



A Bibliometric study of the top 100 most-cited papers in high tibial osteotomy

Ling-Chen Ye, BSc^a, Jing-Yu Zhang, MSc^a, Ying-Ying Jiang, MSc^b, Ren-Jie Xu, MD^{a,*}

Background: High tibial osteotomy (HTO) is a well-established surgical procedure employed to treat medial compartment knee osteoarthritis by modifying the mechanical axis of the lower limb, thereby reducing the load on the affected joint. It has gained increased attention in recent years, resulting in numerous research advancements in this field.

Methods: The top 100 most-cited papers on HTO, published between 1970 and 2023, were identified by searching the Web of Science Core Collection database. Data, including the title, author, keywords, journal, publication year, country, and institution, were extracted. Subsequently, a bibliometric analysis was performed.

Results: The 100 papers collectively garnered a total of 15 833 citations, with a median of 122 and an average of 158.33 citations per article. Since the onset of the 21st century, there has been a significant increase in the number of publications and citations. Lobenhoffer authored the most published papers. The majority of papers originated from the USA. Hannover Medical School produced the most papers. Analysis of keywords in the articles revealed several research hotspots, including open-wedge osteotomy, biomechanical study, tibial slope, patellar height, Puddu plate, TomoFix plate, stability, complications, and accuracy.

Conclusion: This study offers bibliometric insights into HTO, underscoring that the USA is a prominent leader in this field. HTO has garnered increasing attention since the onset of the 21st century and is expected to remain a significant research area in the future. Concurrently, the authors advise focusing on potential research hotspots, such as the navigation system, to augment the accuracy of the correction.

Keywords: bibliometric analysis, CiteSpace, high tibial osteotomy, knee osteoarthritis, web of science core collection

Introduction

Globally, osteoarthritis (OA) is the most prevalent joint disorder affecting adults^[1]. In addition to causing joint pain, deformity, and functional impairment, osteoarthritis can significantly increase the risk of cardiovascular events, lower limb deep vein thrombosis, hip fractures, and overall mortality rates^[2–4]. The primary manifestation of symptomatic knee OA entails the degradation of articular cartilage, predominantly impacting the medial compartment. Consequently, this joint degeneration leads to a varus deformity, which escalates the load transmission through the already degenerated compartment.

High tibial osteotomy (HTO) procedures, originated in the 1960s, were principally designed to address knee OA impacting the medial compartment^[5]. Over the years, various techniques, including closed-wedge, open-wedge, and dome osteotomies, have been developed. The primary goal of HTO surgery is to modify the load distribution within the knee joint, thereby reducing pressure on the medial compartment, alleviating pain, enhancing function, and decelerating the progression of knee OA. Clinical studies showed that HTO surgery produces positive outcomes in patients with early-stage knee OA, considerably reducing pain, augmenting joint function, and improving the quality of life. Furthermore, HTO surgery can postpone the need for total knee replacement, which is particularly vital for younger individuals with high levels of physical activity.

The abundance of published articles on HTO creates challenges for researchers in identifying the most influential papers, discerning research trends, and establishing future directions in this field. Bibliometric analysis involves the statistical evaluation of published papers or books. Undertaking a comprehensive bibliometric analysis of the most frequently cited papers would yield valuable insights and augment our understanding of prospective research directions in this field. Therefore, the objective of this study is to identify the top 100 most-cited papers on HTO, analyze their bibliometric characteristics, and subsequently discern research trends and future directions in this field.

Material and methods

Search strategies and data extraction

The pertinent data for this study were extracted from the Science Citation Index Expanded (SCI-EXPANDED) within the

Departments of ^aOrthopaedics and ^bOperating Theatre, Nanjing Medical University Affiliated Suzhou Hospital: Suzhou Municipal Hospital, Suzhou, China

L.-C.Y. and J.-Y.Z. contributed equally to this work and should be considered co-first authors.

Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

*Corresponding author. Address: Department of Orthopaedics, Nanjing Medical University Affiliated Suzhou Hospital: Suzhou Municipal Hospital, Suzhou, China. Tel.: +86 512 623 620 02. E-mail address: fredxurj@pku.org.cn (R.-J. Xu).

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Annals of Medicine & Surgery (2024) 86:5238–5251

Received 29 February 2024; Accepted 15 April 2024

Published online 15 May 2024

<http://dx.doi.org/10.1097/MS9.0000000000002115>

Clarivate Analytics Web of Science Core Collection (WoSCC). WoSCC, acknowledged as a highly esteemed global database, provides comprehensive information required for bibliometric software and functions as a common choice for bibliometric analysis. TS=(high tibial osteotomy) or TS=(proximal tibial osteotomy) or TS=(upper tibial osteotomy) was used to search relevant articles. A systematic search was performed within the WoSCC for literature published between January 1900 and December 2023. Document retrieval and recording were concluded on 17 December 2023, to prevent any bias resulting from subsequent database updates. Only original articles and reviews with complete manuscripts were considered for bibliometric analysis, regardless of language. Two researchers separately screened the title, abstract, and document type. If necessary, they perused the full article for a more comprehensive evaluation to determine whether to include it. We obtained the records of the top 100 most-cited articles in the “Full Record and Cited References” format from WoSCC, saving them as TXT files (Fig. 1). The impact factors of each journal were derived from the most recent Journal Citation Reports 2022.

Data analysis and visualization

Descriptive statistical analysis and diagram generation were performed using Microsoft Excel 2019. An online analytic platform (<https://bibliometric.com/>) was selected to facilitate collaboration networks among authors and institutions. VOSviewer, a robust bibliometric tool developed by Van Eck and Waltman^[6], facilitates the clear construction of networks involving keywords, authors, and more. In collaboration with Scimago Graphica^[7], creating a world map illustrating the number of countries cited is possible. Additionally, CiteSpace^[8] software was employed to construct author networks, identify keywords with the highest burst strength, and illustrate the relationship between time and keyword bursts. In this study, the downloaded data were integrated into CiteSpace to generate an institutional cooperation network, a co-authorship network of authors, and a co-occurrence network. In the network map rendered by Citespace, different elements, such as institutions, authors, and keywords, were represented by various nodes. The thickness of the connecting lines between nodes signified the strength of the co-authorship and co-occurrence links. In co-occurrence analysis, the correlation of items is determined based on the number of documents in which they occur together, with different clusters denoted by colour. Bibliometrix is an R package that employs bibliometrics for analyzing relevant literature. This approach allows gaining rapid insights into the seminal works, prominent figures, and future trends in the field. Moreover, it aids in organizing the pertinent literature and presenting the results in a visual format. One notable feature of Bibliometrix is its ability to generate Sankey diagrams, also known as Sankey energy balance diagrams. These diagrams depict data flows, with the width of the branches proportional to the magnitude of the flow. They function as effective tools to analyze data visually.

Results

Analysis of publications and citations

All of the 100 most-cited studies were published between 1970 and 2018 (Fig. 2). Table 1 provides detailed information

HIGHLIGHTS

- Pivotal role of the USA in high tibial osteotomy (HTO) research: The study identifies the United States as a leading contributor to HTO research, with a significant number of the top 100 most-cited papers originating from the country. This underscores the nation’s prominent role in shaping the direction and advancements of this surgical procedure.
- Increasing trend in HTO research: The analysis reveals a notable increase in the number of publications and citations related to HTO since the beginning of the 21st century. This surge indicates a growing interest and investment in research aimed at improving the understanding and application of HTO for treating knee osteoarthritis.
- Identification of research hotspots: The bibliometric analysis pinpoints several research hotspots within the field, including open-wedge osteotomy, biomechanical studies, tibial slope, and complications. These areas represent key focus points for current and future investigations, potentially leading to advancements in surgical techniques and patient outcomes.
- Prominent institutions and authors: The study highlights the significant contributions of institutions such as Hannover Medical School and authors like Philipp Lobenhoffer, whose work has greatly influenced the field. These insights help to identify key players and centres of excellence in HTO research.
- Bibliometric tools for research mapping: The use of bibliometric tools like VOSviewer and CiteSpace is emphasized, demonstrating their effectiveness in visualizing research trends, author collaborations, and the intellectual structure of the field. These tools are crucial for understanding the evolution and future directions of HTO research.

pertaining to the 100 most influential publications. The top 100 articles gathered 89–599 citations, with a median of 122 and an average of 158.33 citations per article. Focusing on the top three studies, the first study^[9] (“Proximal tibial osteotomy for osteoarthritis with varus deformity—a 10–13-year follow-up study”) was published in the *Journal of Bone and Joint Surgery—American Volume* in 1987 and received 599 citations. The second most-cited paper^[10] (“Effect of high tibial osteotomy of the knee—arthroscopic study of 54 knee joints”) was published in *Orthopedic Clinics of North America* in 1979 and received 573 citations. The paper^[11] titled “Proximal tibial osteotomy—a critical long-term study of 87 cases,” published in 1993 by the *Journal of Bone and Joint Surgery—American Volume*, received 476 citations. Earlier publications had an advantage in terms of total citation count. However, when ranked according to average citations per year, some later publications with a higher impact can be identified. The paper^[12] titled “Improvements in surgical technique of valgus high tibial osteotomy,” published in 2003 by *Knee Surgery Sports Traumatology Arthroscopy*, received 403 citations, ranking fifth in total citations. It has an average of 19.19 citations per year, ranking first in this aspect.

