balloon kyphoplasty	<i>Spine Journal</i>	2012	63	5.73
42	Knopp-Sihota, J. A.	Calcitonin for treating acute and chronic pain of recent and remote osteoporotic vertebral compression fractures: a systematic review and meta-analysis	<i>Osteoporosis International</i>	2012	63	5.73
43	Buchbinder, R.	Percutaneous vertebroplasty for osteoporotic vertebral compression fracture	<i>Cochrane Database of Systematic Reviews</i>	2015	61	7.63
44	Lee, W. S.	Risk factors of developing new symptomatic vertebral compression fractures after percutaneous vertebroplasty in osteoporotic patients	<i>European Spine Journal</i>	2006	60	3.53
45	Yang, H. L.	Changes of pulmonary function for patients with osteoporotic vertebral compression fractures after kyphoplasty	<i>Journal of Spinal Disorders & Techniques</i>	2007	59	3.69
46	Chen, L. X.	Comparative efficacy and tolerability of three treatments in old people with osteoporotic vertebral compression fracture: a network meta-analysis and systematic review	<i>PLoS One</i>	2015	58	7.25
47	Chen, L.	Unilateral versus bilateral balloon kyphoplasty for multilevel osteoporotic vertebral compression fractures a prospective study	<i>Spine</i>	2011	55	4.58
48	Furtado, N.	Biomechanical investigation of vertebroplasty in osteoporotic compression fractures and in prophylactic vertebral reinforcement	<i>Spine</i>	2007	53	3.31
49	Shindle, M. K.	Vertebral height restoration in osteoporotic compression fractures: kyphoplasty balloon tamp is superior to postural correction alone	<i>Osteoporosis International</i>	2006	53	3.12
50	Yan, D.	Comparative study of percutaneous vertebroplasty and kyphoplasty in the treatment of osteoporotic vertebral compression fractures	<i>Archives of Orthopaedic and Trauma Surgery</i>	2011	52	4.33
51	Yuan, H. A.	Osteoporotic spinal deformity - a biomechanical rationale for the clinical consequences and treatment of vertebral body compression fractures	<i>Journal of Spinal Disorders & Techniques</i>	2004	52	2.74
52	Lovi, A.	Vertebroplasty and kyphoplasty: complementary techniques for the treatment of painful osteoporotic vertebral compression fractures. A prospective non-randomised study on 154 patients	<i>European Spine Journal</i>	2009	51	3.64

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Table 3 (Continued).

Rank	Author	Title	Journal	Year	Citations	Citations/Year
53	Klazen, C. A.	VERTOS II: percutaneous vertebroplasty versus conservative therapy in patients with painful osteoporotic vertebral compression fractures; Rationale, objectives and design of a multicenter randomized controlled trial	<i>Trials</i>	2007	51	3.19
54	Svedbom, A.	Balloon kyphoplasty compared to vertebroplasty and nonsurgical management in patients hospitalised with acute osteoporotic vertebral compression fracture: a UK cost-effectiveness analysis	<i>Osteoporosis International</i>	2013	50	5
55	Li, X.	Comparison of kyphoplasty and vertebroplasty for treatment of painful osteoporotic vertebral compression fractures twelve-month follow-up in a prospective nonrandomized comparative study	<i>Journal of Spinal Disorders & Techniques</i>	2012	48	4.36
56	Robinson, Y.	Kyphoplasty in osteoporotic vertebral compression fractures - guidelines and technical considerations	<i>Journal of Orthopaedic Surgery and Research</i>	2011	48	4
57	Nieuwenhuijse, M. J.	New vertebral fractures after percutaneous vertebroplasty for painful osteoporotic vertebral compression fractures: a clustered analysis and the relevance of intradiskal cement leakage	<i>Radiology</i>	2013	46	4.6
58	Nieuwenhuijse, M. J.	Optimal intravertebral cement volume in percutaneous vertebroplasty for painful osteoporotic vertebral compression fractures	<i>Spine</i>	2012	46	4.18
59	Kumar, K.	A comparative analysis of the results of vertebroplasty and kyphoplasty in osteoporotic vertebral compression fractures	<i>Neurosurgery</i>	2010	46	3.54
60	Zhang, L.	Bone cement distribution in the vertebral body affects chances of recompression after percutaneous vertebroplasty treatment in elderly patients with osteoporotic vertebral compression fractures	<i>Clinical Interventions In Aging</i>	2017	44	7.33
61	Kettler, A.	Biomechanical performance of the new beadex implant in the treatment of osteoporotic vertebral body compression fractures: restoration and maintenance of height and stability	<i>Clinical Biomechanics</i>	2006	44	2.59
62	Sugita, M.	Classification of vertebral compression fractures in the osteoporotic spine	<i>Journal of Spinal Disorders & Techniques</i>	2005	44	2.44
63	Savage, J. W.	Vertebroplasty and kyphoplasty for the treatment of osteoporotic vertebral compression fractures	<i>Journal of The American Academy of Orthopaedic Surgeons</i>	2014	43	4.78
64	Cheng, X.	Comparison of unilateral versus bilateral percutaneous kyphoplasty for the treatment of patients with osteoporosis vertebral compression fracture (OVCF): a systematic review and meta-analysis	<i>European Spine Journal</i>	2016	42	6

