

Original Article

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A 30-Year Worldwide Research Productivity of Scientific Publication in Full-Endoscopic Decompression Spine Surgery: Quantitative and Qualitative Analysis

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Objective: The ever-growing number of articles related to full-endoscopic spine surgery published in the last few decades presents a challenge which is perplexing and time-consuming in identifying the current research status. The study aims to identify and analyze the most cited works related to full-endoscopic decompression spine surgery, compare the articles published by different publishers and area, and show the current publication status of full-endoscopic research.

Methods: Using Bibliometrix, CiteSpace, and VOSviewer, we analyzed the bibliometric data selected from the Web of Science database between 1992 and 2022. Spine has the highest H-index with the most-cited journal in the field of full-endoscopic decompression spine surgery. China ranked as the most productive country, whereas the most cited with high H-index papers came from South Korea. For the author analysis, Yeung AT, Ruetten S, Hoogland T, Ahn Y, Choi G, and Mayer HM were the most impactful authors in the global and local citations. The most productive organization is Wooridul Spine Hospital.

Conclusion: The bibliometric study showed a growing trend of research on full-endoscopic decompression spine surgery over the past 30 years. It has demonstrated that there is a significant increase in the number of authors, institutions, and internationally collaborated countries. However, the quality of studies is still low, and the lack of high-quality clinical evidence and the trend of general journal submissions has somewhat affected the quality of endoscopy journals in recent years.

Keywords: bibliometric analysis, citation analysis, spine, spine surgery, VOSviewer, CiteSpace

INTRODUCTION

The ongoing coronavirus pandemic pneumonia (severe acute respiratory syndrome coronavirus-2, SARS-CoV-2) has spread rapidly worldwide all over the world for more than 2 years since its nomenclature by World Health Organization.¹ Due to its spread around the world, the low cost of postoperative care is a critical need and the clinical care models have gradually changed to accommodate the new healthcare environment. For this reason, so minimally invasive spine surgery as one of the solutions for clinical practice has been attracted by medical decision-makers due to its shorter perioperative period with less approach-related morbidity than traditional spine surgery.² In recent decades, the interest in microscopic and endoscopic surgery has been grown in growing in both developing and developed countries, especially rising fast in the area of full-endoscopic procedure. The ever-growing number of articles related to full-endoscopic technique published recently and present a challenge that is perplexing and time-consuming to recognize the high-impact papers.

The rapid development of modern information technologies significantly influences medical treatment and public health, and knowledge management in clinical medicine has provided new approaches and possibilities. The discipline of “Bibliometry” can be traced back to the beginning of the last century. It is a statistical method branch of information science that combines linguistics, information, and statistics.³ This bibliometric method can measure the information distribution models via quantitative and qualitative analysis of a particular research area from published journals. In general, the cited times were considered as a determined measurement of the impact of an au-

thor, article, or journal. After that, by conducting scientific mathematical methods for data integration and processing, the evolution of the selected research direction could be revealed and help to predict valuable future research directions.⁴ The present study aims to demonstrate the bibliometric analysis of the full-endoscopic spine decompression surgery publications and illustrate the research trends with visible scientific mapping. We also investigate the cost and resource allocation of each author’s country’s National Health System and discuss the impact of their likely willingness to submit to journals.

MATERIALS AND METHODS

1. Search Strategy

In our cross-sectional bibliometric analysis research, a thirty-year timespan of literature was searched on the Web of Science Core Collection database based on the modified evidence-based Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.⁵ Our team performed the search with the “Topic” search function to search the title, abstract, author keywords, and KeyWords Plus on the Web of Science (WOS). The search formula was referenced and designed based on the AOSpine Consensus Paper on Nomenclature for Working-Channel Endoscopic Spinal Procedures of Full-endoscopic Decompression⁶ as follows: (*endoscopy** or *arthroscopy**) and (“Discectomy” or “foraminotomy” or “discectomy” or “laminotomy” or “disc surgery” or “disc herniation” or “disk herniation” or “foraminoplasty” or “nucleotomy” or “facetectomy” or “flavectomy” or “decompression” or “transforaminal” or “interlaminar”) and (*spine* or *spinal* or *lumbar* or *cervical* or *thoracic*). In this research, all the data was publicly available and not necessary for protected

health information. Therefore, Institutional Review Board approval was not sought from our university. The study search strategy referenced the PRISMA guideline, and the reports followed the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) reporting guideline for cross-sectional studies.⁷

2. Eligibility Criteria

We included English-language articles published in all indexed journals from January 1992 to October 2022. Two reviewers (YT and FV) screened the records independently for eligibility. The screening process had 2 stages. First, we screened the titles and abstracts obtained in the database search results to find relevant studies based on the criteria. Articles not accordant with the following inclusion criteria were excluded: Our search criteria included full-endoscopic clinical prospective/retrospective, randomized/nonrandomized, cohort-controlled studies; case series; case reports; technique reports; full-endoscopic relative basic studies such as finite biomechanical analysis. Other endoscopic techniques, such as biportal-endoscopy, epiduroscopy, joint surgery, microendoscopy, neuroendoscopy, laryngoscopy, thoracoscopy, or non-original articles, such as reviews, proceeding papers, editorial materials, early access, letters, corrections, and conferences, were excluded from this study. The selected publications were thoroughly investigated, and relevant details were recorded. Second, we did cross-checking, testing, and processing of the raw data on the 3 bibliometric software to ensure the various raw formats (.txt; BibTeX Database) and these were fully recognized and analyzed. Any disagreements were resolved through discussion involving a senior author (JS) to make a final consensus.