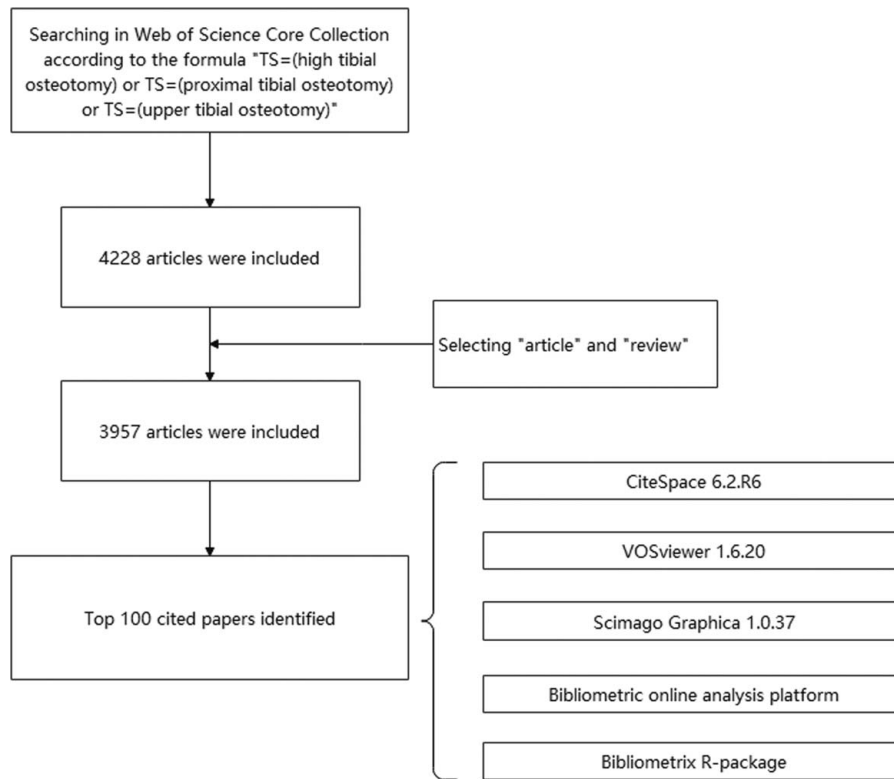


Figure 1. Document screening flow chart.

Analysis of the most productive countries

Figure 3A and B demonstrate that a total of 16 countries/regions contributed to the top 100 most-cited documents, with

10 of them having more than 3 articles. Figure 3C employs Scimago Graphica software to visually display a world map highlighting the countries with the top 100 highly cited publications. The larger the dots, the more substantial the number

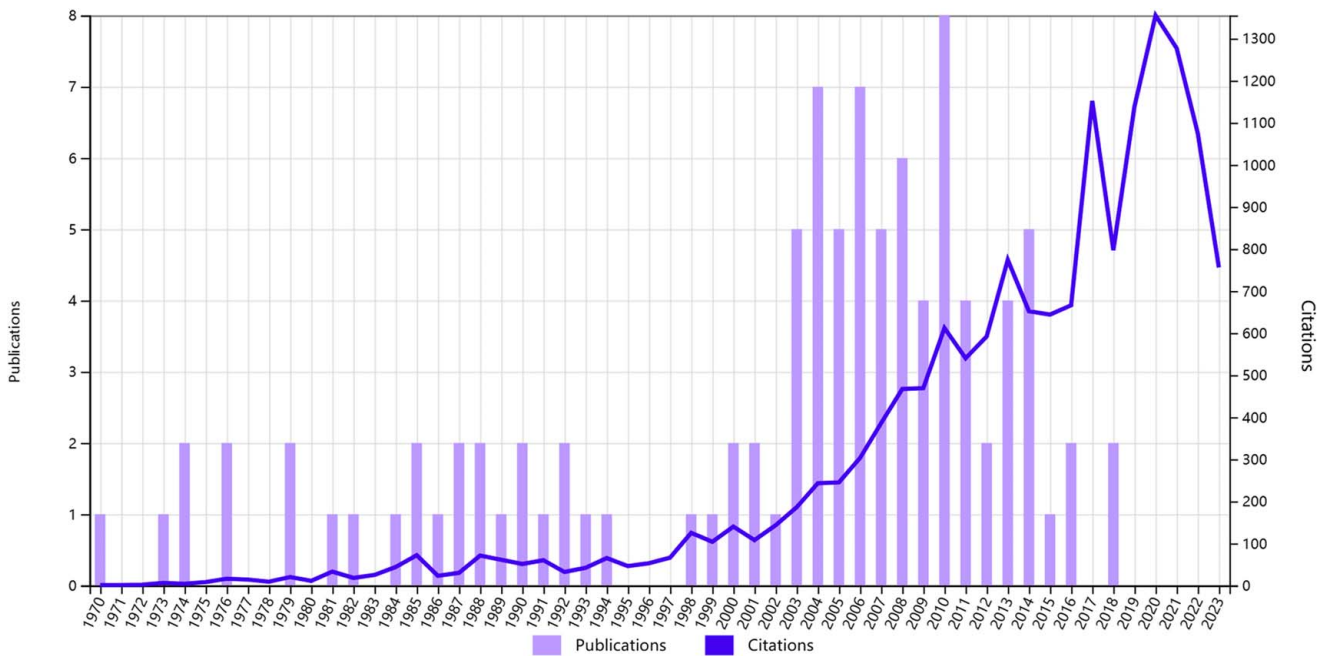


Figure 2. Number and citations of top-cited publications from 1970 to 2023.

Table 1
The 100 most-cited articles in high tibial osteotomy.

