

Top 100 cited articles on infection in orthopaedics

A bibliometric analysis

Yu Jiang, MD^a, Renjing Hu, MD^b, Guoxing Zhu, MD^{a,*}

Abstract

Purpose: The infection is an essential problem in the clinical practice in orthopedics. The bibliometric analysis was conducted to evaluate the top 100 cited articles on infection in orthopaedics.

Methods: The Web of Science (WoS) Core Database was comprehensively searched from 1975 to 2017, and the literature search was limited in Science Citation Index Expanded (SCI-E). The subject terms included “infection”, “infectious”, and “infect*”. All retrieved articles were filtrated by selecting the subspecialty of “Orthopedics”. The searching results were listed by citation times to identify the top 100 cited articles. Significant information was elicited, including the authors, journals, countries, institutions, published year, and types of publication.

Results: A significant increase was observed in the number of annual publications focusing on infection in orthopedics worldwide. Each of the top 100 cited articles was cited more than 150 times. Total citation times was positively associated with citation times in 2016 ($P < .01$) and mean citation times per year ($P < .01$). Conversely, age of the article was negatively associated with citation times in 2016 ($P < .01$) and mean citation times per year ($P < .01$). Besides, citation times in 2016 was positively related to mean citation times per year ($P < .01$). The United States was the most productive country, surgery was the most popular subspecialty and Journal of Bone and Joint Surgery American Volume was the most popular journal.

Conclusion: Infection in orthopaedics has attracted more and more researchers' concern. As for the top 100 cited articles, there were significant relationships among total citation times, citation times in 2016 and mean citation times per year as well as age of the article. The United States was the most productive country, surgery was the most popular subspecialty and Journal of Bone and Joint Surgery American Volume was the most popular journal.

Abbreviation: WoS = Web of Science.

Keywords: bibliometric analysis, infection, orthopedics

1. Introduction

Infection is a tangible problem in the clinical practice in orthopedics, and the gold diagnostic standard for infection has typically been cultivation and subsequent identification of a bacterial sample from the wound or liquid substance from bone tissue.^[1–4] A large number of patients face the risk of infection while undergoing an orthopaedic procedure, as a matter of fact, the incidence of infection in trauma patients even has reached up to 10% in orthopaedics.^[5] Infection increases financial costs and

prolongs course of diseases, and it even decreases the compliance of patients.^[4] Although great progress to prevent infection in orthopedics has been made, the understanding of infection remains unclear. In view of the aforesaid importance, a growing number of researchers pay attention to the developments of infection research in orthopedics. As a result, plenty of articles relevant to infection in orthopedics have been published,^[3–5] which increase the difficulty of catching the critical information for followers in this filed.

Citation number of one article is commonly used to assess the academic influence of the study. Bibliometric analysis is frequently used to evaluate the academic developments of specific specialties, including cancer,^[6,7] neuroscience,^[8] urology,^[9] emergency medicine^[10] and medical imaging.^[11] In recent years, bibliometric analysis becomes increasing popular in orthopedics, which mainly focus on spinal cord tumors,^[12] anterior cruciate ligament injuries,^[13] back pain,^[14] orthopaedic surgeries,^[15] knee research^[16], and hand surgeries.^[17] However, to our knowledge, no bibliometric analysis focusing on infection in orthopedics has been published up to this date. In consideration of this fact, the aim of this bibliometric analysis was to help followers to catch the most important developments of research on infection in orthopedics by assessing the top 100 cited articles.

2. Materials and methods

2.1. Literature searching

This study was approved by Institutional Review Board of Wuxi Second Hospital. Similar to other bibliometric analyses,^[13–15,17,18]

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^a Department of Orthopedics, ^b Department of Clinical Laboratory, Nanjing Medical University Affiliated Wuxi Second Hospital, Wuxi, China.

* Correspondence: Guoxing Zhu, Department of Orthopedics, Nanjing Medical University Affiliated Wuxi Second Hospital, Wuxi 214000, China (e-mail: jiangyu314@sohu.com).

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Web of Science (WoS) Core Collection (Thomson Reuters, NY) was comprehensively searched, and the literature search was limited in Science Citation Index Expanded (SCI-E). The keywords included “infection”, “infectious”, and “infect*”. The articles published from 1975 to 2017 were all elicited, without the restriction on language. Then, all retrieved articles were filtrated by the subspecialty of “Orthopedics”. The top 100 cited articles were finally identified and included into this bibliometric analysis.

2.2. Bibliometric analysis

This bibliometric analysis was performed based on a mature methodology used in other bibliometric studies.^[13,15,16,18] The following information was extracted: total publications, published year, top 100 cited articles, countries, journals, types of article, top productive institutions and authors.

2.3. Statistical analysis

All statistical analyses were performed using SPSS software version 20.0 (SPSS Inc., Chicago, IL). The statistical significance of the correlations among total citation times, citation times in 2016 and mean citation times per year, as well as age of the article, were determined by Spearman test. $P < .05$ was considered to be statistically significant.

