

The 100 Most-Cited Publications in Endoscopic Spine Surgery Research

Tingxiao Zhao, MD^{1,2,3,*}, Jianjian Shen, MD^{4,*}, Biao Zheng, MD^{5,*}, Yazeng Huang, MD^{1,2,3}, Mengran Jin, MD^{1,2}, Kazuaki Morizane⁶, Haiyu Shao, MD^{1,2}, Xinji Chen, MD^{1,2}, and Jun Zhang, MD^{1,2} 

Global Spine Journal
2021, Vol. 11(4) 587-596
© The Author(s) 2020
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/2192568220934740
journals.sagepub.com/home/gsj



Abstract

Study Design: A bibliometric review of the literature.

Objective: Our objective was to identify and analyze the 100 most-cited publications in the field of endoscopic spine surgery (ESS).

Methods: In order to determine the top cited 100 articles, a 3-step approach was employed. First, the 100 most-cited ESS studies were identified using the key phrase “endoscopic spine surgery.” Then, 8 keywords were identified from the 100 studies of step 1 were used to conduct a second round searching in all databases of the Web of Science. Finally, when the results of the first and second steps were overlapped, duplicated studies were removed. The 100 top-cited articles were used for further analysis.

Results: The citation number of the top 100 most-cited articles ranged from 44 to 236 with a mean value of 84.4. The most productive periods were from 2001 to 2010. The majority of publications came from *Spine* and *Neurosurgery*, where *Spine* holds the largest number of 35 articles, followed by *Neurosurgery* with 13 articles. Overall, 10 countries contributed to the 100 articles, with the most productive country being the United States, followed by Germany and Korea.

Conclusion: This bibliometric study is meant to produce a list of intellectual milestones in the field of ESS. This article’s identification of the most influential articles in the field of ESS gives us a unique and comprehensive insight into the development of ESS in the past several decades.

Keywords

endoscopic spine surgery, top cited, citation analysis, bibliometric study, Web of Science

Introduction

With the aging of the global population, the number of patients with degenerative spine disorders (DSDs) specific to the elderly is on rise.¹ These DSDs severely restrict spinal mobility, walking ability, and quality of life. For that reason, elderly patients with a variety of medical comorbidities pose a serious challenge to the choice of surgical methods of spinal surgeons. The conventional surgical technique for spinal pathology is open surgery. However, postoperative sequelae and long recovery time related to surgical trauma have always been the major problems in spinal surgery.^{2,3} Consequently, the need for minimally invasive spine surgery (MISS) is growing as the aging population is dramatically increasing and people pay more attention to quality-of-life issues.^{4,5} Moreover, endoscopic spine surgery (ESS) is a subset of MISS that has been evolving rapidly and continuously to help treat elderly patients to relieve pain.^{6,7}

The advantages of ESS are widely touted to include less injury to paraspinal ligaments and muscles, less extensive epidural scar, feasibility under local anesthesia, minimal neural manipulation, less intraoperative blood loss, a lower infection

¹ Zhejiang Provincial People’s Hospital, Hangzhou, Zhejiang, China

² Hangzhou Medical College People’s Hospital, Hangzhou, Zhejiang, China

³ Bengbu Medical College, Bengbu, Anhui, China

⁴ Cixi People’s Hospital, Ningbo, Zhejiang, China

⁵ Hangzhou Yuhang Orthopedics Hospital, Hangzhou, Zhejiang, China

⁶ Kyoto University, Kyoto, Japan

*These authors contribute equally to this study.

Corresponding Author:

Jun Zhang, Department of Orthopedics, Zhejiang Provincial People’s Hospital, Shangtang Road 158#, Hangzhou, Zhejiang, 310014, China.
Email: spinezhangjun@163.com