Number	First author	Publication year	Title	Journal	Total citations
1	HERNIGOU, P	1987	Proximal tibial osteotomy for osteoarthritis with varus deformity – a 10 to 13-year follow-up study	Journal of Bone and Joint Surgery-American Volume	599
2	FUJISAWA, Y	1979	Effect of high tibial osteotomy on osteoarthritis of the knee – arthroscopic study of 54 knee joints	Orthopedic Clinics of North America	573
3	COVENTRY, MB	1993	Proximal tibial osteotomy – a critical long-term study of 87 cases	Journal of Bone and Joint Surgery-American Volume	476
4	INSALL, JN	1984	High tibial osteotomy for varus gonarthrosis – a long-term follow-up study	Journal of Bone and Joint Surgery-American Volume	438
5	Lobenhoffer, P	2003	Improvements in surgical technique of valgus high tibial osteotomy	Knee Surgery Sports Traumatology Arthroscopy	403
6	PRODRAMOS, CC	1985	A relationship between gait and clinical changes following high tibial osteotomy	Journal of Bone and Joint Surgery-American Volume	341
7	DUGDALE, TW	1992	Preoperative planning for high tibial osteotomy – the effect of lateral tibiofemoral separation and tibiofemoral length	Clinical Orthopaedics and Related Research	333
8	Staubli, AE	2003	Tomofix: a new lcp-concept for open wedge osteotomy of the medial proximal tibia – early results in 92 cases	Injury-International Journal of The Care of The Injured	300
9	Sprenger, TR	2003	Tibial osteotomy for the treatment of varus gonarthrosis – survival and failure analysis to twenty-two years	Journal of Bone and Joint Surgery-American Volume	257
10	Naudie, D	1999	Survivorship of the high tibial valgus osteotomy – a 10-to 22-year followup study	Clinical Orthopaedics and Related Research	247
11	Brinkman, J. -M.	2008	Osteotomies around the knee patient selection, stability of fixation and bone healing in high tibial osteotomies	Journal of Bone and Joint Surgery-British Volume	242
12	Amendola, Annunziato	2010	Results of high tibial osteotomy: review of the literature	International Orthopaedics	238
13	Agneskirchner, Jens Dominik	2007	The effects of valgus medial opening wedge high tibial osteotomy on articular cartilage pressure of the knee: a biomechanical study	Arthroscopy-The Journal of Arthroscopic and Related Surgery	233
14	MINIACI, A	1989	Proximal tibial osteotomy – a new fixation device	Clinical Orthopaedics and Related Research	229
15	Agneskirchner, JD	2004	Effect of high tibial flexion osteotomy on cartilage pressure and joint kinematics: a biomechanical study in human cadaveric knees – winner of the aga-donjoy award 2004	Archives of Orthopaedic and Trauma Surgery	227
16	Akizuki, S.	2008	The long-term outcome of high tibial osteotomy – a ten- to 20-year follow-up	Journal of Bone and Joint Surgery-British Volume	222
17	Marti, CB	2004	Accuracy of frontal and sagittal plane correction in open-wedge high tibial osteotomy	Arthroscopy-The Journal of Arthroscopic and Related Surgery	222
18	Noyes, FR	2000	High tibial osteotomy and ligament reconstruction for varus angulated anterior cruciate ligament-deficient knees	American Journal of Sports Medicine	215
19	COVENTRY, MB	1985	Upper tibial osteotomy for osteoarthritis	Journal of Bone and Joint Surgery-American Volume	205
20	Floerkemeier, Stephanie	2013	Outcome after high tibial open-wedge osteotomy: a retrospective evaluation of 533 patients	Knee Surgery Sports Traumatology Arthroscopy	200
21	Koshino, T	2003	Medial opening-wedge high tibial osteotomy with use of porous hydroxyapatite to treat medial compartment osteoarthritis of the knee	Journal of Bone and Joint Surgery-American Volume	186
22	Takeuchi, Ryohei	2012	Fractures around the lateral cortical hinge after a medial opening-wedge high tibial osteotomy: a new classification of lateral hinge fracture	Arthroscopy-The Journal of Arthroscopic and Related Surgery	184
23	COVENTRY, MB	1979	Upper tibial osteotomy for gonarthrosis – evolution of the operation in the last 18 y and long-term results	Orthopedic Clinics of North America	183
24	Noyes, FR	2005	Opening wedge tibial osteotomy – the 3-triangle method to correct axial alignment and tibial slope	American Journal of Sports Medicine	180
25	Miller, Bruce S	2009	Complication after medial opening wedge high tibial osteotomy	Arthroscopy-The Journal of Arthroscopic and Related Surgery	174
26	Billings, A	2000	High tibial osteotomy with a calibrated osteotomy guide, rigid internal fixation, and early motion – long-term follow-up	Journal of Bone and Joint Surgery-American Volume	174
27	Takeuchi, Ryohei	2009	Medial opening wedge high tibial osteotomy with early full weight bearing	Arthroscopy-The Journal of Arthroscopic and Related Surgery	166
28	Agneskirchner, JD	2006	Primary stability of four different implants for opening wedge high tibial osteotomy	Knee Surgery Sports Traumatology Arthroscopy	166
29	WANG, JW	1990	The influence of walking mechanics and time on the results of proximal tibial osteotomy	Journal of Bone and Joint Surgery-American Volume	163
30	Stoffel, K	2004	Open wedge high tibial osteotomy: biomechanical investigation of the modified compic steotomy plate (puddu plate) and the tomofix plate	Clinical Biomechanics	161
31	Amis, Andrew A.	2013	Biomechanics of high tibial osteotomy	Knee Surgery Sports Traumatology Arthroscopy	154
32	Hui, Catherine	2011	Long-term survival of high tibial osteotomy for medial compartment osteoarthritis of the knee	American Journal of Sports Medicine	153
33	Brouwer, R. W.	2006	Osteotomy for medial compartment arthritis of the knee using a closing wedge or an opening wedge controlled by a puddu plate – a one-year randomised, controlled study	Journal of Bone and Joint Surgery-British Volume	152
34	Koshino, T	2003	Regeneration of degenerated articular cartilage after high tibial valgus osteotomy for medial compartmental osteoarthritis of the knee	Knee	151
35	Brouwer, RW	2005	Patellar height and the inclination of the tibial plateau after high tibial osteotomy -: the open versus the closed-wedge technique	Journal of Bone and Joint Surgery-British Volume	150
36	IVARSSON, I	1990	High tibial osteotomy for medial osteoarthritis of the knee – a 5 to 7 and an 11 to 13 year follow-up	Journal of Bone and Joint Surgery-British Volume	149
37	Dallari, D.	2007	Enhanced tibial osteotomy healing with use of bone grafts supplemented with platelet gel or platelet gel and bone marrow stromal cells	Journal of Bone and Joint Surgery-American Volume	145
38	INSALL, J	1974	High tibial osteotomy – 5-year evaluation	Journal of Bone and Joint Surgery-American Volume	144

Table 1

(Continued)

Number	First author	Publication year	Title	Journal	Total citations
39	KETTELKAMP, DB	1976	Results of proximal tibial osteotomy – effects of tibiofemoral angle, stance-phase flexion-extension, and medial-plateau force	Journal of Bone and Joint Surgery-American Volume	142
40	KOSHINO, T	1982	The treatment of spontaneous osteonecrosis of the knee by high tibial osteotomy with and without bone-grafting or drilling of the lesion	Journal of Bone and Joint Surgery-American Volume	140
41	Koshino, T	2004	Fifteen to twenty-eight years' follow-up results of high tibial valgus osteotomy for osteoarthritic knee	Knee	137
42	COVENTRY, MB	1987	Proximal tibial varus osteotomy for osteoarthritis of the lateral compartment of the knee	Journal of Bone and Joint Surgery-American Volume	135
43	Sonnery-Cottet, Bertrand	2014	Proximal tibial anterior closing wedge osteotomy in repeat revision of anterior cruciate ligament reconstruction	American Journal of Sports Medicine	134
44	Flecher, Xavier	2006	A 12-28-year followup study of closing wedge high tibial osteotomy	Clinical Orthopaedics and Related Research	134
45	VAINIONPAA, S	1981	Tibial osteotomy for osteo-arthritis of the knee – a 5 to 10-year follow-up-study	Journal of Bone and Joint Surgery-American Volume	133
46	Rodner, Craig M.	2006	Medial opening wedge tibial osteotomy and the sagittal plane – the effect of increasing tibial slope on tibiofemoral contact pressure	American Journal of Sports Medicine	132
47	Niemeyer, Philipp	2010	Open-wedge osteotomy using an internal plate fixator in patients with medial-compartment gonarthrosis and varus malalignment: 3-year results with regard to preoperative arthroscopic and radiographic findings	Arthroscopy-The Journal of Arthroscopic and Related Surgery	129
48	Jung, Woon-Hwa	2014	Second-look arthroscopic assessment of cartilage regeneration after medial opening-wedge high tibial osteotomy	Arthroscopy-The Journal of Arthroscopic and Related Surgery	127
49	Giffin, J. Robert	2007	Importance of tibial slope for stability of the posterior cruciate ligament-deficient knee	American Journal of Sports Medicine	124
50	El-Azab, Hosam	2010	Patellar height and posterior tibial slope after open- and closed-wedge high tibial osteotomy a radiological study on 100 patients	American Journal of Sports Medicine	123
51	BERMAN, AT	1991	Factors influencing long-term results in high tibial osteotomy	Clinical Orthopaedics and Related Research	121
52	BROUGHTON, NS	1986	Unicompartmental replacement and high tibial osteotomy for osteoarthritis of the knee – a comparative-study after 5-10 y follow-up	Journal of Bone and Joint Surgery-British Volume	121
53	Bonasia, Davide Edoardo	2014	Medial opening wedge high tibial osteotomy for medial compartment overload/arthritis in the varus knee prognostic factors	American Journal of Sports Medicine	120
54	Babis, GC	2002	Double level osteotomy of the knee: a method to retain joint-line obliquity – clinical results	Journal of Bone and Joint Surgery-American Volume	120
55	Martin, Robin	2014	Adverse event rates and classifications in medial opening wedge high tibial osteotomy	American Journal Of Sports Medicine	117
56	Stukenborg-Colsman, C	2001	High tibial osteotomy versus unicompartmental joint replacement in unicompartmental knee joint osteoarthritis: 7-10-year follow-up prospective randomised study	Knee	114
57	Meidinger, Gebhart	2011	May smokers and overweight patients be treated with a medial open-wedge hto? risk factors for non-union	Knee Surgery Sports Traumatology Arthroscopy	113
58	Wright, JM	2005	High tibial osteotomy	Journal of The American Academy of Orthopaedic Surgeons	113
59	Birmingham, Trevor B.	2009	Medial opening wedge high tibial osteotomy: a prospective cohort study of gait, radiographic, and patient-reported outcomes	Arthritis & Rheumatism-Arthritis Care & Research	112
60	Hankemeier, S.	2006	Navigated open-wedge high tibial osteotomy: advantages and disadvantages compared to the conventional technique in a cadaver study	Knee Surgery Sports Traumatology Arthroscopy	112
61	SHOJI, H	1973	High tibial osteotomy for osteoarthritis of knee with valgus deformity	Journal of Bone and Joint Surgery-American Volume	111
62	HOLDEN, DL	1988	Proximal tibial osteotomy in patients who are 50 y old or less – a long-term follow-up-study	Journal of Bone and Joint Surgery-American Volume	110
63	JACKSON, JP	1974	Technique and complications of upper tibial osteotomy – review of 226 operations	Journal of Bone and Joint Surgery-British Volume	110
64	Schuster, Philipp	2018	Ten-year results of medial open-wedge high tibial osteotomy and chondral resurfacing in severe medial osteoarthritis and varus malalignment	American Journal of Sports Medicine	107
65	Nelissen, E. M.	2010	Stability of medial opening wedge high tibial osteotomy: a failure analysis	International Orthopaedics	107
66	Bode, Gerrit	2015	Prospective 5-year survival rate data following open-wedge valgus high tibial osteotomy	Knee Surgery Sports Traumatology Arthroscopy	106
67	Lobenhoffer, P	2004	Open-wedge high tibial osteotomy with special medial plate fixator	Orthopade	106
68	Gaasbeek, Robert D. A.	2010	Correction accuracy and collateral laxity in open versus closed wedge high tibial osteotomy. a one-year randomised controlled study	International Orthopaedics	105
69	Nakayama, Hiroshi	2018	Large correction in opening wedge high tibial osteotomy with resultant joint-line obliquity induces excessive shear stress on the articular cartilage	Knee Surgery Sports Traumatology Arthroscopy	104
70	Schallberger, Alex	2011	High tibial valgus osteotomy in unicompartmental medial osteoarthritis of the knee: a retrospective follow-up study over 13-21 y	Knee Surgery Sports Traumatology Arthroscopy	103
71	El-Azab, H.	2008		Journal of Bone and Joint Surgery-British Volume	103