3. Results

3.1. The top 100 cited articles

As shown in Figure 1, a total of 17,040 articles focusing on infection in orthopedics were identified from WoS. The number of publications concerning infection in orthopedics had an annually significant increase worldwide.

Top 100 cited articles were listed in Table 1. The top 1 cited article, an original study, was published in *Journal of Bone and Joint Surgery American Volume* in 1976 and entitled “Prevention

of infection in treatment of 1000 and 25 open fractures of long bones—retrospective and prospective analyses”, and this paper was totally cited 1770 times. The mean citation times per year and citation times in 2016 of this article were 42.14 and 92, respectively. Besides, this article was also the oldest article among the top 100 cited articles. Each of the top 100 cited articles was cited more than 150 times.

We further explored the associations among total citation times, mean citation times per year, citation times in 2016 and age of the article. The results demonstrated that total citation times was positively associated with citation times in 2016 ($r=0.412$, $P < .001$) (Fig. 2a) and mean citation times per year ($r=0.701$, $P < .001$) (Fig. 2b). However, no significant relationship was observed between total citation times and age of the article ($r=-0.042$, $P=.681$) (Fig. 2c). In additions, age of the article was negatively associated with citation times in 2016 ($r=-0.662$, $P < .001$) (Fig. 2d) and mean citation times per year ($r=-0.679$, $P < .001$) (Fig. 2e). Moreover, citation times in 2016 was positively related to mean citation times per year ($r=0.789$, $P < .001$) (Fig. 2f).

3.2. Journals with no less than 3 of the top 100 cited articles

Regarding to the journals of the top 100 cited articles, we analyzed the journals with no less than 3 top cited articles. As shown in Table 2. *Journal of Bone and Joint Surgery American Volume* was the most popular journal, with 48 articles, followed by *Clinical Orthopedics and Related Research* with 14 articles, *Spine* with 12 articles, *Journal of Bone and Joint Surgery British Volume* with 9 articles, *Acta Orthopedic Scandinavica* with 3 articles, and *Journal of Arthroplasty* with 3 articles. Besides, the *Journal of Bone and Joint Surgery American Volume* also had the highest total citation times, mean citation times per year and citation times in 2016. However, *Clinical Orthopedics and Related Research* had the highest mean citation times per article.

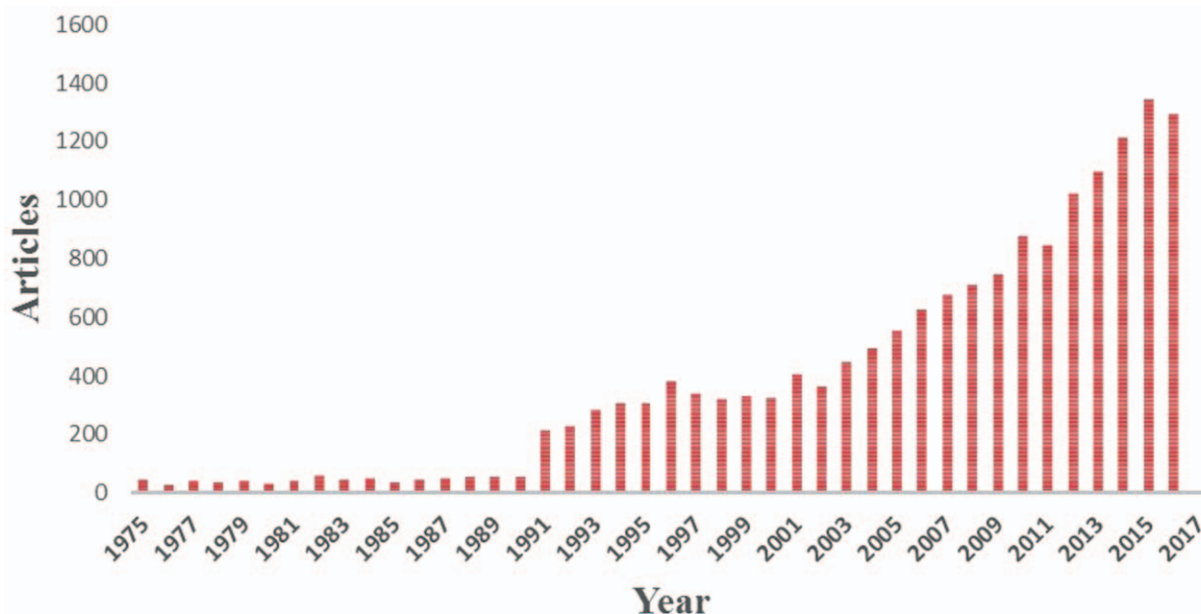


Figure 1. Publications focusing on infection in orthopedics distributing in each year.

Table 1
Top 100 cited articles focusing on infection in orthopaedics.