(Continued)

Table 3 (Continued).

Rank	Author	Title	Journal	Year	Citations	Citations/ Year
65	Muijs, S. P.	Percutaneous vertebroplasty for the treatment of osteoporotic vertebral compression fractures evaluation after 36 months	<i>Journal of Bone and Joint Surgery-British Volume</i>	2009	42	3
66	Matsuyama, Y.	Vertebral reconstruction with biodegradable calcium phosphate cement in the treatment of osteoporotic vertebral compression fracture using instrumentation	<i>Journal of Spinal Disorders & Techniques</i>	2004	42	2.21
67	Mauch, J. T.	Review of the imaging features of benign osteoporotic and malignant vertebral compression fractures	<i>American Journal of Neuroradiology</i>	2018	41	8.2
68	Wang, H. K.	Comparing clinical outcomes following percutaneous vertebroplasty with conservative therapy for acute osteoporotic vertebral compression fractures	<i>Pain Medicine</i>	2010	41	3.15
69	Chung, H. J.	Comparative study of balloon kyphoplasty with unilateral versus bilateral approach in osteoporotic vertebral compression fractures	<i>International Orthopaedics</i>	2008	41	2.73
70	Krueger, A.	Height restoration of osteoporotic vertebral compression fractures using different intravertebral reduction devices: a cadaveric study	<i>Spine Journal</i>	2015	40	5
71	Zhang, Z.	Risk factors for new osteoporotic vertebral compression fractures after vertebroplasty a systematic review and meta-analysis	<i>Journal of Spinal Disorders & Techniques</i>	2013	40	4
72	Ren, H.	Correlative factor analysis on the complications resulting from cement leakage after percutaneous kyphoplasty in the treatment of osteoporotic vertebral compression fracture	<i>Journal of Spinal Disorders & Techniques</i>	2010	40	3.08
73	Freedman, B. A.	Kummel disease: a not-so-rare complication of osteoporotic vertebral compression fractures	<i>Journal of The American Board of Family Medicine</i>	2009	40	2.86
74	Khanna, A. J.	Functional outcomes of kyphoplasty for the treatment of osteoporotic and osteolytic vertebral compression fractures	<i>Osteoporosis International</i>	2006	40	2.35
75	Yuan, W. H.	Vertebroplasty and balloon kyphoplasty versus conservative treatment for osteoporotic vertebral compression fractures a meta-analysis	<i>Medicine</i>	2016	39	5.57
76	Xing, D.	A meta-analysis of balloon kyphoplasty compared to percutaneous vertebroplasty for treating osteoporotic vertebral compression fractures	<i>Journal of Clinical Neuroscience</i>	2013	39	3.9
77	Prather, H.	Nonoperative management of osteoporotic vertebral compression fractures	<i>Injury-International Journal of The Care of The Injured</i>	2007	39	2.44
78	Helmes, E.	A questionnaire to evaluate disability in osteoporotic patients with vertebral compression fractures	<i>Journals of Gerontology Series A-Biological Sciences and Medical Sciences</i>	1995	39	1.39

(Continued)

Table 3 (Continued).