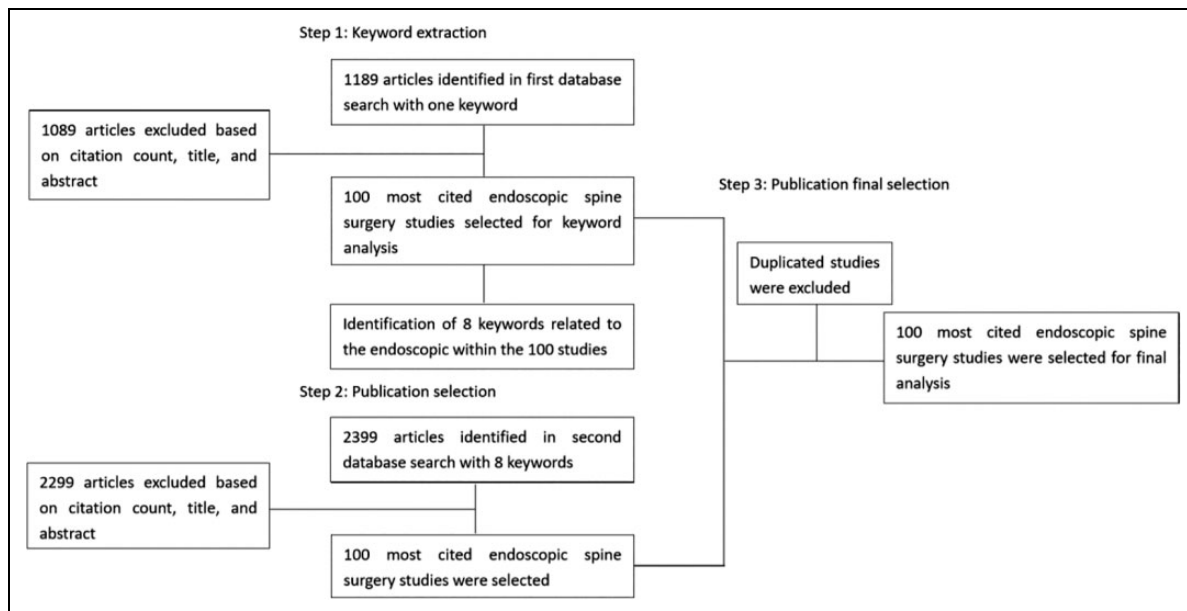


Figure 1. Three-step approach.

rate, and a shorter hospital stay.⁸⁻¹⁰ Given the technical evolution of ESS, including optics design, surgical apparatus, and specific surgical approach, its clinical application has become more practical and standardized.^{11,12} In the past several decades, the broad spectrum of pathologies that could be treated by minimally invasive ESS has garnered increased interest from spine surgeons, other spine care providers, and their patients. ESS, which initially limited to the treatment of intradiscal therapy and soft tissue lesions, has expanded to encompass a myriad of complex surgical procedures such as skull basilar invagination, lesions in the clivus and craniovertebral junction, resection of the odontoid process, primary and recurrent intervertebral disc diseases, spinal stenosis, spondylolisthesis, radiculopathy, spinal tumors, infections, synovial cysts, dural tears, failed back surgery syndrome, and tethered cord syndrome among other surgical techniques along with reported clinical outcomes.¹³⁻¹⁷ The more recent concepts of endoscopic spine care has been promoted by Dr Anthony Yeung, who is reviewing his over 11 000 endoscopic procedures by promoting a staged concept of surgical spine care to address the pain generators early for patients deemed too young, too old, or having too many comorbidities to be recommended for traditional spine surgery.¹⁸ At the rate of current development, it is reasonable to predict that ESS will be an option to treat an increasing number of spine pathology.

Since the beginning of the 20th century, numerous specialists and researchers are committed to providing new insights into ESS, and a large number of articles about ESS are published annually to show clinical application, cases report, the surgical technical note, safety and effectiveness.¹⁹⁻²⁵ Very recently, a bibliometric study on full-ESS demonstrated that the number of published articles increased by 41 times between 1997 and 2017.²⁶ However, the newest study focused only on full-ESS and could not fully reflect the field of ESS due to their

exclusion of thoracoscopic spine surgery, and laparoscopic spine surgery, and nasoendoscopic spine surgery.²⁶ And they included all the related articles regarding their quality and citation number.²⁶ Given this situation, the aim of this study was to determine a ranking of the 100 highest cited articles regarding to all kinds of endoscopies for spine surgery, in order to help researchers better determine the direction of their research. Meanwhile, these articles were further analyzed for better understanding of the qualities of classical studies and highlight the significant contribution of these studies to the field of ESS.

Materials and Methods

On March 15, 2019, we sought to identify the 100 most-cited ESS research articles published between 1950 and 2019, and excluding non-English language studies. All databases of the Web of Science (Web of Science core database, KIC-Korean Journal Database, Medline, Russian Science Citation Index, and SciELO Citation Index) were used to identify eligible studies. In order to achieve a higher comprehensiveness and accurateness of the study, a 3-step approach was adopted, as shown in the flowchart in Figure 1.

The first step, all databases of the Web of Science was searched for the key phrase “endoscopic spine surgery.” The search produced 1189 results, which were then ranked in descending order of the total number of citations. In the initial 500 studies, 100 most-cited papers on ESS were identified based on titles and abstracts. In order to provide a more comprehensive study of ESS, the title and abstract of the 100 most-cited studies were systematically analyzed for possible keywords. Combined with other keywords known to be relevant to the field of ESS research, a search query group composed of 8 phrases was established and used for a second database search by topic. Finally, the 8 key phrase identified were “endoscopic spine

surgery,” “endoscopic interlaminar discectomy,” “endoscopic transforaminal discectomy,” “laparoscopic spine surgery,” “microendoscopic spine surgery,” “thoracoscopic spine surgery,” “endoscopic endonasal spine surgery,” and “endoscopic disc surgery.”