Rank	Article	Author	Journal	Year	Total citation	Mean citation per year	Citation in 2016
1	Prevention of infection in treatment of 1000 and 25 open fractures of long bones—retrospective and prospective analyses	Gustilo, RB	JBJS	1976	1770	42.14	92
2	Recombinant human bone morphogenetic protein-2 for treatment of open tibial fractures—a prospective, controlled, randomized study of 450 patients	Govender, S	JBJS	2002	757	47.31	42
3	Iliac crest bone-graft harvest donor site morbidity—a statistical evaluation	Banwart, JC	Spine	1995	714	31.04	41
4	Complications of iliac crest bone graft harvesting	Arrington, ED	CORR	1996	689	31.32	28
5	Why are total knee arthroplasties failing today?	Sharkey, PF	CORR	2002	589	36.81	51
6	A critical review of recombinant human bone morphogenetic protein-2 trials in spinal surgery: emerging safety concerns and lessons learned	Carragee, Eugene J	Spine Journal	2011	524	74.86	96
7	Osteogenic activity of the 14 types of human bone morphogenetic proteins (BMPs)	Cheng, HW	JBJS	2003	520	34.67	52
8	Evolution of the internal fixation of long bone fractures—the scientific basis of biological internal fixation: choosing a new balance between stability and biology	Perren, SM	JBJS	2002	513	32.06	50
9	An analysis of blood management in patients having a total hip or knee arthroplasty	Bierbaum, BE	JBJS	1999	483	25.42	51
10	A prospective, randomized study of lumbar fusion—preliminary-results	Zdeblick, TA	Spine	1993	482	19.28	14
11	Prognosis of total hip-replacement in sweden—follow-up of 92,675 operations performed 1978 to 1990	Malchau, H	AOS	1993	478	19.12	9
12	Autogenous iliac crest bone graft—complications and functional assessment	Goulet, JA	CORR	1997	457	21.76	33
13	The Epidemiology of Revision Total Hip Arthroplasty in the United States	Bozic, Kevin J	JBJS	2009	455	50.56	84
14	Autologous osteochondral mosaicplasty for the treatment of full-thickness defects of weight-bearing joints—10 years of experimental and clinical experience	Hangody, L	JBJS	2003	455	30.33	27
15	Management of deep infection of total hip-replacement	Buchholz, HW	JBJS	1981	407	11	14
16	Pathophysiology of polytrauma	Keel, M	Injury	2005	395	30.38	29
17	Infection after total hip arthroplasty—a study of the treatment of 106 infections	Tsukayama, DT	JBJS	1996	395	17.95	26
18	United States trends in lumbar fusion surgery for degenerative conditions	Deyo, RA	Spine	2005	386	29.69	45
19	The outcome of charley total hip-arthroplasty with cement after a minimum 20-year follow-up	Schulte, KR	JBJS	1993	371	14.84	3
20	Rates and outcomes of primary and revision total hip replacement in the United States Medicare population	Mahomed, NN	JBJS	2003	369	24.6	24
21	Association between hospital and surgeon procedure volume and outcomes of total hip replacement in the United States Medicare population	Katz, JN	JBJS	2001	368	21.65	35
22	Prospective analysis of preoperative and intraoperative investigations for the diagnosis of infection at the sites of 202 revision total hip arthroplasties	Spanghehl, MJ	JBJS	1999	368	19.37	28
23	The effect of regional gene therapy with bone morphogenetic protein-2-producing bone-marrow cells on the repair of segmental femoral defects in rats	Lieberman, JR	JBJS	1999	361	19	8
24	Complications associated with the technique of pedicle screw fixation—a selected survey of abs members	Esses, SI	Spine	1993	359	14.36	17
25	Necrotizing fasciitis: clinical presentation, microbiology, and determinants of mortality	Wong, CH	JBJS	2003	353	23.53	30