Rank	Author	Title	Journal	Year	Citations	Citations/ Year
79	Liu, J. T.	Long-term follow-up study of osteoporotic vertebral compression fracture treated using balloon kyphoplasty and vertebroplasty	<i>Journal of Neurosurgery-Spine</i>	2015	38	4.75
80	Wang, G.	Osteoporotic vertebral compression fractures with an intravertebral cleft treated by percutaneous balloon kyphoplasty	<i>Journal of Bone and Joint Surgery-British Volume</i>	2010	38	2.92
81	Werner, C. M.	Vertebral body stenting versus kyphoplasty for the treatment of osteoporotic vertebral compression fractures a randomized trial	<i>Journal of Bone and Joint Surgery-American Volume</i>	2013	37	3.7
82	Armingeat, T.	Intravenous pamidronate for pain relief in recent osteoporotic vertebral compression fracture: a randomized double-blind controlled study	<i>Osteoporosis International</i>	2006	37	2.18
83	Chang, X.	Vertebroplasty versus kyphoplasty in osteoporotic vertebral compression fracture: a meta-analysis of prospective comparative studies	<i>International Orthopaedics</i>	2015	36	4.5
84	Chen, C.	Kyphoplasty for chronic painful osteoporotic vertebral compression fractures via unipedicular versus bipedicular approachment: a comparative study in early stage	<i>Injury-International Journal of The Care of The Injured</i>	2010	36	2.77
85	Pateder, D. B.	Vertebroplasty and kyphoplasty for the management of osteoporotic vertebral compression fractures	<i>Orthopedic Clinics of North America</i>	2007	36	2.25
86	Voormolen, M. H.	Bone marrow edema in osteoporotic vertebral compression fractures after percutaneous vertebroplasty and relation with clinical outcome	<i>American Journal of Neuroradiology</i>	2006	36	2.12
87	Chin, D. K.	Efficacy of postural reduction in osteoporotic vertebral compression fractures followed by percutaneous vertebroplasty	<i>Neurosurgery</i>	2006	36	2.12
88	Lane, J. M.	Minimally invasive options for the treatment of osteoporotic vertebral compression fractures	<i>Orthopedic Clinics of North America</i>	2002	36	1.71
89	Tutton, S. M.	Kast study: the kiva system as a vertebral augmentation treatment-a safety and effectiveness trial a randomized, noninferiority trial comparing the kiva system with balloon kyphoplasty in treatment of osteoporotic vertebral compression fractures	<i>Spine</i>	2015	35	4.38
90	Robinson, Y.	Vertebroplasty and kyphoplasty-a systematic review of cement augmentation techniques for osteoporotic vertebral compression fractures compared to standard medical therapy	<i>Maturitas</i>	2012	35	3.18
91	Ren, H. L.	Risk factors of new symptomatic vertebral compression fractures in osteoporotic patients undergone percutaneous vertebroplasty	<i>European Spine Journal</i>	2015	34	4.25

(Continued)

Table 3 (Continued).

Rank	Author	Title	Journal	Year	Citations	Citations/ Year
92	Rebolledo, B. J.	Comparison of unipedicular and bipedicular balloon kyphoplasty for the treatment of osteoporotic vertebral compression fractures a prospective randomised study	<i>Bone & Joint Journal</i>	2013	34	3.4
93	Zou, J.	Is kyphoplasty reliable for osteoporotic vertebral compression fracture with vertebral wall deficiency?	<i>Injury-International Journal of The Care of The Injured</i>	2010	34	2.62
94	Zhang, L.	A comparison of high viscosity bone cement and low viscosity bone cement vertebroplasty for severe osteoporotic vertebral compression fractures	<i>Clinical Neurology and Neurosurgery</i>	2015	33	4.13
95	Venmans, A.	Natural history of pain in patients with conservatively treated osteoporotic vertebral compression fractures: results from VERTOS II	<i>American Journal of Neuroradiology</i>	2012	33	3
96	Fritzell, P.	Cost-effectiveness of balloon kyphoplasty versus standard medical treatment in patients with osteoporotic vertebral compression fracture	<i>Spine</i>	2011	33	2.75
97	Klazen, C. A.	Clinical course of pain in acute osteoporotic vertebral compression fractures	<i>Journal of Vascular and Interventional Radiology</i>	2010	33	2.54
98	Felder-Puig, R.	Kyphoplasty and vertebroplasty for the management of osteoporotic vertebral compression fractures. A systematic review	<i>Orthopade</i>	2009	33	2.36
99	Papadopoulos, E. C.	Unipedicular balloon kyphoplasty for the treatment of osteoporotic vertebral compression fractures: early results	<i>Journal of Spinal Disorders & Techniques</i>	2008	33	2.2
100	Toyone, T.	Changes in vertebral wedging rate between supine and standing position and its association with back pain: a prospective study in patients with osteoporotic vertebral compression fractures	<i>Spine</i>	2006	33	1.94