The second step, every word is delimited by an OR term, by this means further adding search results. The second search showed 2399 results, again were ranked in descending order of the total number of total citations. In the first 500 preliminary studies, 100 articles related to ESS were selected based on titles and abstracts.

In the third step, the studies of the 2 selections were overlapped, and duplicate studies were removed. The 100 most-cited ESS studies were then selected for final analysis.

To accurately identify the top 100 studies on ESS, each result was examined manually by 2 of the listed authors independently to exclude out-of-scope research articles according to the title and abstract. The exclusion criteria were (1) articles on a broad discussion of interventional surgery; (2) articles discussing the technique of percutaneous injection; (3) articles describing only MIS; (4) articles discussing da Vinci or robot-assisted spinal surgery; (5) articles citing only a broad discussion on the history or progress of ESS; and (6) Articles DISCUSSING only microendoscopic surgery. The 100 articles with the most citations were then analyzed further, and the title, authorship, geographic origin, journal of publication, year of publication, impact factor, and citation numbers were recorded.

Results

We conducted a comprehensive search process that resulted in the finalization of 100 most-cited publications related to ESS. The 100 highest cited articles on ESS were cited from 44 (article numbers 95 to 100) to 263 (top article) times, for a total of 8444 citations, with an average of 84.44 citations per article. In these publications, “Posterolateral endoscopic excision for lumbar disc herniation, surgical technique, outcome, and complications in 307 consecutive cases,” by A. T. Yeung et al, was the most-cited article. In order to show the researchers more clearly, the 100 highest cited studies according to the total number of citations can be seen in Table 1.

All the 100 most-cited articles were published between 1992 and 2015. The most productive periods were 2001 to 2005 and 2006 to 2010, with a total of 65 articles (Table 2). The oldest of these publications, “Arthroscopic microdiscectomy.” in *Arthroscopy: The Journal of Arthroscopic & Related Surgery: Official Publication of the Arthroscopy Association of North America and the International Arthroscopy Association* by P. Kambin et al, was published in 1992. The most recent of these articles, “Unsuccessful percutaneous endoscopic lumbar discectomy: a single-center experience of 10 228 cases” was published by K. C. Choi et al.

In total, 28 different journals published the 100 most-cited publications, with the *Spine* contributing most studies (n = 35), followed by *Neurosurgery* (n = 13 articles), *Journal of*

Neurosurgery, *Journal of Neurosurgery-Spine*, and *European Spine Journal* (each published 6 articles of this list) (Table 3).

The 100 articles originated from a total of 10 countries (Figure 2). The country with the highest number of articles was the United States (n = 49), followed by Germany (n = 19) and then Korea (n = 15), Japan (n = 6), and China (n = 5).

Overall, authors with more than two publications of the 100 most-cited articles on ESS are listed in Table 4. Among them, Dr S. Ruetten contributed the most studies (n = 9), followed by J. J. Regan, R. G. Fessler, and G. Godolias (each of them published 7 articles). Three other authors, A. T. Yeung, P. C. McAfee, and S. H. Lee published 6 articles each.

All of the 100 most-cited articles involved 5 separate endoscope designs, including spinal endoscopy, thoracoscopy, laparoscopy, arthroscopy, and nasendoscopy. The endoscopic type with the largest number of articles on the top 100 list was spinal endoscopy (n = 75), followed by thoracoscopy (n = 10), and then laparoscopy (n = 9), nasendoscopy (n = 5), and arthroscopy (n = 1) (Figure 3).

Application of minimally invasive ESS techniques in the top 100 cited articles on ESS was listed in Figure 4. The range of the spinal disease could be covered by ESS is almost anywhere of the entire spine including cranio-vertebral spine, subaxial vertebral spine, thoracic spine, thoracolumbar spine, and lumbar spine. The site with the highest number of articles on the top 100 list was lumbar spine (n = 62), whereas the site with the lowest number was thoracolumbar (n = 2).

Discussion

With the development of minimally invasive surgical techniques, as well as the advantages of modern medical imaging and computer science, significant progression in the field of ESS have been made in recent several decades. Numerous specialists and scholars engaged in research of ESS and published a large number of articles. Recently, a bibliometric study included all the publications related to full-ESS and assessed the characteristics of worldwide research productivity.²⁶ However, there has never been a comprehensive analysis of the literature regarding to all kinds of endoscopies for spine surgery to identify the most influential studies in the field. The current study presents the top 100 most-cited research publications in the field of ESS by measuring the number of citations.