26	The Insall Award paper—infection in total knee replacement—a retrospective review of 6489 total knee replacements	Peersman, G	CORR	2001	344	20.24	40
27	Long-term results of allograft replacement in the management of bone tumors	Mankin, HJ	CORR	1996	339	15.41	9
28	Periprosthetic joint infection: The incidence, timing, and predisposing factors	Pulido, Luis	CORR	2008	332	33.2	65
29	Birmingham hip resurfacing arthroplasty—a minimum follow-up of 5 years	Treacy, RBC	JBJS	2005	332	25.54	7
30	Long-term results of the total condylar knee arthroplasty—a 15-year survivorship study	Ranawat, CS	CORR	1993	322	12.88	14
31	The effect of recombinant human osteogenic protein-1 on healing of large segmental bone defects	Cook, SD	JBJS	1994	311	12.96	3
32	Infection burden for hip and knee arthroplasty in the United States	Kurtz, Steven M	JOA	2008	309	30.9	46
33	The Norwegian Arthroplasty Register—11 years and 73,000 arthroplasties	Havelin, LI	AOS	2000	308	17.11	10
34	Morbidity and mortality in association with operations on the lumbar spine—The influence of age, diagnosis, and procedure	Deyo, RA	JBJS	1992	307	11.81	22
35	Reverse total shoulder arthroplasty: a review of results according to etiology	Wall, Bryan	JBJS	2007	305	27.73	39
36	The surgical and medical perioperative complications of anterior spinal-fusion surgery in the thoracic and lumbar spine in adults—a review of 1223 procedures	Faciszewski, T	Spine	1995	300	13.04	16
37	Neer Award 2005: The Grammont reverse shoulder prosthesis: results in cuff tear arthritis, fracture sequelae, and revision arthroplasty	Boileau, Pascal	JSAES	2006	296	24.67	37
38	Effect of recombinant human osteogenic protein-1 on healing of segmental defects in nonhuman-primates	Cook, SD	JBJS	1995	296	12.87	3
39	Infection in bone allografts—incidence, nature, and treatment	Lord, CF	JBJS	1988	295	9.83	6
40	The Bagby and Kuslich method of lumbar interbody fusion—history, techniques, and 2-year follow-up results of a United States prospective, multicenter trial	Kuslich, SD	Spine	1998	286	14.3	7
41	Operative versus nonoperative treatment of achilles-tendon rupture—a prospective randomized study and review of the literature	Cetti, R	AJSM	1993	280	11.2	14
42	The Epidemiology of Revision Total Knee Arthroplasty in the United States	Bozic, Kevin J	CORR	2010	278	34.75	55
43	The reverse shoulder prosthesis for glenohumeral arthritis associated with severe rotator cuff deficiency—a minimum 2-year follow-up study of 60 patients	Frankle, M	JBJS	2005	271	20.85	27
44	New Definition for Periprosthetic Joint Infection: From the Workgroup of the Musculoskeletal Infection Society	Parvizi, Javad	CORR	2011	268	38.29	68
45	Current concepts review infection after total hip-arthroplasty past, present, and future	Garvin, KL	JBJS	1995	268	11.65	4
46	Infection as a complication of total knee-replacement arthroplasty—risk-factors and treatment in 67 cases	Wilson, MG	JBJS	1990	260	9.29	10
47	Total knee replacement in young, active patients—long-term follow-up and functional outcome	Diduch, DR	JBJS	1997	258	12.29	13
48	Association between hospital and surgeon procedure volume and the outcomes of total knee replacement	Katz, JN	JBJS	2004	256	18.29	30
49	Hematogenous pyogenic spinal infections and their surgical management	Hadjipavlou, AG	Spine	2000	253	14.06	20
50	Complications of total shoulder arthroplasty	Bohsali, Kamal I	JBJS	2006	247	20.58	36
51	2-stage reimplantation for the salvage of infected total knee arthroplasty	Insall, JN	JBJS	1983	247	7.06	10
52	Risk factors for surgical site infection following orthopaedic spinal operations	Olsen, Margaret A	JBJS	2008	246	24.6	35