The top 100 most cited articles cover a total of 19 countries/regions. According to the national article statistics, the largest contributor of article counts was China (n = 25), followed by the United States (n = 19), the Netherlands (n = 13), Germany (n = 8), South Korea (n = 7), Japan (n = 6), Canada, Sweden (n = 4) and France, Italy (n = 2) (Figure 4C). But the most cited articles were from the United States, with 2624 citations and 138.11 average citations. The countries of higher average citations were France (n = 196.5), the United States (n = 138.11) and the Netherlands (n = 113). Although China ranked first in terms of number of articles, the per citations of articles were lower.

There are 42 different journals which generated the top 100 articles. Among them, the *Spine* was the most prolific journal, with 13 articles and 1759 citations, followed by *Journal of Spinal Disorders & Techniques* (8 articles, 358 citations), *American Journal of Neuroradiology* (7 articles, 1284 citations), *European Spine Journal* (7 articles, 451 citations), *Osteoporosis International* (7 articles, 507 citations), *Radiology* (5 articles, 592 citations), *Journal of Vascular and Interventional Radiology* (4 articles, 313 citations) (Table 4). The top 7 journals of the 100 most cited articles on OVCF were mainly from the United States and the United Kingdom. It can be seen that have a strong scientific research strength and the high scientific research investment, especially in the United States.