A number of top-cited studies in the field of spinal surgery have been reported. In 2012, Murray et al²⁷ reported for the first time that the citation number of the top 100 most-cited spine articles ranged from 240 to 1695. Till 2016, Huang et al²⁸ reported that the citation number of top 100 cited articles on low back pain ranged from 249 to 1638. In the same year, Rügsegger et al²⁹ found that the citation number of the 100 most influential publications in cervical spine research ranged from 173 to 879. Most recently, Badhiwala³⁰ et al reported that the citation number of the top 100 most-cited articles published in spine journals ranged from 343 to 1949. The only article published so far about the top 50 cited articles about MISS was published in 2017, with the citation number up to 321.67.³¹ To

Table I. The 100 Most-Cited Articles on Endoscopic Spine Surgery.

Rank	First author	Year	Title	Journal	No. of citations	No. of citations per year
1	A. T. Yeung	2002	Posterolateral endoscopic excision for lumbar disc herniation. Surgical technique, outcome, and complications in 307 consecutive cases	<i>Spine</i>	263	15.5
2	S. Ruetten	2008	Full-endoscopic interlaminar and transforaminal lumbar discectomy versus conventional microsurgical technique	<i>Spine</i>	227	20.6
3	P. C. McAfee	1995	The incidence of complications in endoscopic anterior thoracolumbar spinal reconstructive surgery a prospective multicenter study comprising the first 100 consecutive cases	<i>Spine</i>	219	9.1
4	H. M. Mayer	1993	Percutaneous endoscopic discectomy: surgical technique and preliminary results compared to microsurgical discectomy	<i>Journal of Neurosurgery</i>	216	
5	A. B. Kassam	2005	The expanded endonasal approach: a full endoscopic transnasal approach and resection of the odontoid process: technical case report	<i>Neurosurgery</i>	197	14.1
6	L. T. Khoo	2002	Microendoscopic decompressive laminotomy for the treatment of lumbar stenosis	<i>Neurosurgery</i>	175	10.3
7	R. E. Isaacs	2005	Minimally invasive microendoscopy-assisted transforaminal lumbar interbody fusion with instrumentation	<i>Journal of Neurosurgery-Spine</i>	158	11.3
8	S. D. Boden	1998	Laparoscopic anterior spinal arthrodesis with rhBMP-2 in a titanium interbody threaded cage	<i>Journal of Spinal Disorders & Techniques</i>	156	7.4
9	J. J. Regan	1999	Laparoscopic fusion of the lumbar spine: minimally invasive spine surgery. A prospective multicenter study evaluating open and laparoscopic lumbar fusion	<i>Spine</i>	150	7.5
10	B. H. Guiot	2002	A minimally invasive technique for decompression of the lumbar spine	<i>Spine</i>	140	8.2
11	D. Rosenthal	1994	Removal of a protruded thoracic disc using microsurgical endoscopy. A new technique	<i>Spine</i>	133	5.3
12	P. C. McAfee	1998	Minimally invasive anterior retroperitoneal approach to the lumbar spine. Emphasis on the lateral BAK	<i>Spine</i>	130	6.2
13	R. G. Fessler	2002	Minimally invasive cervical microendoscopic foraminotomy: an initial clinical experience	<i>Neurosurgery</i>	125	7.4
14	T. E. Adamson	2001	Microendoscopic posterior cervical laminoforaminotomy for unilateral radiculopathy: results of a new technique in 100 cases	<i>Journal of Neurosurgery-Spine</i>	121	6.7
15	T. J. Huang	2005	Less systemic cytokine response in patients following microendoscopic versus open lumbar discectomy	<i>Journal of Orthopaedic Research</i>	119	8.5
16	Y. Ahn	2004	Percutaneous endoscopic lumbar discectomy for recurrent disc herniation: surgical technique, outcome, and prognostic factors of 43 consecutive cases	<i>Spine</i>	115	7.7
17	J. F. Zucherman	1995	Instrumented laparoscopic spinal fusion. Preliminary results	<i>Spine</i>	113	4.7
18	J. J. Regan	1995	A technical report on video-assisted thoracoscopy in thoracic spinal surgery. Preliminary description	<i>Spine</i>	110	4.6
19	S. Ruetten	2007	Use of newly developed instruments and endoscopes: full-endoscopic resection of lumbar disc herniations via the interlaminar and lateral transforaminal approach	<i>Journal of Neurosurgery-Spine</i>	109	9.1
20	P. O. Newton	1997	Anterior release and fusion in pediatric spinal deformity. A comparison of early outcome and cost of thoracoscopic and open thoracotomy approaches	<i>Spine</i>	104	4.7
21	S. Ruetten	2008	Full-endoscopic cervical posterior foraminotomy for the operation of lateral disc herniations using 5.9-mm endoscopes: a prospective, randomized, controlled study	<i>Spine</i>	104	9.5
22	T. A. Zdeblick	2000	A prospective comparison of surgical approach for anterior L4-L5 fusion: laparoscopic versus mini anterior lumbar interbody fusion	<i>Spine</i>	104	5.5
23	L. T. Khoo	2002	Minimally invasive percutaneous posterior lumbar interbody fusion	<i>Neurosurgery</i>	102	6.0
24	B. W. Cunningham	1999	Osteogenic protein versus autologous interbody arthrodesis in the sheep thoracic spine. A comparative endoscopic study using the Bagby and Kuslich interbody fusion device	<i>Spine</i>	101	5.1
25	T. Hoogland	2006	Transforaminal posterolateral endoscopic discectomy with or without the combination of a low-dose chymopapain: a prospective randomized study in 280 consecutive cases	<i>Spine</i>	99	7.6
26	X. Wu	2006		<i>Spine</i>	97	7.5