(continued)

Table 1
(continued).

Rank	Article	Author	Journal	Year	Total citation	Mean citation per year	Citation in 2016
53	Incidence rates of dislocation, pulmonary embolism, and deep infection during the first 6 months after elective total hip replacement	Phillips, CB	JBJS	2003	245	16.33	12
54	Tuberculosis of bones and joints	Watts, HG	JBJS	1996	245	11.14	12
55	The effect of pedicle screw instrumentation on functional outcome and fusion rates in posterolateral lumbar spinal fusion: a prospective, randomized clinical study	Thomsen, K	Spine	1997	244	11.62	11
56	Semiconstrained arthroplasty for the treatment of rheumatoid-Arthritis of the elbow	Morrey, BF	JBJS	1992	244	9.38	12
57	Anterior cervical Discectomy and fusion associated complications	Fountas, Kostas N	Spine	2007	241	21.91	43
58	Thoracic pedicle screw fixation in spinal deformities—are they really safe?	Suk, SI	Spine	2001	240	14.12	17
59	Internal fixation compared with arthroplasty for displaced fractures of the femoral neck—a meta-analysis	Bhandari, M	JBJS	2003	239	15.93	17
60	Perioperative complications of posterior lumbar decompression and arthrodesis in older adults	Carreon, LY	JBJS	2003	238	15.87	36
61	Early failures in total knee arthroplasty	Fehring, TK	CORR	2001	236	13.88	25
62	Accuracy of pedicle screw insertion with and without computer assistance: a randomised controlled clinical study in 100 consecutive patients	Laine, T	Eur Spine J	2000	231	12.83	11
63	Studies of the mechanism by which the mechanical failure of polymethylmethacrylate leads to bone-resorption	Horowitz, SM	JBJS	1993	231	9.24	1
64	Systemic inflammation after trauma	Lenz, Andreas	Injury	2007	228	20.73	29
65	Fix and flap: the radical orthopaedic and plastic treatment of severe open fractures of the tibia	Gopal, S	JBJS	2000	221	12.28	23
66	The incidence of deep prosthetic infections in specialist orthopaedic hospital—a 15-year prospective survey	Phillips, J. E	JBJS	2006	214	17.83	30
67	Regional gene therapy with a BMP-2-producing murine stromal cell line induces heterotopic and orthotopic bone formation in rodents	Lieberman, JR	J Orthop Res	1998	214	10.7	1
68	Infection after total knee arthroplasty—a retrospective study of the treatment of 81 infections	Segawa, H	JBJS	1999	213	11.21	19
69	Pyogenic vertebral osteomyelitis	Carragee, EJ	JBJS	1997	213	10.14	10
70	Obesity and perioperative morbidity in total hip and total knee arthroplasty patients	Namba, RS	JOA	2005	207	15.92	36
71	The incidence of complications in endoscopic anterior thoracolumbar spinal reconstructive surgery—a prospective multicenter study comprising the first 100 consecutive cases	Mcafee, PC	Spine	1995	207	9	3
72	The impact of infection after total hip arthroplasty on hospital and surgeon resource utilization	Bozic, KJ	JBJS	2005	204	15.69	25
73	Economic Burden of Periprosthetic Joint Infection in the United States	Kurtz, Steven M	JOA	2012	201	33.5	71
74	2-stage reimplantation for the salvage of total knee arthroplasty complicated by infection—further follow-up and refinement of indications	Windsor, RE	JBJS	1990	199	7.11	5
75	Improved detection of infection in hip replacements—a currently underestimated problem	Tunney, MM	JBJS	1998	198	9.9	9
76	Infection-rates after 3175 total hip and total knee replacements performed with and without a horizontal unidirectional filtered air-flow system	Salvati, EA	JBJS	1982	196	5.44	4
77	Nonunion of the femoral diaphysis—the influence of reaming and non-steroidal anti-inflammatory drugs	Giannoudis, PV	JBJS	2000	195	10.83	17
78	Survival and clinical-results with use of large-segment replacements in the treatment of high-grade bone sarcomas	Malawer, MM	JBJS	1995	194	8.43	7
79	Risk factors for infection after spinal surgery	Fang, A	Spine	2005	193	14.85	33
80	The Coonrad-Morrey total elbow arthroplasty in patients who have rheumatoid arthritis—a 10 to 15-year follow-up study	Gill, DRJ	JBJS	1998	189	9.45	10
81	Diagnosis of periprosthetic infection	Bauer, TW	JBJS	2006	187	15.58	14
82	Biofilm theory can guide the treatment of device-related orthopaedic infections	Costerton, JW	CORR	2005	184	14.15	12
83	Latissimus-dorsi transfer for the treatment of irreparable tears of the rotator cuff	Gerber, C	CORR	1992	184	7.08	9
84	Open reduction and internal-fixation of tibial plafond fractures—variables contributing to poor results and complications	Teeny, SM	CORR	1993	183	7.32	18
85	Total knee arthroplasty in morbidly obese patients	Winiarsky, R	JBJS	1998	182	9.1	16
86	Infection of the surgical site after arthroplasty of the hip	Ridgeway, S	JBJS	2005	181	13.92	25
87	The pathology of total joint arthroplasty—II. Mechanisms of implant failure	Bauer, TW	Skeletal Radiology	1999	181	9.53	9
88	The influence of skeletal implants on incidence of infection—experiments in a canine model	Petty, W	JBJS	1985	181	5.48	9
89	Treatment of acute achilles tendon ruptures—a meta-analysis of randomized, controlled trials	Khan, RJK	JBJS	2005	179	13.77	16
90	Epidemiology of total knee replacement in the United States Medicare population	Mahomed, NN	JBJS	2005	179	13.77	22
91	Factors influencing the incidence and outcome of infection following total joint arthroplasty	Poss, R	CORR	1984	179	5.26	12
92	Revision with gentamicin-impregnated cement for deep infections in total hip arthroplasties	Carlsson, AS	JBJS	1978	179	4.47	1
93	Postoperative spinal wound infection: a review of 2,391 consecutive index procedures	Weinstein, MA	JSD	2000	178	9.89	17
94	The Swedish knee arthroplasty register—a nationwide study of 30,003 knees 1976 to 1992	Knutson, K	AOS	1994	178	7.42	1
95	Perioperative testing for joint infection in patients undergoing revision total hip arthroplasty	Schinsky, Mark F	JBJS	2008	175	17.5	19
96	Factors associated with prolonged wound drainage after primary total hip and knee arthroplasty	Patel, Vipul P	JBJS	2007	175	15.91	22
97	Iliosacral screw fixation: early complications of the percutaneous technique	Routt, MLC	JOT	1997	175	8.33	18
98	Predisposing factors for infection in spine surgery: a survey of 850 spinal procedures	Wimmer, C	JSD	1998	173	8.65	14
99	Treatment of open fractures of the tibial shaft with the use of interlocking nailing without reaming	Whittle, AP	JBJS	1992	173	6.65	6
100	Pyogenic non-tuberculous spinal infection—analysis of 30 cases	Digby, JM	JBJS	1979	173	4.44	4

AJSM = American Journal of Sports Medicine, AOS = Acta Orthopaedica Scandinavica, CORR = Clinical Orthopaedics And Related Research, Eur Spine J = European Spine Journal, J Orthop Res = Journal of Orthopaedic Research, JBJS = Journal of Bone And Joint Surgery-American Volume, JBJSB = Journal of Bone And Joint Surgery-British Volume, JOA = Journal of Arthroplasty, JOT = Journal of Orthopaedic Trauma, JSAES = Journal of Shoulder And Elbow Surgery, JSD = Journal of Spinal Disorders.