Table 1**(Continued)**

Number	First author	Publication year	Title	Journal	Total citations
72	WEALE, AE	1994	The effect of closed- and open-wedge high tibial osteotomy on tibial slope – a retrospective radiological review of 120 cases	Clinical Orthopaedics and Related Research	102
73	MAQUET, P	1976	Unicompartmental arthroplasty and high tibial osteotomy for osteoarthritis of the knee – a comparative-study with a 12-year to 17-year follow-up period	Clinical Orthopaedics and Related Research	101
74	HARRIS, WR	1970	Valgus osteotomy for osteo-arthritis of knee	Journal of Bone and Joint Surgery-American Volume	101
75	Saragaglia, D	2005	High tibial osteotomy for osteo-arthritis of knee	Orthopedics	100
76	Woodacre, T.	2016	Navigated osteotomies around the knee in 170 patients with osteoarthritis secondary to genu varum	Knee	99
77	Niemeyer, Philipp	2008	Complications associated with opening wedge high tibial osteotomy – a review of the literature and of 15 y of experience	Arthroscopy-The Journal of Arthroscopic and Related Surgery	99
78	Arthur, Andrew	2007	Two-year results of open-wedge high tibial osteotomy with fixation by medial plate fixator for medial compartment arthritis with varus malalignment of the knee	American Journal of Sports Medicine	98
79	Noyes, Frank R.	2006	Proximal tibial opening wedge osteotomy as the initial treatment for chronic posterolateral corner deficiency in the varus knee – a prospective clinical study	American Journal of Sports Medicine	98
80	Spahn, G	2006	Opening wedge high tibial osteotomy – an operative technique and rehabilitation program to decrease complication and promote early union and function	Osteoarthritis and Cartilage	98
81	Naudie, DDR	2004	Factors that influence high tibial osteotomy results in patients with medial gonarthrosis: a score to predict the results	American Journal of Sports Medicine	98
82	Lee, Dae-Hee	2016	Opening wedge high tibial osteotomy for symptomatic hyperextension-varus thrust	Knee Surgery Sports Traumatology Arthroscopy	97
83	Brosset, T.	2011	Effect of soft tissue laxity of the knee joint on limb alignment correction in open-wedge high tibial osteotomy	Orthopaedics & Traumatology-Surgery & Research	97
84	Salzmann, Gian M.	2009	Opening wedge high tibial osteotomy performed without filling the defect but with locking plate fixation (tomofix™) and early weight-bearing: prospective evaluation of bone union, precision and maintenance of correction in 51 cases	American Journal of Sports Medicine	96
85	Mina, Curtis	2008	Sporting activity after high tibial osteotomy for the treatment of medial compartment knee osteoarthritis	American Journal of Sports Medicine	95
86	Michaela, Gstoettner	2008	High tibial osteotomy for unloading osteochondral defects in the medial compartment of the knee	Archives of Orthopaedic and Trauma Surgery	95
87	Gaasbeek, RDA	2004	Long-term outcome after high tibial osteotomy	Knee	95
88	Hernigou, P	2001	Distal tuberosity osteotomy in open wedge high tibial osteotomy can prevent patella infera: a new technique	Knee	95
89	KIRGIS, A	1992	Open wedge tibial osteotomy with acrylic bone cement as bone substitute	Journal of Bone and Joint Surgery-American Volume	95
90	Izaham, Raja Mohd Aizat Raja	2012	Palsy of the deep peroneal nerve after proximal tibial osteotomy – an anatomical study	Injury-International Journal of The Care of The Injured	94
91	LaPrade, Robert F.	2010	Finite element analysis of puddu and tomofix plate fixation for open wedge high tibial osteotomy	American Journal of Sports Medicine	94
92	MATTHEWS, LS	1988	Patellar height and tibial slope after opening-wedge proximal tibial osteotomy a prospective study	Clinical Orthopaedics and Related Research	94
93	Staubli, Alex E.	2010	Proximal tibial osteotomy – factors that influence the duration of satisfactory function	International Orthopaedics	93
94	Hoell, S	2005	Evolution of open-wedge high-tibial osteotomy: experience with a special angular stable device for internal fixation without interposition material	Archives of Orthopaedic and Trauma Surgery	93
95	Duivenvoorden, T.	2014	The high tibial osteotomy, open versus closed wedge, a comparison of methods in 108 patients	Journal of Bone and Joint Surgery-American Volume	92
96	Spahn, Gunter	2013	Comparison of closing-wedge and opening-wedge high tibial osteotomy for medial compartment osteoarthritis of the knee a randomized controlled trial with a six-year follow-up	Knee Surgery Sports Traumatology Arthroscopy	92
97	Han, Seung Boem	2013	The impact of a high tibial valgus osteotomy and unicondylar medial arthroplasty on the treatment for knee osteoarthritis: a meta-analysis	Knee Surgery Sports Traumatology Arthroscopy	91
98	Gaasbeek, Robert	2007	A safe zone in medial open-wedge high tibia osteotomy to prevent lateral cortex fracture	Knee Surgery Sports Traumatology Arthroscopy	91
99	Rinonapoli, E	1998	The influence of open and closed high tibial osteotomy on dynamic patellar tracking: a biomechanical study	Clinical Orthopaedics and Related Research	90
100	Song, E. K.	2010	Tibial osteotomy for varus gonarthrosis – a 10- to 21-year followup study	Journal of Bone and Joint Surgery-British Volume	89
			The complications of high tibial osteotomy: closing- versus opening-wedge methods		

of articles the country has. The lines in the figure denote the presence of cooperative relationships between countries. The USA dominated this field with 26 out of the 100 papers and 4426 citations, with an average citation count of 170.23 (Fig. 4). Germany secured the second rank, contributing 23

papers and receiving 3490 citations, with an average citation count of 151.74. Switzerland was the third, contributing 9 articles and receiving 1597 citations, with an average citation count of 177.44. Switzerland boasted the highest average number of citations per publication (177.44).