(continued)

Table 1. (continued)

Rank	First author	Year	Title	Journal	No. of citations	No. of citations per year
27	M. G. Kaiser	2002	Microendoscopic discectomy for lumbar disc herniation: surgical technique and outcome in 873 consecutive cases	<i>Neurosurgery</i>	95	5.6
28	S. Ruetten	2005	Comparison of the mini-open versus laparoscopic approach for anterior lumbar Interbody fusion: a retrospective review	<i>Spine</i>	93	6.6
29	N. Anand	2002	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	<i>Spine</i>	88	5.2
30	S. Ruetten	2009	Video-assisted thoracoscopic surgery for thoracic disc disease: classification and outcome study of 100 consecutive cases with a 2-year minimum follow-up period	<i>Journal of Spinal Disorders & Techniques</i>	87	8.7
31	T. Hoogland	2008	Recurrent lumbar disc herniation after conventional discectomy: a prospective, randomized study comparing full-endoscopic Interlaminar and transforaminal versus microsurgical revision	<i>Spine</i>	86	7.8
32	D. L. Bergey	2004	Endoscopic transforaminal discectomy for recurrent lumbar disc herniation: a prospective, cohort evaluation of 262 consecutive cases	<i>Spine</i>	86	5.7
33	C. A. Dickman	1996	Thoracic vertebrectomy and reconstruction using a microsurgical thoracoscopic approach	<i>Neurosurgery</i>	86	3.7
34	T. Moro	2003	An anatomic study of the lumbar plexus with respect to retroperitoneal endoscopic surgery	<i>Spine</i>	85	5.3
35	J. P. Wolinsky	2007	Endoscopic image-guided odontoidectomy for decompression of basilar invagination via a standard anterior cervical approach. Technical note	<i>Journal of Neurosurgery-European Spine Journal</i>	85	7.1
36	S. Lee	2007	Percutaneous endoscopic lumbar discectomy for migrated disc herniation: classification of disc migration and surgical approaches	<i>European Spine Journal</i>	84	7.0
37	K. Ikuta	2005	Short-term results of microendoscopic posterior decompression for lumbar spinal stenosis. Technical note	<i>Journal of Neurosurgery-European Spine Journal</i>	84	6.0
38	J. Nellensteijn	2010	Transforaminal percutaneous endoscopic discectomy in the treatment of far-lateral and foraminal lumbar disc herniations	<i>European Spine Journal</i>	83	9.2
39	S. M. Lew	2001	Transforaminal endoscopic surgery for symptomatic lumbar disc herniations: a systematic review of the literature	<i>Journal of Neurosurgery</i>	83	4.6
40	S. H. Lee	2006	Operative failure of percutaneous endoscopic lumbar discectomy: a radiologic analysis of 55 cases	<i>Spine</i>	83	6.4
41	P. O. Newton	2000	Defining the pediatric spinal thoracoscopy learning curve: sixty-five consecutive cases	<i>Spine</i>	83	4.4
42	G. Choi	2008	Percutaneous endoscopic approach for highly migrated intracanal disc herniations by foraminal plastic technique using rigid working channel endoscope	<i>Spine</i>	82	7.5
43	A. T. Yeung	2000	The evolution of percutaneous spinal endoscopy and discectomy	<i>Mount Sinai Journal of Medicine</i>	82	4.3
44	H. H. Mathews	1995	Laparoscopic discectomy with anterior lumbar interbody fusion. A preliminary review	<i>Spine</i>	82	3.4
45	M. Teli	2010	Higher risk of dural tears and recurrent herniation with lumbar micro-endoscopic discectomy	<i>European Spine Journal</i>	81	9.0
46	J. R. de Almeida	2009	Defining the nasopalatine line: the limit for endonasal surgery of the spine	<i>Laryngoscope</i>	81	8.1
47	L. M. Cavallo	2007	The extended endoscopic endonasal approach to the clivus and cranio-vertebral junction: anatomical study	<i>Childs Nervous System</i>	78	6.5
48	J. V. Nayak	2007	Experience with the expanded endonasal approach for resection of the odontoid process in rheumatoid disease	<i>American Journal of Rhinology</i>	77	6.4
49	S. Ruetten	2006	A new full-endoscopic technique for the interlaminar operation of lumbar disc herniations using 6-mm endoscopes: prospective 2-year results of 331 patients	<i>Minimally Invasive Neurosurgery</i>	76	5.8
50	D. Rosenthal	1998	Thoracoscopic microsurgical excision of herniated thoracic discs	<i>Journal of Neurosurgery</i>	76	3.6
51	D. Rosenthal	1996	Anterior decompression and stabilization using a microsurgical endoscopic technique for metastatic tumors of the thoracic spine	<i>Journal of Neurosurgery</i>	76	3.3