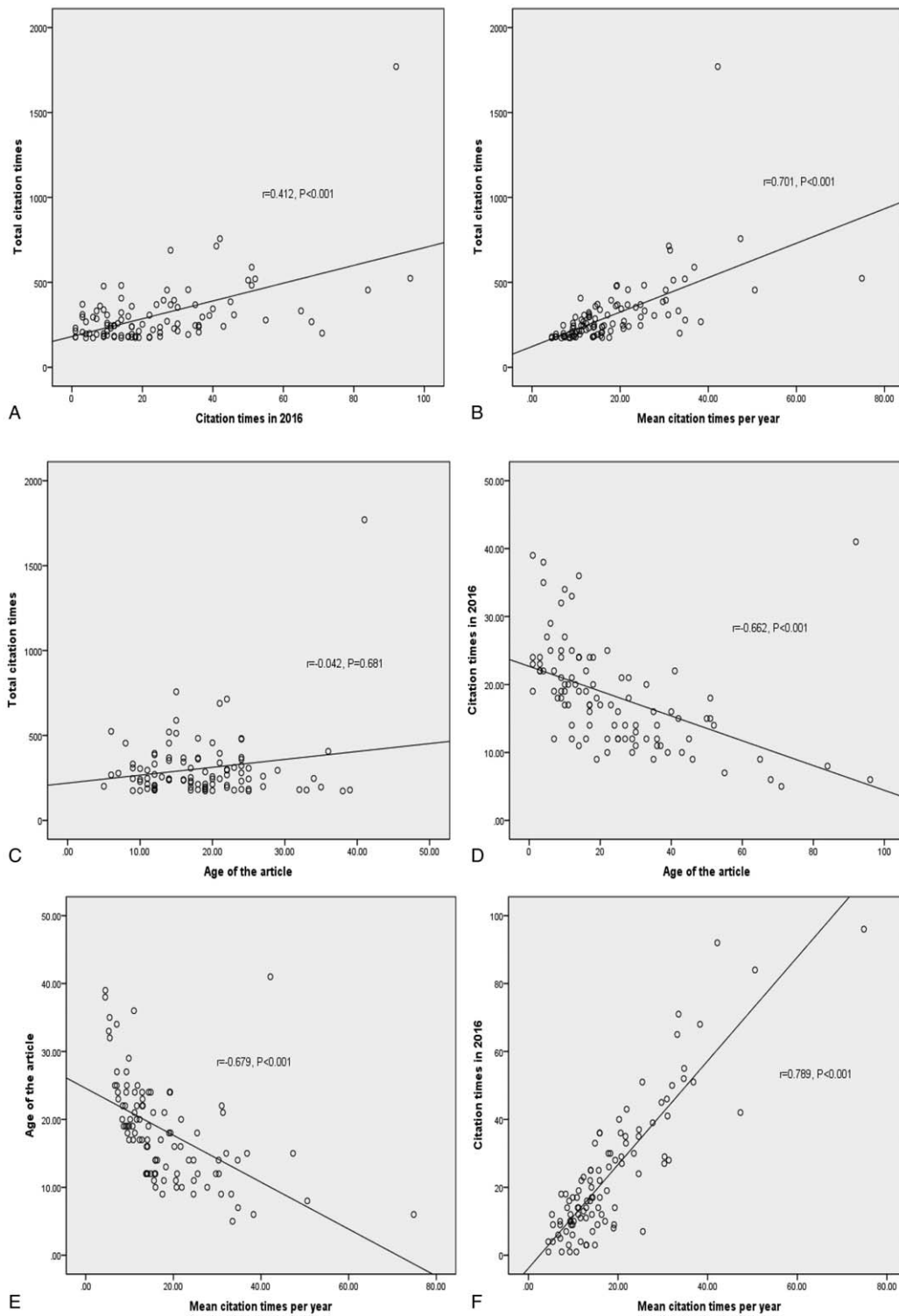


Figure 2. The relationships among total citation time, mean citation per year, citation in 2016 and age of the article. (a, total citation time and citation in 2016; b, total citation time and mean citation per year; c, total citation time and age of the article; d, age of the article and citation in 2016; e, age of the article and mean citation per year; f, citation in 2016 and mean citation per year).

3.3. Countries with no less 3 of the top 100 cited articles

As listed in Table 3, a total of 22 countries produced the top 100 cited papers. The United States was the most productive country with 75 articles, followed by England with 9 articles, Canada

with 7 articles, France with 3 articles, Sweden with 3 articles and Switzerland with 3 articles. Moreover, the United States had the highest total citation times, mean citation times per year and mean citation times in 2016, France had the highest mean citation times per article with 452.67 times.

Table 2

Journals with no less than 3 of the top 100 cited articles.