3. Bibliometrics Analysis

In our study, 3 professional bibliometric software (Bibliometrix 4.0.0,⁸ Citaspace 6.1.R3,⁹ and VOSviewer 1.6.18¹⁰) were used for data processing. No software is superior to the others in every aspect. Therefore, the various most valuable elements of the 3 software were discussed and then used separately in our research for different analyses. Bibliometrix (University of the University of Naples Federico II, Naples, Italy) was an R-studio package from the bibliographic database for performance bibliometric analysis. VOSviewer 1.6.18 (Centre for Science and Technology Studies, Leiden University, Leiden, The Netherlands) is a free software tool for drawing graphical representations of bibliometric maps to construct and visualize the bibliometric networks which used to create a keyword co-occurrence net-

work, overlay, and density visualization map in this study. It is based on the bibliographic data unit of the author keywords or KeyWords Plus. The correlation relationship between different units was measured by total link strength (TLS). CiteSpace is a Java application for analyzing and visualizing the scientific literature's bibliometric character for analyzing an institution's contribution, decomposing a network into clusters, and creating dual-map thematic overlays on global maps of science.^{9,11} Figures used for knowledge visualization consist of nodes and links. Each node in the diagram represented one element, such as the institution or cocited reference. The size of each node indicated the occurrence frequency, the lines between the nodes suggested a co-occurrence or cocitation link, and the varying colors of the circles from the inner to the exterior of the node represented the progression of time. Furthermore, we believe that the economic strength of the country and the percentage of investment in the health system may one of the potential crucial factors influencing the implementation of full-endoscopy development and publication. Therefore, we surveyed the selected country's population, gross domestic product, current estimates of health expenditures, and distribution of medical personnel from the World Bank Open Data which compiles country-level statistical data using information from the statistical systems of member countries and free access.

4. Data Processing

In our research, the number of published articles was considered an index of the quantity of research productivity. The number of citations was considered a quality indicator. Compared to the previous bibliometric publications, we do not rank the results with numbers, only presenting the most influential items of authors, countries, and institutions on tables. Before putting together, the keyword trends and clusters in Bibliometrix, CiteSpace, or VOSviewer, we manually standardized the keywords by merging similar keywords that were similar and replacing keywords that had nothing to do with the research. This improved the validity and quality of the research. Moreover, an independent Java engineer (DX) built Java programs and used secondary filtering and other processing on the raw data to make it fit the expected design of the method. For example, regarding the author analysis, extracting and analyzing only the first author and corresponding author is not available through 3 bibliometric software or the WOS directly. Because of this, it is crucial to get the needed information from the raw document correctly.

The core journals of full-endoscopic decompression spine

surgery (FEDS) are evaluated using Bradford's law of scattering in descending order of the number of articles carried on the subject.¹² The first zone is the nucleus of journals devoted to the given subjects, publishing about a third of the journals in the entire collection. We gathered data from the citing journal and the cited journal to construct a visual dural map for assessing, comparing, and contrasting publishing portfolio features.¹³ Moreover, our team designed a topic dendrogram to depict the object's hierarchical relationship in FEDS research. It is generally obtained because of hierarchical clustering and is usually used to figure out the best way to allocate objects to clusters.

To find and describe the most-cited FEDS articles, as well as to compare the most-cited articles from the specialty journal and publisher (whether they are comprehensive or commercial publishers), the Scientific Information Web of Science's Science Citation Index Expanded was used. We compared the top 3 most published established comprehensive publishers' and open access (OA) or non-OA articles on the same metrics. The analysis was performed on the metrics with H-index, average per item (API), average citations per year (APY) and total number of ci-

tations (TC). In addition, we also divided the publishers into comprehensive and specific publishers according to the way they were established. For comprehensive publishers, such as Hindawi Publishing Group, MDPI, and Frontier Media Sa, these journals are peer-reviewed for multidisciplinary scientific publications. Conversely, specialized journals are often established by societies, specific or other medical special issues. The American Society of Interventional Pain Physicians, Thieme Medical Publishers, and the American Association of Neurological Surgeons are a few examples.

5. Statistical Analysis

The Stata 16.0 (Stata Corp., College Station, TX, USA) was used for all statistical analyses, and Microsoft Excel 2016 (Microsoft Corporation, Redmond, WA, USA) was used to analyze and present the data. For statistical analysis, 2-sample Wilcoxon rank-sum (Mann-Whitney) tests and Kruskal-Wallis H-tests were used to compare the TC and the average number of citations per year between OA and non-OA, the most published publisher and comprehensive with specific publishers. Shapiro-Wilk test and normal quantile plot for determining the normal-

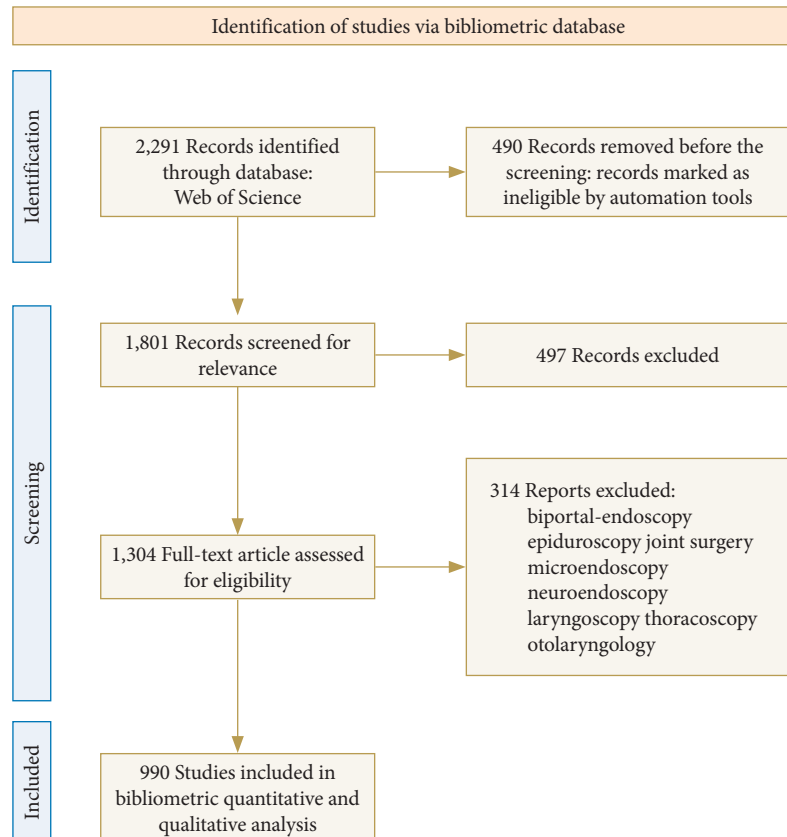


Fig. 1. Flowchart diagram illustrating the included articles included in the bibliometric analysis.

ity of data distribution. After applying Levene's test for variance, Mann-Whitney U was used. The Pearson correlation coefficient test (r) determined the statistical significance of correlations. Statistical significance was defined as a p -value of 0.05.