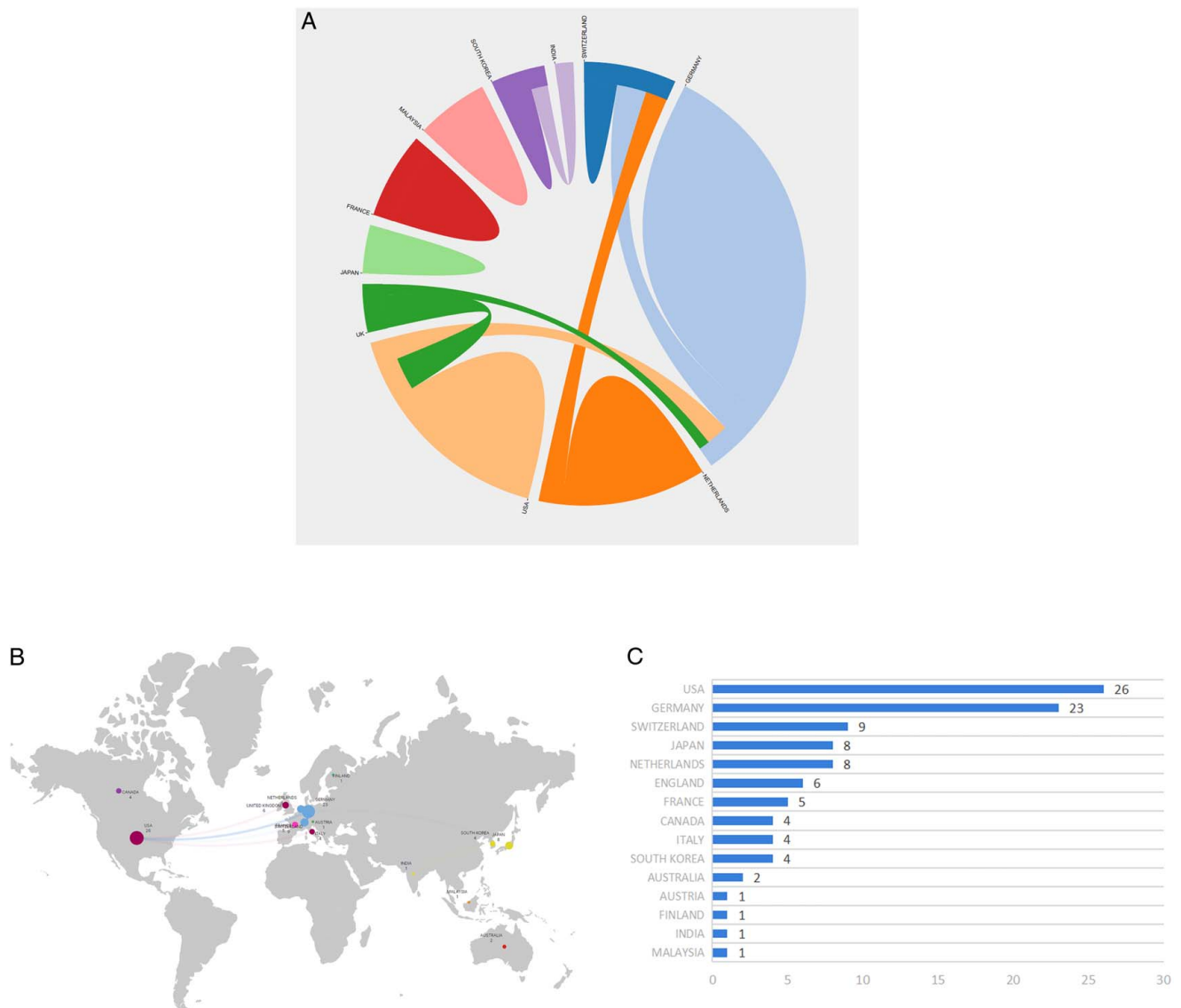


Figure 3. The most productive countries. (A) The network map shows the countries involved in this research area. (B) Number of publications by country. (C) The world map displays the number of national publications.

Institution analysis

Regarding institutions, 129 institutions contributed to the top 100 articles in this study. Figure 5A presents the publication count of the most relevant affiliations. Among them, Hannover Medical School was the leading institution, producing the highest number of top-cited articles ($n=6$). The study employed the Citespace software to visualize the connections between institutions. The size of the circle in the graph correlates with the number of publications by the institution in the field, and the lines denote collaborative relationships between institutions. Figure 5B depicts the emergence of several prominent research institutions as leaders in their respective countries. Such institutions comprise the Hannover Medical School and Technical University of Munich (Germany), the Mayo Clinic and University of Iowa (USA), the Western University (University of Western Ontario) (Canada), the Korea University and Korea University Medicine (KU Medicine) (Korea), and the University of Bern (Switzerland).

Author analysis

Employing the Bibliometrix R package, the most relevant authors were identified. Figure 6A demonstrates that Philipp Lobenhoffer had the highest number of published papers ($n=6$). Figure 6B depicts the author's production over time. Coventry MB was a predecessor author. His paper titled "Proximal tibial osteotomy—a critical long-term study of 87 cases," published in 1993 in the *Journal of Bone and Joint Surgery—American Volume*, collected 476 citations, ranking third regarding total citations. Since the onset of the 21st century, there has been an increase in the number of authors publishing high-impact articles. In Figure 6C, the size of each node correlates with the number of articles authored by the author among the top 100 articles in this field. The lines in the figure denote collaborative relationships among authors. The analysis disclosed that author collaboration is relatively frequent, and the partnership between authors is consistent. Figure 6D depicts the relationship between countries, institutions, and

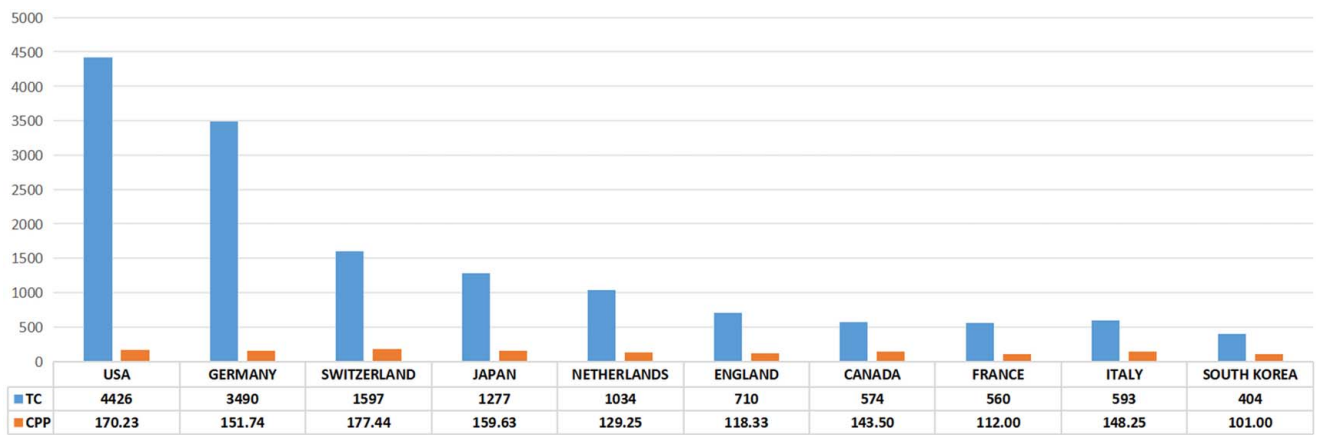


Figure 4. Top 10 countries with the most publications. CPP, citations per publication; TC, total citation.

authors. Authors from Germany and the Netherlands had a substantial impact.

Analysis of journals

Table 2 displays relevant journals of the 100 articles. The Journal of Bone and Joint Surgery—American Volume published the highest number of articles ($n=21$), with 4307 citations. It was succeeded by the American Journal of Sports Medicine, which published 16 papers and had 1984 citations. Knee Surgery Sports Traumatology Arthroscopy followed the latter, contributing 13 articles and receiving 1834 citations, with an average citation count of 141.08. Furthermore, 8 journals published more than 3 articles: Clinical Orthopaedics and Related Research, Journal of Bone and Joint Surgery—British Volume, Arthroscopy—the Journal of Arthroscopic and Related Surgery, Knee, and International Orthopaedics, accumulating 1451, 1338, 1334, 691, 543, and 415 citations, respectively.

Keywords and research hotspots

Keywords play a pivotal role in describing the main focus of an article, providing researchers with a deeper understanding of the subject matter. The co-occurrence of two keywords within the same paper signifies an internal relationship between them, and the frequency of their appearance indicates the strength of their association. By conducting keyword co-occurrence and emergent

item analysis, we can identify hot topics in a specific field during different periods and cluster the keywords provided by authors in the dataset. The size of each sphere in the analysis correlates with the occurrence frequency of the respective keyword.

Figure 7A depicts the keyword cloud map, where closely connected keywords are assigned the same colour, implying a potential shared relationship. The following keywords appeared more than 10 times: osteoarthritis ($n=34$), knee ($n=30$), high tibial osteotomy (HTO) ($n=29$), gonarthrosis ($n=21$), long term ($n=19$), arthritis ($n=18$), follow-up ($n=18$), and fixation ($n=12$).

Keyword clustering characterizes the internal knowledge structure of a specific research field and classifies its domain. Cluster analysis disclosed that keywords in the field of high tibial osteotomy (HTO) could be divided into nine categories (Fig. 7B): “open wedge,” “osteoarthritic knees,” “biomechanical study,” “medial osteoarthritis,” “knee osteoarthritis,” “ACL revision,” “survivorship analysis,” “cartilage defects,” and “posterior tibial slope.”

Figure 8 illustrates the trend of keyword modifications over time. Figure 8A portrays the dynamic relationship between keywords and time. The size of each block relates to the popularity of the respective keyword, whereas a larger block denotes a higher frequency of keyword occurrence. Moreover, keywords exhibiting an increasing trend and appearing more frequently in recent years might emerge as popular research topics in the future.

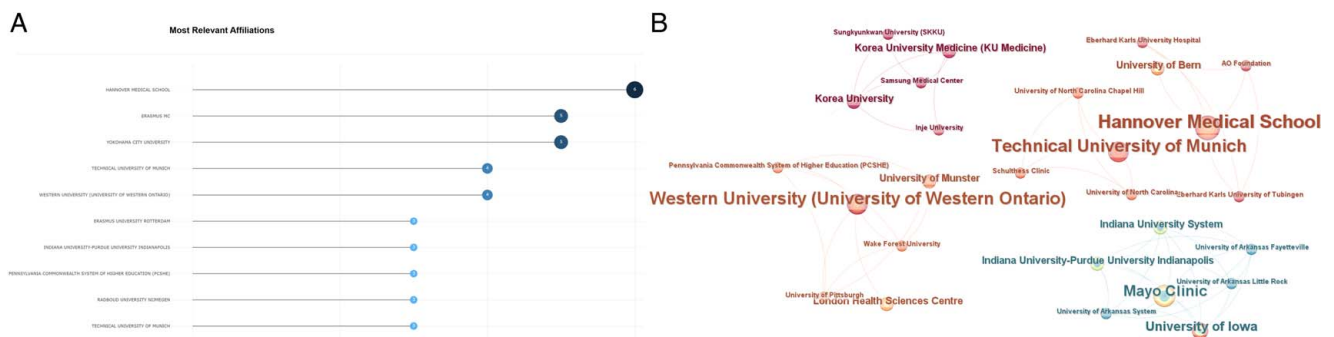


Figure 5. Institution analysis. (A) The most relevant institutions. (B) Partnerships between institutions.