Journals	Articles	Total citation	Mean citation per article	Mean citation per year	Citation (2016)
Journal of Bone And Joint Surgery American Volume	48	15052	313.58	367.12	1035
Clinical Orthopedics And Related Research	14	4584	327.43	199.3	439
Spine	12	3905	325.42	162.71	267
Journal of Bone And Joint Surgery British Volume	9	2434	270.44	64.05	179
Acta Orthopedic Scandinavica	3	964	321.33	38.56	20
Journal of Arthroplasty	3	623	311.5	47.92	58

Table 3

Countries with no less 3 of the top 100 cited articles.

Country	Articles	Total citation	Mean citation per article	Mean citation per year	Citation (2016)
USA	75	23556	314.08	574.54	1925
England	9	2659	295.44	69.97	178
Canada	7	2536	362.29	133.47	198
France	3	1358	452.67	90.53	118
Sweden	3	835	278.33	21.41	11
Switzerland	3	1092	364	54.6	88

Table 4

Institutions with no less 4 of the top 100 cited articles.

Institution	Articles	Total citation	Mean citation per article	Mean citation per year
Harvard University	6	1806	301.00	60.20
Massachusetts General Hospital	6	2132	355.33	71.07
Boston University	5	1411	282.20	83.00
Brigham and Women’s Hospital	5	1421	284.20	52.63
Hospital Special Surgery	5	1287	257.40	25.75
The University of California, San Francisco	5	1887	377.40	125.80
Dartmouth Coll School Medicine	4	1172	293.00	68.94
Exponent Inc	4	1243	310.75	138.11
Mayo Clinic	4	1190	297.50	62.63

3.4. Institutions and authors with no less than 4 articles of the top 100 cited articles

With respect to institutions (Table 4), Harvard University and Massachusetts General Hospital were both the most productive institutions with 6 articles, followed by Boston University, Brigham and Women’s Hospital, Hospital Special Surgery and The University of California San Francisco with 5 articles. As for authors (Table 5), Parvizi J, Katz JN, Losina E, and Mahomed NN were the most productive authors who published 5 articles.

3.5. Publication type and subspecialty of the top 100 cited articles

Regarding to the type of the top 100 cited articles, as shown in Table 6, 91 manuscripts in the form of “Article” and 9

Table 5

Authors with no less than 4 of the top 100 cited articles.

Author	Articles
Parvizi J	5
Katz JN	5
Losina E	5
Mahomed NN	5
Kurtz SM	4
Lau E	4
Poss R	4

manuscripts in the form of “Review” were totally cited 27,793 and 2738 times, respectively. The manuscripts in the form of “Article” had higher average citation times per article with 305.42 times than “Review” with 304.22 times. When considering the subspecialty, as listed in Table 7, surgery was the most popular subspecialty, with 74 articles, followed by Neurosciences/neurology with 16 articles and sport sciences with 3 articles. The articles in the subspecialty of surgery were with the highest total citation times, mean citation times per year and citation times in 2016. However, articles in the subspecialty of neurosciences/neurology had the highest mean citation times per article among aforesaid subspecialties.

4. Discussion

In our study, a significant increase was observed in the number of annual publications focusing on infection in orthopedics worldwide. Each of top 100 cited articles was cited more than 150 times. Total citation times were positively associated with citation times in 2016 and mean citation times per year. Conversely, age of the article was negatively associated with citation times in 2016 and mean citation times per year. Besides, citation times in 2016 was positively related to mean citation times per year. Journal of Bone and Joint Surgery American Volume was the most popular journal, the United States was the most productive country and surgery was the most popular subspecialty.

Table 6**Type of articles of the top 100 cited articles.**

Article type	Articles	Total citations	Mean citation per article	Mean citation per year	Citation (2016)
Article	91	27793	305.42	677.88	2101
Review	9	2738	304.22	125.45	267

Table 7**Subspecialty of the top 100 cited articles.**

Subspecialty	Articles	Total citation	Mean citation per article	Mean citation per year	Citation (2016)
Surgery	74	22989	310.66	560.71	1748
Neurosciences neurology	16	5011	313.19	208.79	405
Sport sciences	3	751	250.33	31.29	69
Emergency medicine	2	623	311.5	47.92	58
General internal medicine	2	623	311.5	47.92	58
Radiology nuclear medicine medical imagine	1	181	181	9.53	9

In this bibliometric analysis, the study entitled “Prevention of infection in treatment of 1000 and 25 open fractures of long bones—retrospective and prospective analyses” was the most popular article, which found that cephalosporin was the prophylactic antibiotic of choice to prevent the infection.^[19] The following reasons might account for the popularity of the study. First, this study was conducted in 1976. As is well known, articles published in earlier years were likely to be cited more frequently. Second, the severe wound and following surgery both might increase the risk of infection; therefore, infection caused by open fractures of long bones was a common and intractable problem for orthopedists. Third, the methodology of the study was scientific and strict, which guaranteed the reliability of the conclusion.