RESULTS

1. Descriptive Statistics of Bibliometric Analysis

The WOS database search returned a total of 2,291 records. After manually reviewing the titles and abstracts of records on the marked list, 314 articles that did not meet the inclusion criteria were excluded. In conclusion, 990 FEDS-related studies that met the search criteria were included in the present bibliometric analysis (Fig. 1). The number of authors is 2,306, with 9.39% international coauthorships from 43 countries contributing to the growth of the FEDS research field. The average number of authors per paper with multiple authors is 5.57. Each ar-

ticle comes from one of 147 journals or books. The number of citations per article is 14.84, and there are a total of 10,469 references. The number of articles published between 2016 and 2021 increased by 128.1 per year. The number of articles published recently years has increased by more than eightfold from 2010 to 2015. The annual growth rate was calculated using the compound annual growth rate, and the average annual growth rate of FEDS research's scientific output will be 17.22% until the beginning of 2022 (Table 1).

2. Bibliometric Analysis of Country and Institute Contribution

The world map of worldwide research productivity is illustrated in Fig. 2. The color's intensity and the red line's density indicate the number of articles published and the frequency of international collaborations, respectively. There are 10 major producing countries, with at least 10 papers published in each

Table 1. Basic information about the bibliometric dataset

Description	Results
Software and analyzes	
Bibliometrics: Biblioshiny & Web of Science: Citation report	Basic analysis: total number of publications, annual growth rate, 3 fields plot, etc. Impact of the author (first and corresponding author), countries, institutions, journal Annual scientific production Keywords (plus), citation analysis (reference spectroscopy) General versus specific publisher analysis
CiteSpace	Document cocitation institute and clusters visualization Dural map overlay of journals Time map of clusters
VOSviewer	Keyword co-occurrence network map
World Development Indicators	Country development data
Main information about data	
Timespan	1992:2022
Sources (journals, books, etc.)	147
Documents	990
Authors	2,306
Annual growth rate	17.22%
Country	43
Document average age	4.39
Coauthors per doc	5.57
Average citations per doc	14.84
International coauthorships %	9.39
References	10,469

The coauthors per articles index is calculated as the average number of coauthors per article; the collaboration index is a coauthors per article index calculated only using the multiauthored article set which calculated as total authors of multiauthored articles/total multiauthored articles.

of them. China, South Korea, and the United States were the most productive regions (Table 2). Among the 43 countries with publications, South Korea (t=4,970), China (t=3,896), Germa-

ny (t=2,295), and the United States (t=2,237) achieved the most-cited counts. Moreover, the relatively higher API and H-index in Germany, Korea, and the United States represent the

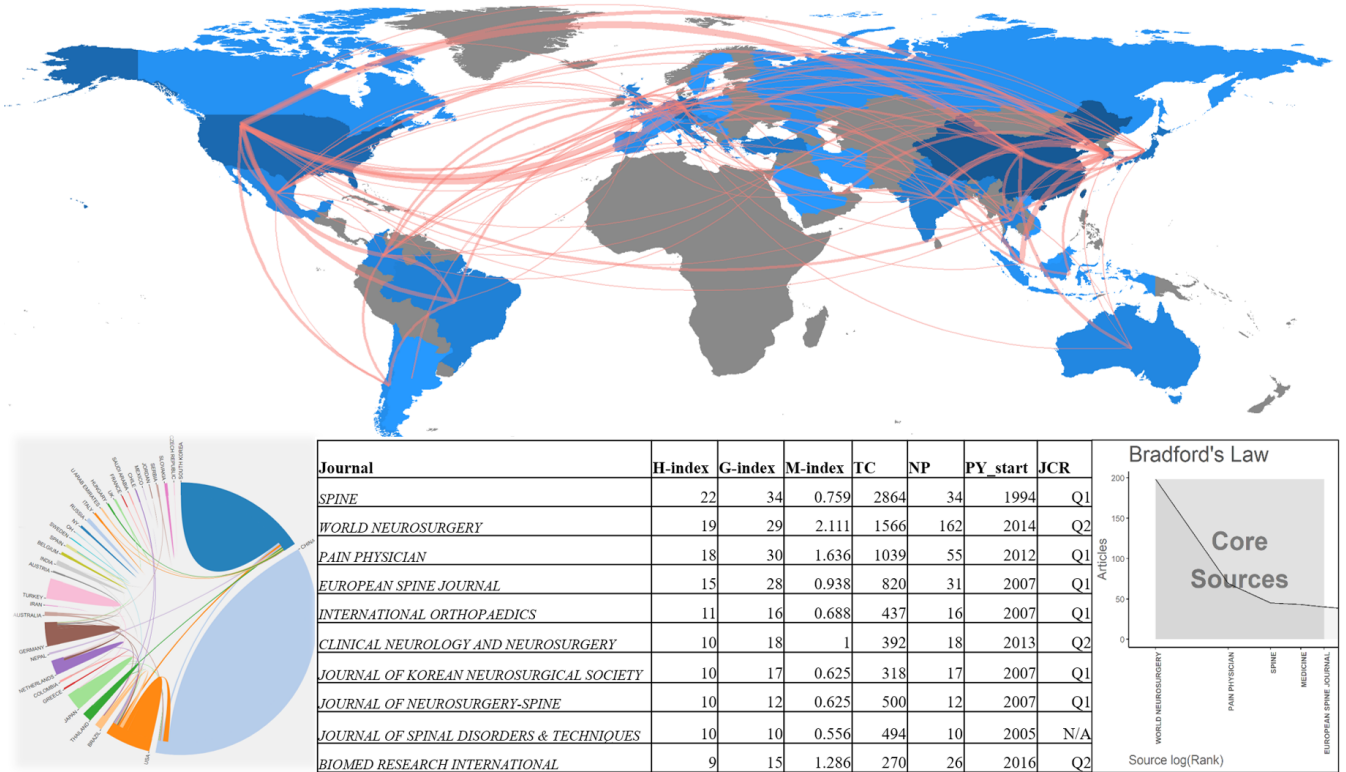


Fig. 2. World map showing the distributions of publications. The color intensity is proportional to the number of publications, and the red line is the relationship of country collaboration.