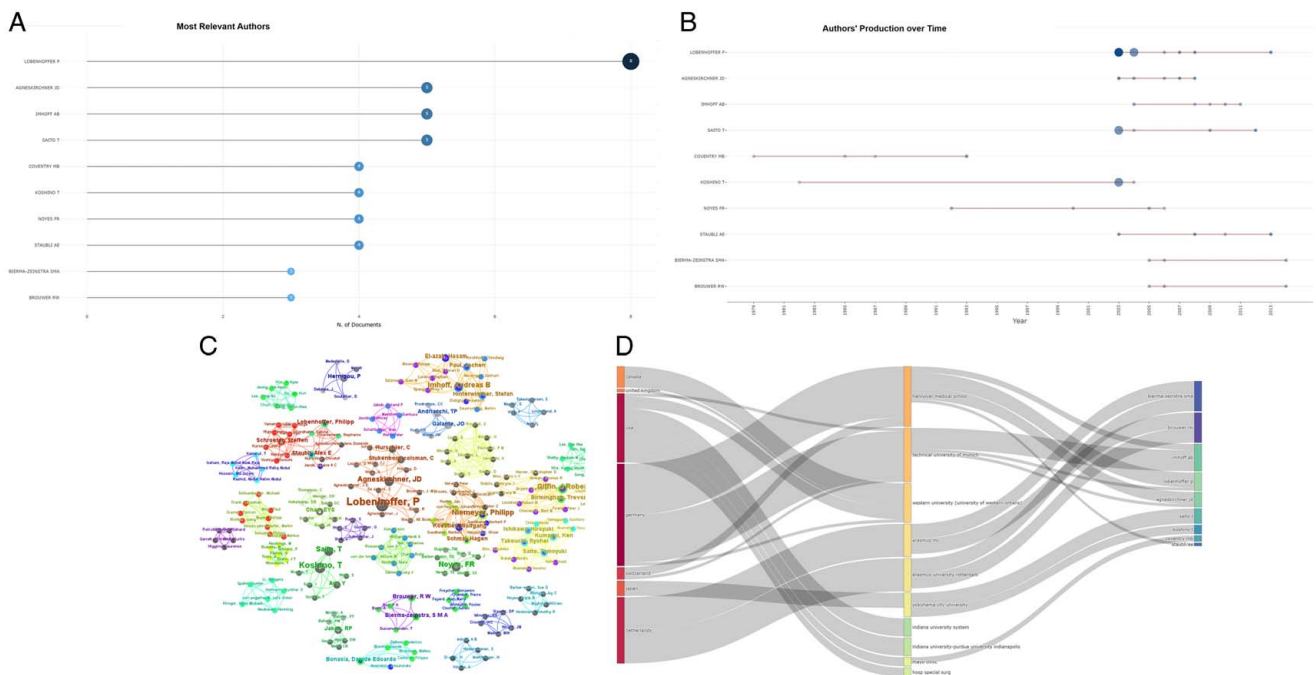


Figure 6. Author analysis. (A) Most relevant authors. (B) Authors' production over time. (C) The author's collaborative relationship map. (D) Three-field plot (country-affiliation-author).

We conducted a burst analysis of the keywords, identifying several prominent keywords, including alignment, osteoarthritic knees, knee osteoarthritis, HTO, long-term follow-up, proximal tibia, posterolateral knee, and mechanical axis. Keywords with the highest burst strength can signify the forefront of research in the specific field. Keywords that burst earlier imply that researchers focused on those areas in the early years, whereas those that burst more recently signal a sudden surge in attention toward the topic.

Figure 8B demonstrates the top five keywords “stability,” “complications,” “tibial slope,” “patellar height,” and “long

term,” with burst strengths of 2.39, 2.36, 1.92, 1.91, and 1.83, respectively. The earliest keywords to burst were “osteoarthritis” and “knee,” while the most recent bursting keywords comprised “puddu plate” and “accuracy.”

Discussion

We conducted data and bibliometric analyses using the top 100 influential publications on HTO.

Table 2
Journals of the 100 most-cited articles in high tibial osteotomy.

Ranking	Journal	Documents	Total citations	IF in 2022	5 years IF	Average citations
1	Journal of Bone and Joint Surgery American Volume	21	4307	5.3	5.9	205.10
2	American Journal of Sports Medicine	16	1984	4.8	6.1	124.00
3	Knee Surgery Sports Traumatology Arthroscopy	13	1834	3.8	3.9	141.08
4	Clinical Orthopaedics and Related Research	9	1451	4.7	4.6	157.56
4	Journal of Bone and Joint Surgery-British Volume	9	1338	4.3	5.2	148.67
6	Arthroscopy—the Journal of Arthroscopic and Related Surgery	8	1334	3.309	3.479	166.75
7	Knee	6	691	1.9	2.3	115.17
8	International Orthopaedics	4	543	2.7	2.9	135.75
9	Archives of Orthopaedic and Trauma Surgery	3	415	2.3	2.5	138.33
10	Orthopedic Clinics of North America	2	756	1.8	2.7	378.00
10	Injury—International Journal of the Care of the Injured	2	394	2.5	2.9	197.00
12	Arthritis & Rheumatism—Arthritis Care & Research	1	112	8.955	8.23	112.00
12	Clinical Biomechanics	1	161	1.8	2.1	161.00
12	Orthopade	1	106	1.004	1.02	106.00
12	Orthopaedics & Traumatology-Surgery & Research	1	97	2.3	2.7	97.00
12	Journal of the American Academy of Orthopaedic Surgeons	1	113	3.2	3.6	113.00
12	Orthopedics	1	100	1.1	1.8	100.00
12	Osteoarthritis and Cartilage	1	98	7	7	98.00

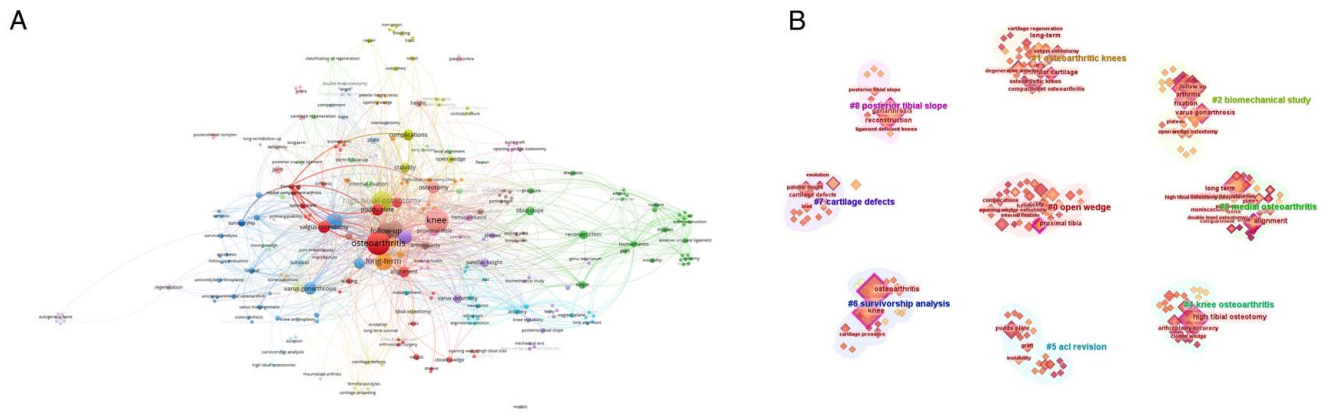


Figure 7. Keyword analysis. (A) The overlay visualization map of keyword co-occurrence. (B) Keyword cluster graph.

The utilization of bibliometric tools like VOSviewer and CiteSpace in our study has significantly deepened our comprehension of the HTO research landscape. These tools serve as powerful analytical instruments that transform complex bibliometric data into visual representations, thereby enhancing our ability to identify patterns, trends, and relationships within the field of HTO. By employing VOSviewer and CiteSpace, we have been able to map out author networks and co-authorship relationships, revealing the collaborative nature of HTO research. These visualizations highlight the most influential researchers and institutions, providing insights into the key players who drive innovation and knowledge dissemination in this field. Additionally, the tools' capability to analyze citation patterns allows us to trace the intellectual evolution of HTO research, pinpointing areas of growing interest and potential new directions for investigation. The temporal analysis features of these tools offer a window into the history of HTO research, showcasing the emergence of new topics and the fading of others. This trend analysis is crucial for understanding the dynamic nature of research focus over time and for predicting future research trajectories. It also aids in identifying gaps in the current literature and suggests where additional research may be most beneficial.