(continued)

Table 1. (continued)

Rank	First author	Year	Title	Journal	No. of citations	No. of citations per year
52	A. M. Nowitzke	2005	Assessment of the learning curve of lumbar microendoscopic discectomy	<i>Neurosurgery</i>	75	5.4
53	S. Ruetten	2009	Surgical treatment for lumbar lateral recess stenosis with the full-endoscopic interlaminar approach versus conventional microsurgical technique: a prospective, randomized, controlled study	<i>Journal of Neurosurgery-Spine</i>	74	7.4
54	Gun Choi	2006	Percutaneous endoscopic interlaminar discectomy for intracanalicular disc herniations at L5-S1 using a rigid working channel endoscope	<i>Neurosurgery</i>	69	5.3
55	Y. Ahn	2003	Posterolateral percutaneous endoscopic lumbar foraminotomy for L5-S1 foraminal or lateral exit zone stenosis. Technical note	<i>Journal of Neurosurgery</i>	68	4.3
56	L. T. Khoo	2002	Thoracoscopic-assisted treatment of thoracic and lumbar fractures: a series of 371 consecutive cases	<i>Neurosurgery</i>	66	3.9
57	P. Kambin	1992	Arthroscopic microdiscectomy	<i>Spine Journal</i>	64	2.4
58	D. Y. Lee	2009	Comparison of percutaneous endoscopic lumbar discectomy and open lumbar microdiscectomy for recurrent disc herniation	<i>Journal of Korean Neurosurgical Society</i>	63	6.3
59	M. Schubert	2005	Endoscopic transforaminal nucleotomy with foraminoplasty for lumbar disk herniation	<i>Operative Orthopädie und Traumatologie</i>	63	4.5
60	P. M. Tsou	2002	Transforaminal endoscopic decompression for radiculopathy secondary to intracanal noncontained lumbar disc herniations: outcome and technique	<i>Spine Journal</i>	63	3.7
61	D. A. Shin	2008	The efficacy of microendoscopic discectomy in reducing iatrogenic muscle injury	<i>Journal of Neurosurgery-Spine</i>	61	5.5
62	C. J. Baird	2009	Radiographic and anatomic basis of endoscopic anterior craniocervical decompression: a comparison of endonasal, transoral, and transcervical approaches	<i>Neurosurgery</i>	61	6.1
63	U. Schick	2002	Microendoscopic lumbar discectomy versus open surgery: an intraoperative EMG study	<i>European Spine Journal</i>	60	3.5
64	S. W. Roh	2000	Endoscopic foraminotomy using MED system in cadaveric specimens	<i>Spine</i>	60	3.2
65	P. O. Newton	2003	Use of video-assisted thoracoscopic surgery to reduce perioperative morbidity in scoliosis surgery	<i>Spine</i>	59	3.7
66	Y. Ahn	2013	Radiation exposure to the surgeon during percutaneous endoscopic lumbar discectomy: a prospective study	<i>Spine</i>	58	9.7
67	B. Wang	2011	An evaluation of the learning curve for a complex surgical technique: the full endoscopic interlaminar approach for lumbar disc herniations	<i>Spine Journal</i>	58	7.3
68	S. Ruetten	2009	Full-endoscopic anterior decompression versus conventional anterior decompression and fusion in cervical disc herniations	<i>International Orthopaedics</i>	58	5.8
69	K. T. Foley	1999	Microendoscopic approach to far-lateral lumbar disc herniation	<i>Neurosurgical Focus</i>	58	2.9
70	J. J. Regan	1996	Laparoscopic fusion of the lumbar spine in a multicenter series of the first 34 consecutive patients	<i>Surgical Laparoscopy & Endoscopy</i>	57	2.5
71	G. Choi	2007	Percutaneous endoscopic discectomy for extraforaminal lumbar disc herniations: extraforaminal targeted fragmentectomy technique using working channel endoscope	<i>Spine</i>	56	4.7
72	E. J. Wall	2005	Endoscopic mechanical spinal hemiepiphysiodesis modifies spine growth	<i>Spine</i>	56	4.0
73	J. J. Regan	1999	Laparoscopic approach to L4-L5 for interbody fusion using BAK cages: experience in the first 58 cases	<i>Spine</i>	56	2.8
74	R. Sasaoka	2006	Objective assessment of reduced invasiveness in MED	<i>European Spine Journal</i>	56	4.3
75	H. Nakagawa	2003	Microendoscopic discectomy (MED) for lumbar disc prolapse	<i>Journal of Clinical Neuroscience</i>	55	3.4
76	D. Y. Lee	2008	Learning curve for percutaneous endoscopic lumbar discectomy	<i>Neurologia Medico-Chirurgica</i>	55	5.0
77	J. S. Jang	2006	Transforaminal percutaneous endoscopic discectomy in the treatment of foraminal and extraforaminal lumbar disc herniations	<i>Journal of Spinal Disorders & Techniques</i>	54	4.2