Table 2. Country’s impact of FEDS publications and country’s medical resources distribution

Item	No. (%)	API*	H-index	SCP	MCP	MCP_ratio	GDP/POP. (T\$/M, 2021)	Health expenditure (T/\$, % of GDP, 2019)	Physicians/nurses (per 1000 people) (2014-19)	Income level
China	516 (52.4)	7.0	26	516	22	0.04	17.7 (1,412.6)	0.96 (5.4)	2.0/2.7	Upper middle income
Korea	212 (21.4)	24.0	40	174	32	0.16	1.8 (51.7)	0.15 (8.2)	2.4/7.5	High income
United States	109 (11.0)	24.6	26	64	18	0.22	23.0 (331.9)	3.86 (16.8)	2.6/15.7	High income
Germany	51 (5.6)	47.6	20	33	4	0.11	4.2 (83.1)	0.49 (11.7)	4.3/13.5	High income
Japan	41 (4.1)	7.3	9	35	1	0.03	4.9 (125.7)	0.52 (10.7)	2.5/12.7	High income
Turkey	21 (2.1)	10.8	7	19	2	0.10	0.8 (85.0)	0.03 (4.3)	1.8/3.0	Upper middle income
Netherlands	17 (1.7)	15.9	9	5	4	0.44	1.0 (17.5)	0.10 (10.1)	3.7/11.5	High income
India	14 (1.4)	7.4	5	9	0	0	3.1 (1,393.4)	0.09 (3.0)	0.9/2.4	Lower middle income
Brazil	11 (1.1)	3.0	3	4	1	0.20	1.6 (214.0)	0.15 (9.6)	2.3/7.4	Upper middle income
Italy	10 (1.00)	5.8	5	8	0	0	2.1 (59.1)	0.18 (8.7)	8.0/5.9	High income

FEDS, full-endoscopic decompression spine surgery; API, average per item; SCP, single country publications; MCP, multiple country publications; GDP, gross domestic product; POP, population.

*Average for each item represents the overall results set’s average number of cited articles. It is calculated by dividing the total number of results in the set by the times cited count.

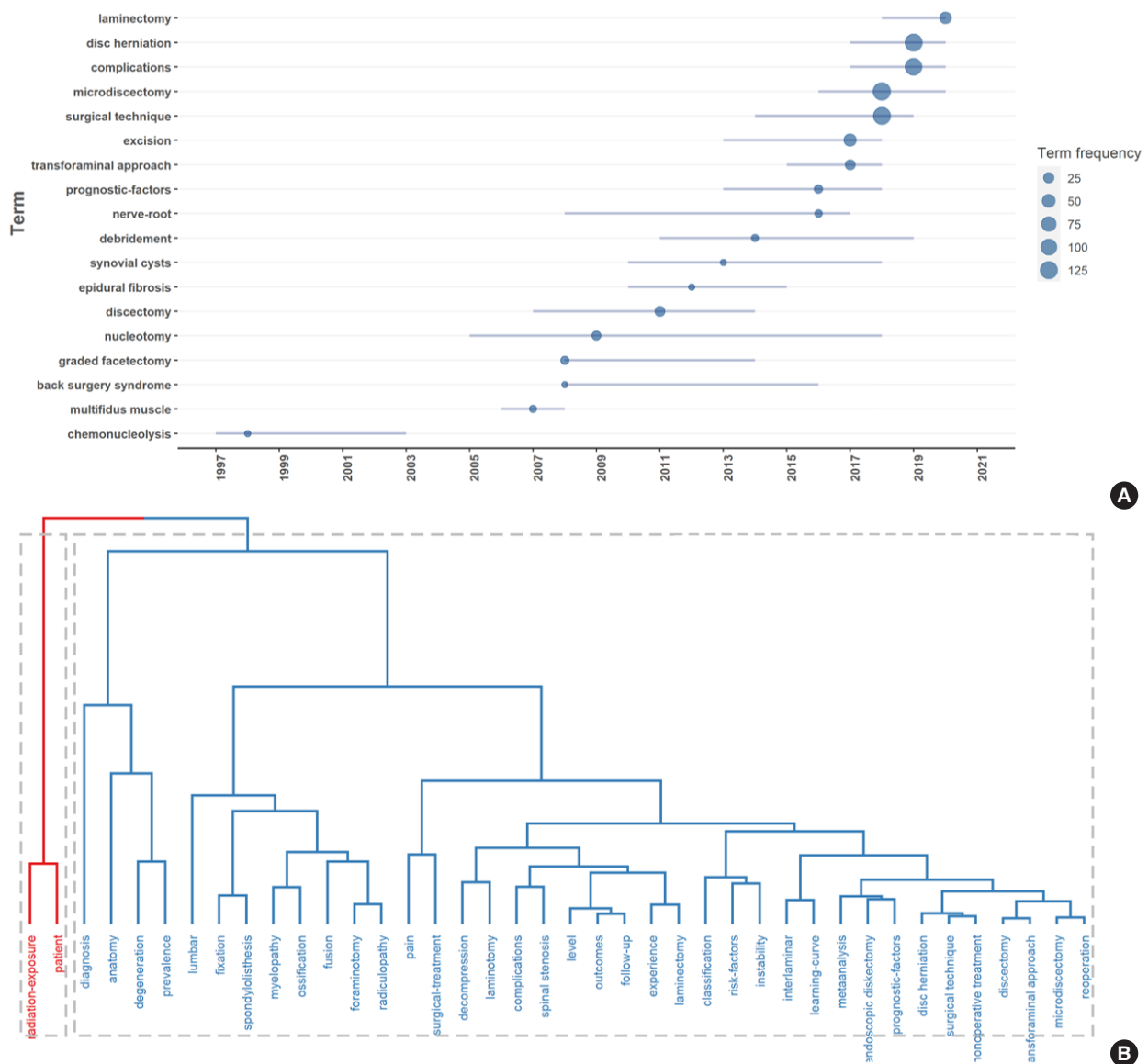


Fig. 6. (A) High-frequency terms and their burst time. The size of circle represents the strength of the burst. (B) The topic dendrogram is a diagram that depicts the full-endoscopic decompression spine surgery research hierarchical relationship.