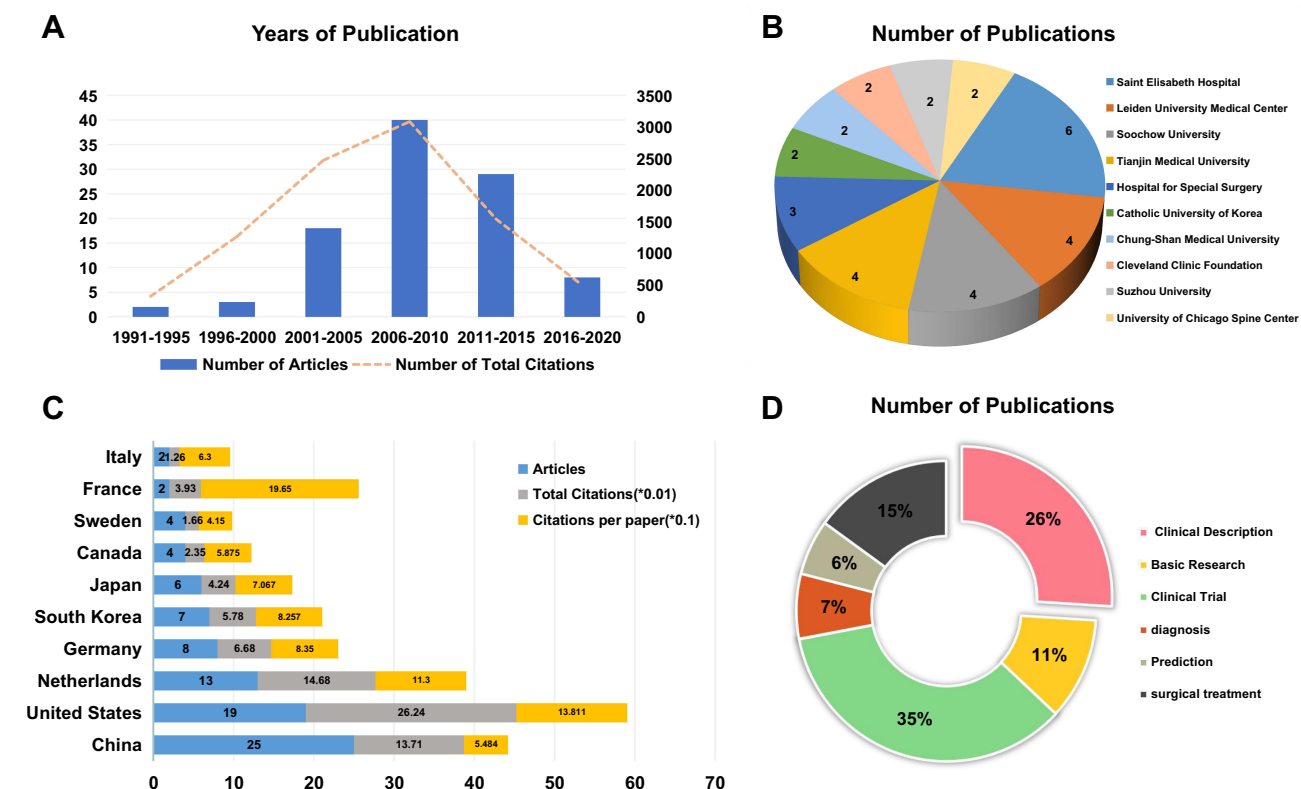


Figure 4 Top 100 most cited publications on OVCF. (A) Years of publication. (B) Institution analysis. (C) Analysis of the top 10 countries with top 100 most cited articles. Total citations (*0.01) represents the number of 100 times smaller. The citations per paper (*0.1) represents the number of 10 times smaller. Different colors indicated represent research types, blue for articles, gray for total citations, yellow for citations per paper. (D) Publication topics.

In this research, the top 100 articles cover a wide range of topics in this field of OVCF. Among these articles, 35% of articles were related to clinical trial, which has become the world's largest research direction on OVCF. The next three high-production fields were clinical description ($n = 26\%$), surgical treatment ($n = 15\%$) and basic research ($n = 11\%$) (Figure 4D).

Table 4 Journals with More Than Three of the Top 100 Cited Articles on Osteoporotic Vertebral Compression Fracture

Journal	Articles	Total Citations	Mean Citations	2021 Impact Factor	2021 JCR Partition	Country
<i>Spine</i>	13	1759	135	4.166	Q2	United States
<i>Journal of Spinal Disorders & Techniques</i>	8	358	45	NA	NA	United States
<i>American Journal of Neuroradiology</i>	7	1284	183	3.825	Q2	United States
<i>European Spine Journal</i>	7	451	64	3.134	Q3	United States
<i>Osteoporosis International</i>	7	507	72	4.507	Q2	United Kingdom
<i>Radiology</i>	5	592	118	3.173	Q2	United States
<i>Journal of Vascular and Interventional Radiology</i>	4	313	78	3.464	Q2	United States

Discussion

Osteoporotic vertebral compression fracture (OVCF) is one of the most common causes of lumbago and backache, especially among the elderly, and generates a great challenge to researchers and clinicians.^{13,15,27,28} Most patients regarding OVCF, in addition to frequently suffering from consistent pain, have also been confirmed to have multiple adverse impacts such as impacting quality of life, physical function, mental health, and survival.^{13,29–33} Moreover, vertebral fracture is closely related to the increase in morbidity and mortality in the elderly.^{34,35} According to relevant studies, higher age and lower BMD are associated with fracture risk.^{36,37} BMD is also an important indicator for screening fracture risk and diagnosing osteoporosis. In fact, prior fracture history has the highest risk of osteoporotic fracture and is the strongest determinant of impending fracture risk.³⁸ Other risk factors for OVCF include glucocorticoid use, family history of fracture, cigarette smoking, excessive alcohol intake, rheumatoid arthritis, low body weight, falls and frailty in elderly.^{38,39} In addition, studies have shown that bone-specific alkaline phosphatase is also associated with the risk of fracture and predicts fracture risk.⁴⁰ For patients with osteoporosis, proper and timely use of anti-osteoporosis drugs can also be effective in reducing the risk of fracture, such as bisphosphonates and teriparatide.