(continued)

Table 1. (continued)

Rank	First author	Year	Title	Journal	No. of citations	No. of citations per year
78	H. H. Mathews	1996	Transforaminal endoscopic microdiscectomy	<i>Neurosurgery Clinics of North America</i>	54	2.3
79	S. H. Lee	2006	Comparative radiologic evaluation of percutaneous endoscopic lumbar discectomy and open microdiscectomy: a matched cohort analysis	<i>Mount Sinai Journal of Medicine</i>	53	4.1
80	F. Asgarzadie	2007	Minimally invasive operative management for lumbar spinal stenosis: overview of early and long-term outcomes	<i>Orthopedic Clinics of North America</i>	52	4.3
81	D. A. Ditsworth	1998	Endoscopic transforaminal lumbar discectomy and reconfiguration: a postero-lateral approach into the spinal canal	<i>Surgical Neurology</i>	52	2.5
82	S. Ruetten	2007	A new full-endoscopic technique for cervical posterior foraminotomy in the treatment of lateral disc herniations using 6.9-mm endoscopes: prospective 2-year results of 87 patients	<i>Minimally Invasive Neurosurgery</i>	50	4.2
83	J. Destandau	1999	A special device for endoscopic surgery of lumbar disc herniation	<i>Neurological Research</i>	50	2.5
84	H.T. Hsu	2013	Learning curve of full-endoscopic lumbar discectomy	<i>European Spine Journal</i>	49	8.2
85	B. W. Cunningham	1998	Video-assisted thoracoscopic surgery versus open thoracotomy for anterior thoracic spinal fusion. A comparative radiographic, biomechanical, and histologic analysis in a sheep model	<i>Spine</i>	49	2.3
86	J. J. Regan	1997	Endoscopic techniques in spinal surgery	<i>Clinical Orthopaedics and Related Research</i>	48	2.2
87	P. C. McAfee	1995	Anterior thoracic corpectomy for spinal cord decompression performed endoscopically	<i>Surgical Laparoscopy & Endoscopy</i>	48	2.0
88	K. Muramatsu	2001	Postoperative magnetic resonance imaging of lumbar disc herniation: comparison of microendoscopic discectomy and Love's method	<i>Spine</i>	47	2.6
89	Y. Ahn	2012	Transforaminal percutaneous endoscopic lumbar discectomy: technical tips to prevent complications	<i>Expert Review of Medical Devices</i>	47	6.7
90	E. Escobar	2003	Video-assisted versus open anterior lumbar spine fusion surgery: a comparison of four techniques and complications in 135 patients	<i>Spine</i>	47	2.9
91	M. Ito	2007	Clinical outcome of posterolateral endoscopic surgery for pyogenic spondylodiscitis: results of 15 patients with serious comorbid conditions	<i>Spine</i>	46	3.8
92	P. M. Tsou	2004	Posterolateral transforaminal selective endoscopic discectomy and thermal annuloplasty for chronic lumbar discogenic pain: a minimal access visualized intradiscal surgical procedure	<i>Spine Journal</i>	46	3.1
93	K. Parikh	2008	Operative results and learning curve: microscope-assisted tubular microsurgery for 1- and 2-level discectomies and laminectomies	<i>Neurosurgical Focus</i>	45	4.1
94	A. T. Yeung	2003	Advances in endoscopic disc and spine surgery: foraminal approach	<i>Surgical Technology International</i>	45	2.8
95	T. G. Burke	2000	Microendoscopic posterior cervical foraminotomy: a cadaveric model and clinical application for cervical radiculopathy	<i>Journal of Neurosurgery</i>	44	2.3
96	K. C. Choi	2015	Unsuccessful percutaneous endoscopic lumbar discectomy: a single-center experience of 10228 cases	<i>Neurosurgery</i>	44	11.0
97	V. A. Morera	2010	Far-medial expanded endonasal approach to the inferior third of the clivus: the transcondylar and transjugular tubercle approaches	<i>Neurosurgery</i>	44	4.9
98	H. Wang	2004	Learning curve for percutaneous endoscopic lumbar discectomy depending on the surgeon's training level of minimally invasive spine surgery	<i>Clinical Neurology and Neurosurgery</i>	44	2.9
99	G. D. Picetti III	2013	Thoracoscopic techniques for the treatment of scoliosis: early results in procedure development	<i>Neurosurgery</i>	44	7.3
100	K. M. Eichholz	2002	Thoracic microendoscopic discectomy	<i>Journal of Neurosurgery-Spine</i>	44	2.6

Table 2. Top 100 Most-Cited Articles on Endoscopic Spine Surgery According to Years of Publication.