Y has the greatest H-index and G-index of all the authors, and his FEDS paper in FEDS received the most citations with highest fractionalized score (Fig. 4). According to our data, Lee SH and Ahn Y were the authors with the longest period of continuous publication, from 2003 to 2022. Telfian AE and Kim HS authored a large number of articles with high citations in 2016 and 2018, respectively. Moreover, Yeung AT, Ruetten S, Hoogland T, Ahn Y, Choi G, and Mayer HM’s papers are the most impactful according to the global and local bibliometrics analysis (Supplementary Material 1). These articles are highly influential in spinal endoscopy and are also widely referenced in other subdisciplines or disciplines, indicating that other researchers

serve them as spine endoscopic flagship for their research. In addition, the 3 field plots highlight the most productive authors’ intellectual origins and research orientation.

5. Bibliometric Analysis of Keywords and Reference Assemblies

A total of 150 keywords were considered in the network analysis (Figs. 5, 6). The 3 frequently co-occurrence keywords are “discectomy” (TLS= 1,663; occurrences = 346), “disc herniation” (TLS= 1,456; occurrences = 281), and minimally invasive spine surgery (TLS= 978; occurrences = 198). In cluster analysis, we obtained 10 different clusters from the analysis. Cluster 1 (color

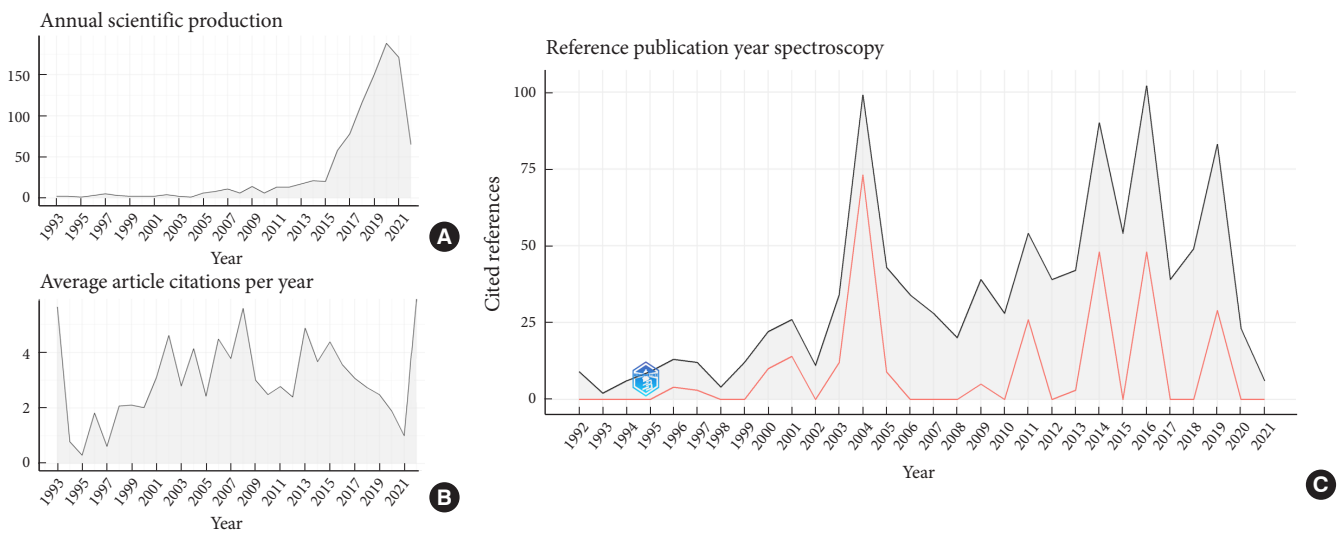


Fig. 7. (A) Annual scientific production. (B) Average article citation per year. (C) Reference publication year spectroscopy. Black line: number of cited references per year; red line: deviation from the 5-year median.

red) enrolled 28 units related to the general terminology of full-endoscopic approach, technique, and indication, such as transforaminal approach, laminotomy, and stenosis. Cluster 2 (color green) enrolled 22 units related to the full-endoscopic application terms at the cervical level, such as transcorporeal approach, foraminotomy, and instrumentation. Cluster 3 (color blue) enrolled 19 units related to the comparison to microscopic surgery, such as microdiscectomy, recurrence, and cohort trial. Cluster 4 (color yellow) enrolled 17 units related to the focus terms of early technology, such as arthroscopic microdiscectomy, chemonucleolysis, and multifidus muscle. The other clusters from 5 to 10 describe other aspects of endoscopic techniques that are classified separately, such as anesthetic modalities, adjunctive techniques, anatomy, etiology, or complications. From the overlay visualization, we obtained the recent 10 years of mainstream research areas of anesthetic methods, cost-effective analysis, and cervical or thoracic applications. The density visualization shows the greatest weight of research directions with transforaminal, interlaminar, complications, and spinal stenosis surrounding the lumbar discectomy. Moreover, based on the line chart of annual publications and average citations per year, the jump in 2015 was the turning point of production (Fig. 7). In addition, the most influential articles in the field of FEDS are shown in Table 3.

6. Bibliometric Analysis of Various Classifications by Type of Journal or Publisher

Non-OA, Lippincott, and specific publisher shows the high-

est H-index, API, TC, and APY. The proportion rate of OA was highest in the comprehensive journal (as higher as 87.6%). China is the most productive country that contributes to specific and comprehensive publishers. Conversely, South Korea, and the United States shows a higher proportion of publication in a specific publisher. Woorldul Spine Hospital is the highest contribution to the specific journal, whereas Tongji comprehensively shows the highest contribution to the comprehensive journal.