Bibliometrics, first defined by Alan Pritchard in 1969, is an effective tool to quantitatively analyze the status and trends of a research field by using mathematics and statistical methods.⁴¹ It is also considered an important approach to compare the contributions of different countries, institutions, authors and journals in a certain field.⁴² Moreover, in addition to assessing trends in a particular study, it can also uncover valuable information hidden in the data and display it intuitively by the visualization.²⁶ In recent years, with the growth in the number of publications and the development of visualization tools, bibliometric analysis has been widely used in biomedical sciences.^{43,44} Nevertheless, the trend of OVCF research is unclear, and it is also a challenge to gain a comprehensive analysis of the research in OVCF. Therefore, we achieved the visual analysis of research results through the VOSviewer, bibliometrics online analysis platform and Excel software. At the same time, this study will help related researchers with valuable information and guide the direction of future research.

Publication Trends in OVCF Research

The data analysis revealed a rapid growth trend on OVCF research in the last 20 years, especially from 2016 to 2020. The total publications of China ranked first of all the countries, suggesting that China made major contributions to the development of OVCF research. The cooperation among countries is growing closer, with between China and Canada, as well as China and the United States cooperating most frequently. With respect to institutional contributions, China was also the most active country and accounted for nine of the top 10 high-yield institutions. But in terms of total citations, Saint Elizabeth Hospital in the United States was the biggest contributor, with 1080 citations. At the same time, Institutions from the Netherlands should also pay special attention. The result indicated that the number of papers published by scientific research institutions can represent the research capacity in their field. Among these journals, the top 5 active journals on OVCF were *Osteoporosis International* from the United Kingdom, followed by journals from the United States, including *Spine*, *World Neurosurgery*, *European Spine Journal* and *Medicine*. Therefore, we can roughly infer publications from the United States and the United Kingdom were with relatively higher quality. Researchers studying OVCF should pay close attention to their dynamics and strengthen cooperation with these institutions and countries.

Research Interests

Keywords represent the core of the article and the research direction. In the co-occurrence analysis of keywords, the high-frequency keywords were “kyphoplasty”, “vertebroplasty”, “osteoporosis”, “balloon kyphoplasty”, and “percutaneous vertebroplasty”, and finally, three color clusters were formed on the basis of cluster analysis. To further explore the dynamic development of research hotspots, we evaluated the evolution of keywords over time. The analysis results indicate that the research direction has changed from clinical description to conservative treatment, complications and risk factor analysis. For example, the early common keywords are “injection”, “fracture”, “osteoporosis”, and “women”, while the newest keywords are mostly “conservative treatment”, “risk factors”, “zoledronic acid” and “recompression.” It

can be seen that the research associated with “conservative treatment” and “risk factors” are the hot topics in recent years and have excellent developing trends in the future.

The Most Influential Articles

The number of citations can roughly reflect the quality and importance of the article. In this analysis, the most cited article on OVCF was the 1997 paper in *the American Journal of Neuroradiology* by Jensen et al, with 758 citations: “Percutaneous polymethylmethacrylate vertebroplasty in the treatment of osteoporotic vertebral body compression fractures: technical aspects”, which introduced the advantages of percutaneous vertebroplasty (PVP) for OVCF.⁴⁵ The technique has been confirmed in 29 patients with 47 painful vertebral fractures. The main process includes percutaneous puncture of the involved vertebra and injection of polymethylmethacrylate (PMMA) into the related vertebral body. Furthermore, the surgical procedure and treatment experience of percutaneous vertebroplasty are described in detail in the article. At the same time, the technology provided that the easiest, safest, and efficient method was the fluoroscopically guiding transpedicular approach. Finally, the results show that the skill of percutaneous vertebroplasty (PVP) can relieve the pain of patients with OVCF and achieve early activities. To date, the PVP has become a classic surgery for the treatment of OVCF and attracted more and more attention. Although the PVP has been widely used in clinical practice to treat symptomatic OVCF, some recent studies have questioned its role in daily practice.^{46,47} According to randomized controlled trial analysis, the PVP was slightly different or no significant difference compared with placebo or sham procedure in terms of pain relief.^{47–49} At the same time, the bone cement distribution is related to postoperative complications, including bone cement leakage, kyphosis, adjacent segment fracture and loss of height.^{50–52}