It is worth mentioning that our study first explored the relationships among total citation times, age of the article, mean citation times per article and citation times in 2016, which were not performed in previous studies.^[12,14,18] We unexpectedly found that total citation times was not obviously associated with age of the article, which challenged the conventional viewpoint that earlier papers were more frequently cited.^[20] The main reason might be that investigators paid more attention to the latest developments in this field. In additions, another explanation for why classic papers were cited less frequently was that they had been absorbed and accepted into the body of current knowledge, therefore no longer being directly attributed to their source. Predictably, total citation times were significantly related to mean citation times per year and citation times in 2016. Our results also indicated age of the article was negatively associated with citation times in 2016, which might be explained with previous theory that peak citation usually occurred after articles were published for 3 to 10 years.

Journal of Bone and Joint Surgery American Volume had the largest number of paper, total citation times, mean citation times per year and citation times in 2016. Therefore, this journal was the most popular journal focusing on infection in orthopaedics. However, it should be noted that Clinical Orthopedics and Related Research had the highest citation times per article among top 6 journals, which demonstrated articles in this journal were of relatively higher quality. Other than that, Spine ranked third, indicating infection was also a problematic issue in spine surgeries. However, when assessing journals' contribution, we should not ignore that those journals had different publication

cycle time and circulation time. Shorter publication cycle time and longer circulation time were beneficial to increasing the citation times of articles. Furthermore, these journals were founded at different time, which also might affect the number of articles and citation times. It should be noted that none of the top 100 cited articles was published in 4 famous medical journals, including British Medical Journal, Journal of American Medical Association, Lancet and The New England Journal of Medicine. This phenomenon indicated that researchers focused on not only the impact factor but also the influence in their research field when choosing journals to publish their studies. Of course, several other factors might influence the selection process of target journal, including difficulty to be accepted, time from submission to acceptance, charges and so on, especially difficulty to be accepted.

The United States ranked first with 75 articles, which was far more than the other countries. This finding was accorded with other previous studies.^[21–23] The United States had the highest total citation times, mean citation times per year and citation times in 2016. Besides, most of productive institutions and authors were in the United States. Overall, all this information supported that the United States made the greatest contribution to the developments of research on infection in orthopaedics. Besides, our study found that no developing country such as China was selected in rankings. Previous studies have proved that China made great contribution to the progress of several biomedical fields.^[24,25] However, our results uncovered although developing countries such as China published a good deal of papers, the quality of many papers needed further improvement. Therefore, developing countries should try their best to improve the quality of articles in future.

In our study, original articles had higher mean citation times per article when compared with reviews. This finding indicated orthopedists paid more attention to the new findings in this topic. Besides, our bibliometric analysis proved that surgery was the most popular subspecialty. Infection associated with surgery was indeed a very important and common problem in orthopedics,^[5] which should raise more researchers' concern.

To our knowledge, this study was the first bibliometric analysis to identify the top 100 cited papers focusing on infection in orthopedics. And this study helped researchers to catch the scientific developments and promote the cooperation in this field. Nevertheless, our study was not without limitations. First,

citation time was not the “Golden Standard” when evaluating the importance of the research. The citation times could be easily affected by several factors, such as time of peer-review process and publication cycle. In recent years, increasing researchers suggested that the impact factor based on citation times should be optimized and even abandoned. Second, this bibliometric analysis was conducted based on WoS database, however, Google Scholar and Scopus were also frequently used to perform the bibliometric analysis, therefore, the results of our study might not be comprehensive. Third, despite of aforesaid methods, we could not guarantee that all retrieved articles exactly focused on this topic, which was an inherent weakness of all bibliometric analyses. Fourth, generally, joint replacement surgeries, degenerative spine surgeries, and infected non-unions were focused in clinical practice when discussing the infection in orthopedics, however, few publications concerned these topics among the top 100 cited articles. This phenomenon might be explained that many factors could affect the citation times of articles and then determine the top 100 cited articles. In spite of limitations, we believed this study could contribute to obtaining vital developments of infection in orthopedics and providing new insights into innovation in this field.

5. Conclusions

Infection in orthopaedics has attracted increasing researchers' concern. As for the top 100 cited articles, there were significant relationships among total citation times, citation times in 2016 and mean citation times per year as well as age of the article. The United States was the most productive country, surgery was the most popular subspecialty and *Journal of Bone and Joint Surgery American Volume* was the most productive journal.

Author contributions

Guoxing Zhu designed the study; Guoxing Zhu and Yu Jiang conducted the statistical analysis; Yu Jiang and Renjing Hu wrote the manuscript; Guoxing Zhu revised the manuscript; All authors read and approved the final manuscript.

Conceptualization: Yu Jiang.

Data curation: Yu Jiang, Renjing Hu, Guoxing Zhu.

Formal analysis: Yu Jiang, Guoxing Zhu.

Funding acquisition: Guoxing Zhu.

Investigation: Yu Jiang, Renjing Hu, Guoxing Zhu.

Methodology: Yu Jiang, Renjing Hu, Guoxing Zhu.

Resources: Guoxing Zhu.

Software: Guoxing Zhu.

Validation: Guoxing Zhu.

Writing – original draft: Yu Jiang, Renjing Hu, Guoxing Zhu.

Writing – review & editing: Yu Jiang, Renjing Hu, Guoxing Zhu.

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