The publication number of these journals was differentiated according to the different OA or professional attributes (Fig. 8). The differences in TC and APY between the OA and non-OA are statistically significant between each other ($Z = -6.964$, $p < 0.05$; $Z = -5.760$, $p < 0.05$), as shown in Table 4. The number of TC and APY citations for OA and non-OA is also considered different. There is no statistical difference in APY times between the 3 most productive publishers ($\chi^2 = 5.654$, degrees of freedom [df] = 2, $p > 0.05$); however, it can be assumed that the APY counts of the 3 different journals are not all the same ($\chi^2 = 15.252$, $df = 2$, $p < 0.001$). Based on the statistical test results, the difference between Elsevier and Springer Nature is not statistically significant (rank means: 12.62, $p = 0.198$). However, the difference between the TC of Lippincott Williams & Wilkin's and Elsevier (rank means: 57.15, $p < 0.05$); and between Lippincott Williams & Wilkin's and Springer Nature (rank means: 69.77, $p < 0.05$); are statistically significant. The differences in TC and APY between the comprehensive and specific journals were statistically significant ($Z = 6.944$, $p < 0.001$); ($Z = 5.765$, $p < 0.001$). It can

Table 3. The most influence articles in the field of full-endoscopic decompression spine surgery

No.	Title	Authors	Source	Year	Citations	APY
1	Posterolateral endoscopic excision for lumbar disc herniation - Surgical technique, outcome, and complications in 307 consecutive cases	Yeung AT, Tsou PM	Spine	2002	430	20.48
2	Full-endoscopic interlaminar and transforaminal lumbar discectomy versus conventional microsurgical technique - A prospective, randomized, controlled study	Ruetten S, Komp M, Merk H, Godolias G	Spine	2008	418	27.87
3	Percutaneous endoscopic discectomy: surgical technique and preliminary results compared to microsurgical discectomy	Mayer HM, Brock M	JNS	1993	275	9.17
4	A prospective, randomized study comparing the results of open discectomy with those of video-assisted arthroscopic microdiscectomy	Hermantin FU, Peters T, Quartararo L, Kambin P	JBJS	1999	199	8.29
5	Transforaminal posterolateral endoscopic discectomy with or without the combination of a low-dose chymopapain: A prospective randomized study in 280 consecutive cases	Hoogland T, Schubert M, Miklitz B, Ramirez A	Spine	2006	198	11.65
6	Full-endoscopic cervical posterior foraminotomy for the operation of lateral disc herniations using 5.9-mm endoscopes - A prospective, randomized, controlled study	Ruetten S, Komp M, Merk H, Godolias G	Spine	2008	190	12.67
7	Use of newly developed instruments and endoscopes: full-endoscopic resection of lumbar disc herniations via the interlaminar and lateral transforaminal approach	Ruetten S, Komp M, Merk H, Godolias G	JNS	2007	185	11.56
8	Percutaneous endoscopic lumbar discectomy for recurrent disc herniation: Surgical technique, outcome, and prognostic factors of 43 consecutive cases	Ahn Y, Lee SH, Park WM, Lee HY, Shin SW, Kang HY	Spine	2004	184	9.68
9	Percutaneous endoscopic approach for highly migrated intracanal disc herniations by foraminoplastic technique using rigid working-channel endoscope	Choi G, Lee SH, Lokhande P, Kong BJ, Shim CS, Jung B, Kim JS	Spine	2008	149	9.93
10	An extreme lateral access for the surgery of lumbar disc herniations inside the spinal canal using the full-endoscopic uniportal transforaminal approach-technique and prospective results of 463 patients	Ruetten S, Komp M, Godolias G	Spine	2005	146	8.11

APY, average citations per year.

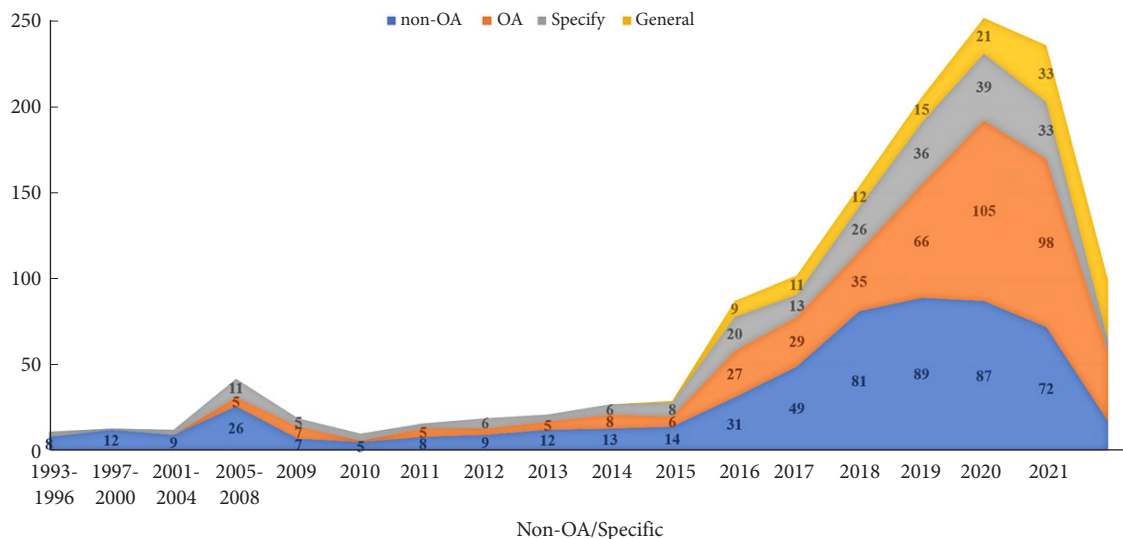


Fig. 8. Stacked area graph of different classification by journal type. OA, open access.