These 100 papers received a total of 15 833 citations, with an average of 158.33 citations per paper (range: 89–599). The top

100 articles accumulated 89–599 citations, with a median of 122 and an average of 158.33 citations per article. Since the beginning of the 21st century, there has been a significant surge in the number of publications and citations. Philipp Lobenhoffer had the highest number of publications ($n=6$). The majority of the papers were from the USA ($n=26$), followed by Germany ($n=23$) and Switzerland ($n=9$). Hannover Medical School produced the highest number of papers ($n=6$). Keyword analysis revealed several research hotspots, such as open-wedge osteotomy, biomechanical study, tibial slope, patellar height, Puddu plate, TomoFix plate, stability, complications, and accuracy.

Rapidly growing trend of HTO

The rising trend in HTO research since the 21st century reflects a growing interest in this treatment for knee joint diseases. HTO is a well-established orthopaedic procedure that addresses joint imbalance and pain by altering the proximal tibia's anatomy, thereby optimizing force distribution within the knee joint. As Figure 2 illustrates, there was a notable increase in HTO-related publications and citations post-2000, indicating its expanding role in orthopaedic research.

Initially, HTO faced skepticism due to complications such as loss of correction and prolonged immobilization. The advent of total knee arthroplasty (TKA) further overshadowed HTO, as it

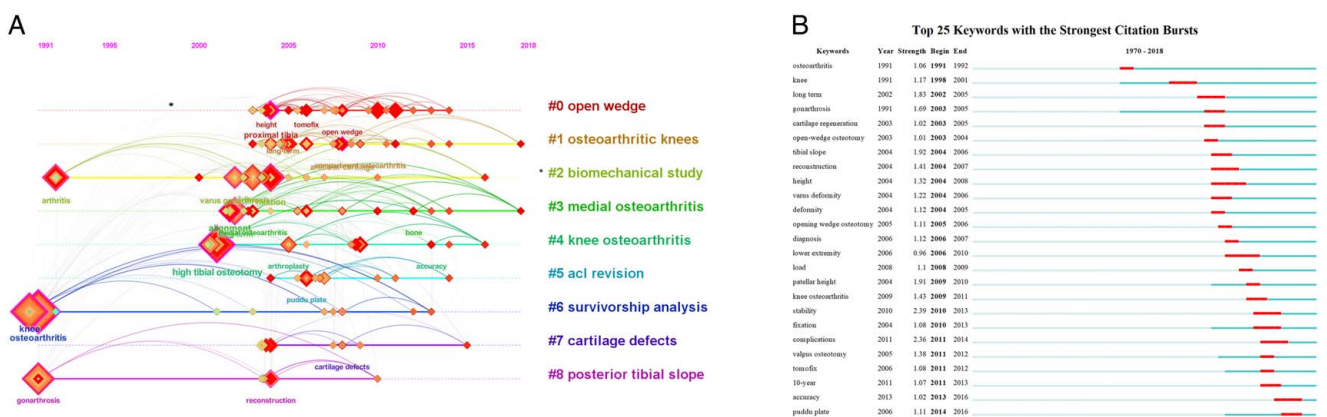


Figure 8. Keyword modifications over time. (A) Timeline view of keywords. (B) Burst test of keywords.

offered a more definitive solution. However, recent concerns about TKA's complications^[13], particularly in younger and more active patients^[14], have reignited interest in HTO. Innovations in surgical techniques and fixation devices, along with evidence of cartilage regeneration post-HTO, have revitalized the procedure's appeal.

Advancements in minimally invasive techniques, personalized surgical planning, and enhanced fixation methods have improved HTO precision and patient outcomes. The recognition of HTO as an alternative to TKA has been bolstered by clinical studies showing high patient satisfaction, influencing both patient and surgeon decision-making. Economic considerations, such as potential cost savings compared to TKA, have also fuelled research interest in HTO.

This surge in research activity has several implications for future directions. Technological advancements may lead to new technologies and refinement of surgical techniques, aiming to improve HTO precision and recovery. Detailed studies on patient selection and outcomes could identify factors predicting success and explore long-term impacts. Comparative effectiveness research will likely increase, evaluating various HTO techniques and their comparison with other treatments.

Biomechanical and material research may delve into the knee's post-HTO biomechanics and develop new biomaterials for fixation devices. Global collaboration could lead to multicenter trials or registries for a broader understanding of HTO outcomes. Education and training programs for surgeons may become more extensive, focusing on improving surgical skills. Economic evaluations could assess HTO's cost-effectiveness, and longitudinal studies could examine long-term survivorship and failure rates.

In summary, the current research trends in HTO point towards a future of continuous refinement through technological innovation, improved patient selection, and comprehensive research. These efforts will likely enhance HTO as a treatment option, improving patient care and outcomes.

Surgical techniques in HTO

In the field of HTO, surgical techniques are pivotal, with lateral close-wedge, dome, and medial open-wedge osteotomies being the primary methods for valgus realignment of the proximal tibial articular surface. Each technique presents distinct outcomes and applicability, which are crucial for informing clinical practice.

The lateral close-wedge osteotomy, known for its significant correction potential and rapid healing, avoids the need for bone grafting. Yet, it carries risks such as peroneal nerve injury and leg shortening, and may necessitate a fibular osteotomy, adding to its complexity^[15]. In contrast, the dome osteotomy preserves the tibia's natural shape and limb length, simplifying bone healing and future joint replacements. However, its rarity in clinical practice is due to the technical demands and extensive intraoperative exposure it requires.

The open-wedge osteotomy, currently a significant focus of research, allows for corrections in both coronal and sagittal planes, eliminating the need for fibular osteotomy. It minimizes the risk of peroneal nerve injury and limb shortening and enables intraoperative adjustment of corrections. Despite these advantages, the procedure's main drawback is the risk of non-union or delayed union^[16], leading to the development of modified techniques that have gained widespread clinical recognition and application^[12].

Understanding the nuances of these techniques is essential for clinicians. The choice of HTO technique must be customized based on the patient's anatomy, the severity of the varus deformity, and the surgeon's expertise. Factors such as the patient's age, activity level, bone quality, and comorbidities must be carefully considered. Advanced imaging and navigation systems can enhance preoperative planning and optimize outcomes, while postoperative rehabilitation should be tailored to the specific technique used.

Ongoing research is vital to compare long-term outcomes, complication rates, and patient satisfaction across different HTO techniques, guiding evidence-based decision-making in clinical practice. In summary, a thorough understanding of the advantages and challenges of each HTO technique is crucial for achieving successful outcomes and improving patient care.

USA's dominance in HTO research

The United States' prominent role in high HTO research, marked by its significant presence in the top-cited papers, owes much to its well-funded research institutions and the interdisciplinary collaboration they foster. These institutions, bolstered by financial support from federal agencies, private foundations, and industry partners, have cultivated an environment that not only drives innovation in HTO but also encourages the cross-pollination of ideas between fields such as orthopaedics, biomechanics, and materials science. This holistic approach has been further enhanced by the country's sophisticated healthcare system, which provides access to advanced medical facilities and technologies, facilitating the implementation of the latest surgical techniques. Moreover, the U.S.'s strong emphasis on evidence-based medicine has led to a proliferation of clinical trials, which are crucial for validating the efficacy and safety of HTO procedures and contribute to the nation's high volume of citable research. The publish-or-perish culture prevalent in U.S. academia further motivates researchers to produce work that not only influences clinical practice but also advances the global understanding of HTO. This culture of innovation and rigorous publication standards has not only shaped the domestic research landscape but also has significant implications for global knowledge dissemination and collaboration. As the U.S. continues to set global standards for surgical techniques and research methodologies, its research findings and advancements play a pivotal role in shaping training programs and influencing patient care worldwide, thereby ensuring that the next generation of surgeons is well-equipped with the latest knowledge and skills in HTO.

Prominent research institutions

The prominence of research institutions like Hannover Medical School and Technical University of Munich in the field of HTO is indicative of their significant contributions to the advancement of this surgical technique. Their success in producing top-cited articles can be attributed to several key factors that have a direct impact on clinical practice and patient outcomes.

These institutions excel due to their commitment to interdisciplinary research, fostering collaboration between experts in orthopaedics, biomechanics, and rehabilitation sciences. This holistic approach leads to comprehensive studies that cover all aspects of HTO, from surgical techniques to postoperative care. Additionally, their robust research infrastructure, including state-of-the-art facilities and advanced technologies, enables them to

conduct cutting-edge research and produce high-quality, impactful work.

The emphasis on methodological rigour at these institutions ensures that their research meets the highest standards, contributing to the development of evidence-based guidelines for HTO. Furthermore, their focus on clinical outcomes and survivorship studies provides valuable data that can influence patient management, guiding surgeons in making informed decisions and improving surgical planning.