“Initial outcome and efficacy of kyphoplasty in the treatment of painful osteoporotic vertebral compression fractures” by Lieberman et al in 2001 was the second most influential article with 665 citations.²⁹ The authors describe a new technique called kyphoplasty proposed by Dr. Mark Reiley that can restore the height of the collapsed vertebral body due to osteoporosis vertebral fracture. The new technology mainly includes two parts: inflatable bone tamps into the collapsed vertebral body and creating a cavity to fill bone cement. In this study, they evaluated the safety and effectiveness of kyphoplasty via 70 kyphoplasty procedures in 30 patients. It turns out that the kyphoplasty restored 47% of the lost height in 70% of the vertebral bodies and improvement of pain and function. Although vertebroplasty has been widely used to relieve the pain of VCF, about 30% of extravasation is still inevitable. Kyphoplasty is a valuable new tool in the treatment of osteoporotic vertebral compression fractures resulting in progressive kyphosis, effectively reducing the cement extravasation and the loss of vertebral height. Recent research, however, shows that kyphoplasty may increase the stresses and strains in the levels of adjacent vertebra and lead to new fractures.^{53–55}

The third most cited article was published in the *Lancet* by Klazen et al from the Netherlands in 2010, which received 544 citations.¹⁴ Although the percutaneous vertebroplasty has been widely accepted, its efficacy, cost-effectiveness and safety are still questioned. In this study, they aimed at clarify whether percutaneous vertebroplasty has additional value compared with optimum conservative treatment in patients with acute osteoporotic vertebral fracture. A total of 431 patients were enrolled in the trial, of whom 202 patients with persistent pain were randomly assigned to treatment (101 vertebroplasty, 101 conservative treatments). Studies have shown that in patients with acute osteoporotic vertebral fractures with persistent severe pain, vertebroplasty can relieve pain faster and better than conservative treatment. In addition, vertebroplasty was more reliable for pain relief and cost-effectiveness than conservative treatment at 1-year follow-up. The authors’ study comprehensively compares vertebroplasty with the reference therapy, thus providing clinicians with directly applicable information for optimal treatment of patients.

Conventional conservative treatment is appropriate for patients with mild-to-moderate pain and without significant vertebral deformity, including bed rest, pain medication, physical therapy, bracing and anti-osteoporosis drugs.^{55,56} However, it is difficult to prevent the deterioration of fracture displacement, with the risk of nonunion, residual pain, malunion in kyphosis, decubitus ulcers and venous thromboembolism, especially elderly patients.^{57,58} Conversely, if the patient’s pain is severe and acute, PVP is effective and safe.⁵⁹ However, there are no benefits to be found in patients with older fractures or fractures of no pain. For balloon kyphoplasty, it is more suitable for height deformity and has many advantages, such as a less injected cement volume, better short-term pain relief, a lower cement leakage rate and better improvement of kyphotic angle.^{58,60} However, vertebroplasty changes the strength of the fractured vertebral body, which increases the risk of

fracture and degeneration of adjacent vertebral bodies.^{61,62} Neurological deficit, posterior wall involvement or severe vertebral collapse are contraindications to these minimally invasive techniques.⁵⁷ If there is a neurological deficit, the surgical fusion techniques are appropriate. Vertebroplasty with posterior spinal fusion, which is a less invasive procedure, is characterized by low risk, shorter operation time, less blood loss and a lower perioperative complication rate.^{63,64} Therefore, it is widely used for OVCF patients with neurological deficits.⁶⁵ Different schemes are applicable to different patients, so it is necessary to provide personalized schemes through full preoperative evaluation.

Limitations

Although bibliometric analysis can provide relatively comprehensive and objective information, it still has several limitations. First of all, only articles published in Web of Science Core Collection database-related OVCF were extracted into this research. It is possible that some high-quality articles are excluded because they are not included in this database. Secondly, due to the dynamic changes of data, the retrieval results of this study will be different from the actual inclusion. Finally, only English articles were obtained in this research, thus we may lose some articles in non-English languages on OVCF research.

Conclusion

Quantitative analysis showed that there is a growing trend in annual publications regarding OVCF research worldwide in the last 20 years. In this research, China is the most productive on OVCF research, Soochow University from China is the most productive institution, Yang, H. L. is the major contributor. Osteoporosis International, Spine, World Neurosurgery, European Spine Journal and Medicine are the top five most popular journals on this topic. Percutaneous vertebroplasty and kyphoplasty are the most influential research fields. “conservative treatment”, “risk factors”, and “zoledronic acid” are the latest research hotspots, which will have a good developing trend in the future.

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Disclosure

The authors report no conflicts of interest in this work.

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