Table 4. Statistical analysis of various classification by type of journal or publisher

Variable	OA	Non-OA	P-value	Elsevier	Springer Nature	Lippincott	P-value	Specific (≥5)	General (≥5)	p-value	Specific (1993–2022)	General (2015–2022)
No.	441	549		249	158	101		228	137			
H-index	30	50		26	23	30		35	12			
API (time)	8.83	19.81		11.17	12.23	40.49		19.19	4.2			
OA (%)	N/A	N/A		5.6 (14/249)	58.2 (92/158)	45.4 (46/101)		43.0 (98/228)	87.6 (120/137)			
TC (P ₂₅ –P ₇₅ , time)	3 (0–9)	7 (2–20)	≤0.05	6 (2–12)	4 (1–14)	10 (3–39)	≤0.05	6 (1–22)	2 (0–5)	≤0.05		
APY (P ₂₅ –P ₇₅ , time/yr)	0.86 (0–1.86)	1.5 (0.5–2.86)	≤0.05	1.33 (0.5–2.5)	1.225 (0.5–2.38)	1.75 (0.67–4.07)	0.059	1.4 (0.5–3.0)	0.5 (0–1.3)	≤0.05		
Country (%)											China (37.28) South Korea (29.83) USA (16.27)	China (83.94) South Korea (11.68) USA (3.65)
Affiliation (%)											Wooridul Spine Hospital (7.90) Tokushima Univ. (5.26) Seoul St. Mary's Hospital (4.825)	Tongji Univ. (5.84) Capital Medical Univ. (5.11) Chongqing Medical Univ. (5.11)

OA, open access; API, average per item (times cited); APY, average citations per year. Publishers at least 5 publications are selected from general (comprehensive) journal or specific journals.

still be considered that the number of citations of TC and APY for specific publishers and comprehensive publishers is significantly different.

DISCUSSION

In this research, we have manually screened and double-checked all results to find any calculation biases inherent in the software used to perform the analyses. We discovered that when the software identifies the name of authors, it aggregates and analyzes the data of all the individual authors of that abbreviation from a bibliometric file, resulting in analytical inaccuracies. The software cannot determine the difference between authors' names with abbreviations. The WOS or bibliometric software automatically recognizes the abbreviation name, which causes a statistical error when doing the analysis. In our study, we filtered the data, and only the first and corresponding authors were included in our analysis. Meanwhile, we observed that an analysis based just on the number of coauthors would be biased concerning the contribution of authors to the actual research field. Therefore, we believe that the first and corresponding authors tend to contribute the most to clinical endoscopic studies. To the best of our knowledge, similar inaccuracies may have occurred in the published statistics of the past. As a result, the quality of analysis for identical bibliometric findings can vary when using different software. Thus, we selected the high-quality elements from each software for data analysis.

According to our knowledge, the preliminary form of the Full-endoscopic technique was earlier applied at 1993. Then, it has been developing rapidly and published high cited flagship articles which reported with high-safety surgical access and technical improvements. Recently, the areas of interest primarily explore technique indications or collect high-quality clinical evidence. Among of them, before 2015, the Germany, South Korean, the United States contributions as pioneers of FEDS research in spine surgery, followed by the entry of China led to a substantial increase in literature publication. Moreover, from our analysis results of references spectroscopy, the history of publication illustrates that the first 3 peaks from Mayer, Yeung, Rutten, Choi from the 1993 to 2007. They are the pioneer of the Full-endoscopic research which provide solid evidence for the crucial clinical considerations and practice of spinal endoscopic surgery; however, then there is no peak continues to appear after them. We found that even though the number of endoscopic studies published now is more significant than in the past, the citation rate of endoscopy-related papers continues to decline.

This, of course, cannot be separated from the precipitous decline in average citations in the literature in the last 2 years impacted by the severe acute respiratory syndrome coronavirus-2. But the more important question is that although various endoscopic novel assisted techniques described recently, such as O-arm navigation system, robots-assisted technique, the high cost blocks the step of other clinicians to replicate despite the popularity.

It is essential to identify demographic risk factors for degenerative spinal conditions to understand the risk, prevention, treatment, and outcome of spinal injuries and distinguish between acute injuries and degenerative disorders.¹⁴ In our study, the topic dendrogram revealed the hierarchical relationship between objects in FEDS research. It shows that the surgical treatment method of myelopathy is related to the nearby bony ossification or ligamentum flavum hypertrophy. Furthermore, disc herniation also indicates a solid connection to radiculopathy. As we understand, reherniation is the most common reason for surgical revision in patients after endoscopic surgery.¹⁵ Thus, it is crucial to consider preoperative risk factors for the patient's prognosis, such as the characteristics of the pain generator; herniation size and location; patient's comorbidity; or the access problems due to the patient's excessive obesity or adjacent anatomical tissue obscuring the access itself (e.g., patients with higher iliac wings than usual).¹⁶ Furthermore, we found that the FEDS research focuses on the impact of biomechanical instability, which is closely linked to the fusion study. In addition, microscopic surgery is strongly associated with endoscopic surgery, primarily since microscopy is frequently used as a revision surgical approach to endoscopic surgery. Likewise, endoscopic surgery through the transforaminal approach can also be used as a solution for revision surgery after microsurgery.¹⁷ Full-endoscopic technique avoids tissue scar adhesions caused by the same approach. At the same time, the magnified view of full-endoscopy improves the surgical view and the safety of nerve tissue stripping during revision surgery. Lastly, due to the steep learning curve in endoscopic surgery, early endoscopic clinicians are frequently advised to select the transforaminal approach as the primary case for adaptation to endoscopic techniques.¹⁸

We have discovered that many OA articles exist in the included studies. Therefore, the statistical analysis on the various classification of journal type and publisher was conducted and found that the non-OA articles usually have a higher impact than OA articles on the H-index, API, TC, and APY. We discovered that Elsevier published the most articles among the 3 most productive publishers, followed by Springer Nature and Lippincott, re-

spectively. However, Springer Nature is related to relatively lower quality of papers, as shown in the evaluated metrics. Although Lippincott has published the lowest number of articles, their papers have a relatively high quality. Furthermore, comparing the comprehensive and specific journals, the latter shows far exceeds the quality of prior journals. Among them, China has the highest number of publications in both types of journals but with a higher number of publications in the comprehensive journal. Comparatively, researchers in South Korea and the United States prefer more than specific journals for their publication. This may also contribute to more government spending on the healthcare sector, as usually seen in high-income nations, as well as the comparatively high number of specialists and nursing staff, which enables physicians to focus more on high-quality clinical research.