The findings from these institutions have a ripple effect on clinical practice. Their research outcomes inform the development of new surgical techniques, the design of fixation devices, and the formulation of rehabilitation protocols. As a result, patients benefit from more precise surgeries, reduced complication rates, and enhanced recovery processes.

In summary, the success of Hannover Medical School and Technical University of Munich in HTO research is driven by their interdisciplinary collaboration, advanced research infrastructure, and commitment to methodological excellence. Their contributions have a profound impact on clinical practice, leading to improved patient outcomes and setting the stage for future advancements in the field.

Contributions of Philipp Lobenhoffer

Philipp Lobenhoffer stands as a prominent contributor to the field of HTO, with his research and publications shaping the progression of this surgical technique and its clinical application. His work has been pivotal in refining surgical methods, deepening the understanding of knee biomechanics post-HTO, and evaluating the long-term success of the procedure.

Lobenhoffer's refinements to the open-wedge HTO technique have focused on enhancing precision and stability, which in turn has led to improved patient outcomes and a reduction in post-operative complications. His biomechanical research has provided critical insights into joint load distribution and stability after HTO, guiding the development of surgical strategies for optimal and enduring correction.

Through his clinical research, Lobenhoffer has offered invaluable data on the success rates, patient satisfaction, and survivorship of HTO, reinforcing its position as a viable alternative to arthroplasty for suitable patients. His findings have been instrumental in standardizing HTO techniques, providing clear guidelines for surgeons to achieve reliable results. Furthermore, his insights into the biomechanical forces at play have influenced the design of fixation devices and implants, contributing to the creation of more stable and durable surgical constructs.

In summary, Philipp Lobenhoffer's extensive research and publications on HTO have significantly advanced the field, leading to improved surgical techniques, and a more robust evidence base for the procedure. His work has not only influenced clinical practice but also set a standard for future research in HTO, ensuring that patients receive the highest quality of care.

Collaborative research efforts

The strong collaborative network identified among authors and institutions in HTO research is a key factor that enriches the field, offering a multitude of benefits alongside challenges. These partnerships have the potential to significantly influence research outcomes and spur innovation.

Collaborations bring a diversity of expertise, merging knowledge from orthopaedics, bioengineering, and rehabilitation sciences, leading to comprehensive research designs and innovative solutions that span all aspects of HTO. Shared resources, including data and funding, enhance research efficiency and enable studies that would be impractical for individual entities. Methodological rigour is bolstered through peer review and validation, while the broader reach of combined patient populations and experiences yields more generalizable findings. Furthermore, the accelerated dissemination of knowledge through collaborative efforts ensures that research findings reach the wider community promptly.

However, the management of large networks is not without its complexities. Coordination and communication can be challenging due to varying time zones, institutional cultures, and research priorities. Data management and privacy are also significant concerns, requiring robust systems and compliance with regulations. Issues of authorship and credit distribution can be contentious, as can funding and financial interests, with potential conflicts arising from differing policies and commercial interests.

Despite these challenges, collaborations have a profound impact on research outcomes and innovation. They increase the potential for high-quality, impactful research, with diverse expertise and pooled resources leading to novel surgical techniques and implants that enhance HTO outcomes. Moreover, these collaborations foster an environment conducive to the exchange of ideas, paving the way for exploration into new areas of HTO research, such as advanced imaging and digital health integration.

In summary, the benefits of collaborative research in HTO outweigh the challenges. Such collaborations enhance research quality, speed up the spread of knowledge, and drive innovation, ultimately improving patient care and outcomes. To fully realize these benefits, it is essential to establish clear collaboration guidelines, robust data management, and mechanisms to resolve conflicts and ensure fair credit distribution.

Research hotspots in HTO

The identification of research hotspots in HTO, including open-wedge osteotomy, biomechanical studies, and complications, is instrumental in enhancing our understanding of HTO outcomes and patient management. These areas not only shed light on current research trends but also chart a course for future investigations.

Open-wedge osteotomy, a widely adopted technique, is at the forefront of HTO research. It emphasizes the correction of the mechanical axis while preserving the native knee. Studies in this domain have led to advancements in surgical techniques, fixation optimization, and graft integration, crucial for understanding procedural intricacies and patient selection. Moving forward, long-term studies will be essential to evaluate survivorship and to explore innovative materials and methods that could further refine outcomes and minimize complications.

Biomechanical studies play a pivotal role in deciphering the impact of HTO on knee function. By examining force distribution, joint contact changes, and muscle activation, these studies are fundamental in refining surgical planning and rehabilitation protocols. Future research should leverage advanced imaging and modelling to predict biomechanical changes preoperatively and to tailor surgical approaches to individual patients.

Investigations into complications offer vital insights into enhancing patient safety and surgical outcomes. By examining non-union, malalignment, and other adverse events, researchers can develop strategies to prevent or manage these complications, thereby improving patient care. Future research should focus on creating predictive models for complication risks and on comparing the effectiveness of various surgical techniques, as well as exploring innovative preventive and treatment approaches.

The collective findings from these research areas profoundly influence patient management, guiding surgical decisions, and refining preoperative and postoperative care. A more nuanced understanding of the factors leading to successful HTO outcomes can result in more personalized treatment plans, enhancing patient satisfaction and long-term results, and potentially reducing the need for revision surgeries.

Focus on research hotspots

The paper's emphasis on navigation systems as a critical research hotspot in HTO procedures highlights the potential for these technologies to revolutionize the field by enhancing the precision of surgical corrections. As future research priorities are shaped, there is a clear need to investigate the integration of advanced technologies, such as computer-assisted and robot-assisted surgeries, which could further refine bone cuts and improve surgical outcomes. Concurrently, the development of comprehensive education and training programs will be essential to equip surgeons with the necessary skills to utilize these technologies effectively. Comparative studies will play a pivotal role in evaluating the benefits and risks of navigation-assisted HTO against traditional methods, guiding the development of best practice guidelines and informing surgical decision-making. Moreover, the potential for customization and personalization in HTO, facilitated by navigation systems, opens new avenues for patient-specific planning and implant design, ultimately leading to a more tailored approach to treatment.

In clinical practice, the adoption of navigation systems promises to improve surgical precision, reducing the risk of under- or overcorrection and optimizing patient selection for HTO procedures. Insights gained from these systems can tailor postoperative rehabilitation protocols to better align with the unique biomechanics of each patient's knee, enhancing recovery and function. As the evidence base for navigation systems expands, it will be crucial to consider the balance of advantages and additional costs when making strategic decisions regarding their implementation. Furthermore, healthcare policymakers will need to consider the significant investment required for technology and training, and research will play a vital role in guiding these decisions to ensure the most effective allocation of resources.

In summary, the focus on navigation systems in HTO research is set to shape the field's future, steering it towards technologically enhanced surgeries and personalized treatment plans. Rigorous research is essential to fully understand the benefits and limitations of these systems, ensuring they contribute positively to improved patient care and outcomes in HTO.

Limitations

This study has several limitations. Despite being the most commonly used database for literature search, Web of Science does not encompass all previous publications. To ensure the accuracy of our analysis, we chose to employ the topic search method instead of the

subject keywords search method. Although our search results demonstrate some precision, they could have been more comprehensive. The reliance on citation counts as a selection criterion may overlook recent publications that may have a significant impact but have not yet accumulated a high citation count. Additionally, the potential for citation bias exists, as papers from certain institutions or by well-known authors may receive more citations than equally valuable works from less prominent sources.

Conclusion

This study provides bibliometric information on HTO. Our results show that the USA is a clear leader in this field. HTO has received increasing attention since the beginning of the 21st century and is expected to be a significant area of research in the future. Meanwhile, focusing on potential research areas of interest, such as the navigation system to enhance the accuracy of the correction, is recommended.

Ethical approval

Ethics approval was not required for this review.

Consent

Informed consent was not required for this review.

Sources of funding

This study received support from the Gusu Health Talents program (GSWS2020069) and the Suzhou Science and Technology Program (SLJ2022014).

Author contribution

L.-C.Y.: investigation, data curation, writing—original draft preparation. J.-Y.Z.: investigation, methodology, software. Y.-Y.J.: methodology, validation, visualization. R.-J.X.: conceptualization, supervision, writing—reviewing and editing, project administration, funding acquisition.

Conflicts of interest disclosure

The authors declare that they have no competing interests.

Research registration unique identifying number (UIN)

Not applicable.

Guarantor

The corresponding author, Ren-Jie Xu, serves as the Guarantor for this manuscript. Dr Xu accepts full responsibility for the work and the conduct of the study, including the data presented and its interpretation. Dr Xu had full access to all of the data in the study and takes responsibility for the decision to submit the manuscript for publication. The Guarantor confirms that the manuscript has

been read and approved by all listed authors and that all contributors who are not authors have been acknowledged.

Data availability statement

Data included in the article/supplementary material are referenced in the article.

Data sharing statement

Research data supporting this publication are available from the Web of Science at located at www.webofknowledge.com.

Provenance and peer review

Not invited.

Acknowledgement

The authors express their gratitude to Prof. Chen for generously providing free access to the CiteSpace software for researchers.

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