Here comes another interesting question. Initially, the original purpose of OA was to make it easier for academics to undertake more collaborative research publicly and to permit more researchers to study and cite more publications without being restricted by a paywall, hence accelerating the speed of overall clinical research. However, we found that the general assessment indicators of quality from the OA articles are lower than non-OA articles in the area of FEDS. The reasons could be the following. As is well known, comprehensive publishers frequently use the article processing charge publication model. Nonetheless, this pricey strategy can still not deter endoscopic researchers from submitting their findings. Although many of these comprehensive publishers are indexed in the WOS and have high-impact factors, a high-frequency rate of fast turnaround times and a high acceptance rate make the quality of its review doubtful. Our research results confirm this skepticism. Even though many papers are published among the high-impact factors journals, the quality of the publication from comprehensive journals is worrisome. Unsurprisingly, innumerable early-career academics choose these publishers over the more reputable ones to speed up their publication in the journal with the highest impact factor possible. These researchers could be poisoned and captivated by incentives from institutions or countries, as they could boost their citation rank among the professionals in a short time as opposed to the quality of their work. Therefore, using impact metrics alone to evaluate the quality of an article related to FEDS seems inappropriate.

We have some limitations in our research. Firstly, our bibliometric analysis was only the extracted data from the WOS core collection database, which may cause source bias. Secondly, since the dissemination of the article and the efficacy of the technique

require practice to demonstrate, we regret that we were unable to uncover very recent articles of high quality and potential through our research. These could also reflect the significant influences despite the short-term development of FEDS. However, technologically advanced research typically generates most discussions after 2 years; recent papers published in 2020 and prior have yet to create much-heated discussions. It is also possible that the lack of the appearance of papers related to clinical decision-making with available clinical options or a wide publication base to bury the data of high-quality papers. Finally, since our search strategy was designed and implemented in the middle of the year, it is impossible to generate a descriptive statistic for the articles published later that year. In this instance, we have modified some of the statistical analyses in our research, such as calculating the growth rate solely through the beginning of 2022.

CONCLUSION

The bibliometric study showed a growing trend of research on FEDS over the past 30 years. The number of authors, institutions, and internationally collaborated countries have been significantly increased, but high-quality studies are still lacking. However, a paradigm shift is emerging in a recent series of publications as the higher-quality studies including meta-analysis or attempts to develop standard guidelines have been increasingly published. This indicated that full-endoscopic spine surgery is gradually reaching its maturity.

NOTES

Supplementary Material: Supplementary Material 1 can be found via <https://doi.org/10.14245/ns.2245042.521>.

Conflict of Interest: The corresponding author, Jin-Sung Kim, is a consultant of Richard Wolf, GmbH, and Elliquence, LLC. The other authors have no conflicts of interest to declare.

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REFERENCES

- Adil MT, Rahman R, Whitelaw D, et al. SARS-CoV-2 and the pandemic of COVID-19. *Postgrad Med J* 2021;97:110-6.
- Khan NR, Clark AJ, Lee SL, et al. Surgical outcomes for minimally invasive vs open transforaminal lumbar interbody fusion: an updated systematic review and meta-analysis. *Neurosurgery* 2015;77:847-74; discussion 874.
- Okubo Y. OECD Science, Technology and Industry Working Papers 1997/01. Bibliometric indicators and analysis of research systems. Paris: OECD Publishing; 1997. Available from: <https://doi.org/10.1787/208277770603>.
- Ellegaard O, Wallin JA. The bibliometric analysis of scholarly production: how great is the impact? *Scientometrics* 2015; 105:1809-31.
- Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021;372:n71.
- Hofstetter CP, Ahn Y, Choi G, et al. AOSpine consensus paper on nomenclature for working-channel endoscopic spinal procedures. *Global Spine J* 2020;10:111S-121S.
- von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Lancet* 2007;370:1453-7.
- Aria M, Cuccurullo C. bibliometrix: an R-tool for comprehensive science mapping analysis. *J Informetr* 2017;11:959-75.
- Chen C. CiteSpace II: detecting and visualizing emerging trends and transient patterns in scientific literature. *J Assoc Inf Sci Technol* 2006;57:359-77.
- van Eck NJ, Waltman L. Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics* 2010;84:523-38.
- Chen C. Searching for intellectual turning points: progressive knowledge domain visualization. *Proc Natl Acad Sci U S A* 2004;101 Suppl 1(Suppl 1):5303-10.
- Brookes BC. Bradford's law and the bibliography of science. *Nature* 1969;224:953-6.
- Chen C, Leydesdorff L. Patterns of connections and movements in dual-map overlays: a new method of publication portfolio analysis. *J Assoc Inf Sci Technol* 2014;65:334-51.
- Parenteau CS, Lau EC, Campbell IC, et al. Prevalence of spine degeneration diagnosis by type, age, gender, and obesity using Medicare data. *Sci Rep* 2021;11:5389.
- Phan K, Xu J, Schultz K, et al. Full-endoscopic versus micro-endoscopic and open discectomy: a systematic review and meta-analysis of outcomes and complications. *Clin Neurol Neurosurg* 2017;154:1-12.
- Nie H, Zeng J, Song Y, et al. Percutaneous endoscopic lumbar discectomy for L5-S1 disc herniation via an interlaminar approach versus a transforaminal approach: a prospective randomized controlled study with 2-year follow up. *Spine*

- (Phila Pa 1976) 2016;41 Suppl 19:B30-7.
17. Ruetten S, Komp M, Merk H, et al. Full-endoscopic interlaminar and transforaminal lumbar discectomy versus conventional microsurgical technique: a prospective, randomized, controlled study. *Spine (Phila Pa 1976)* 2008;33:931-9.
18. Hsu HT, Chang SJ, Yang SS, et al. Learning curve of full-endoscopic lumbar discectomy. *Eur Spine J* 2013;22:727-33.