Years of publication	No. of articles	No. of total citations	Mean no. of citations
1991-1995	8	985	123.1
1996-2000	21	1676	77
2001-2005	32	2967	92.7
2006-2010	33	2516	76.2
2011-2015	6	300	50

Table 3. Journals With More Than One Article in the 100 Most-Cited Articles on Endoscopic Spine Surgery.

Journal title	No. of articles	No. of total citations	Mean no. of citations	Impact factor
<i>Spine</i>	35	3511	100.31	2.792
<i>Neurosurgery</i>	13	1183	91.00	4.475
<i>Journal of Neurosurgery</i>	6	563	93.83	4.318
<i>Journal of Neurosurgery-Spine</i>	6	736	122.67	2.761
<i>European Spine Journal</i>	6	413	68.83	2.634
<i>Spine Journal</i>	4	231	57.75	3.119
<i>Journal of Spinal Disorders & Techniques</i>	3	297	99	2.31
<i>Neurosurgical Focus Minimally Invasive Neurosurgery</i>	2	103	51.5	2.647
<i>Surgical Laparoscopy & Endoscopy</i>	2	126	63	NA
<i>Mount Sinai Journal of Medicine</i>	2	105	52.5	0.986
	2	135	67.5	NA

Abbreviation: NA, not available.

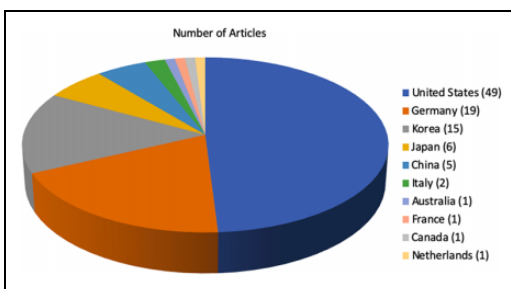


Figure 2. The top 100 cited articles on endoscopic spine surgery based on country.

the best of our knowledge, this present study is the first to identify the 100 most-cited studied focused on all kinds of ESS. However, the current 100 highest cited articles on ESS were cited 44 to 263 times. In comparison, the citation number of articles on ESS was relatively smaller than most of the previous bibliometric studies. This could be attributed to the relatively late application of endoscope in the field of spine surgery. In 1988, Dr P. Kambin et al³² first proposed the concept of

Table 4. Authors With More Than 2 Articles in the 100 Most-Cited Articles on Endoscopic Spine Surgery.

Author	No. of articles	No. of total citations	Mean no. of citations
S. Ruetten	9	878	97.56
J. J. Regan	7	595	85
R. G. Fessler	7	804	114.86
G. Godolias	7	752	107.43
A. T. Yeung	6	580	96.67
P. C. McAfee	6	697	116.17
S. H. Lee	6	352	58.67
L. T. Khoo	5	520	104
Y. Ahn	5	335	67
A. B. Kassam	4	383	95.75
D. Rosenthal	3	285	95
T. Hoogland	3	248	82.67
G. Choi	3	207	69
P. O. Newton	3	246	82

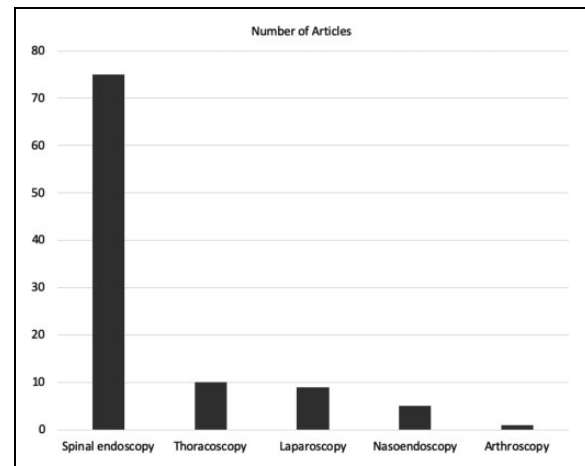


Figure 3. Types of endoscopes used in the top 100 cited articles.

endoscopic lumbar discectomy. Since then, a growing number of researchers and surgeons have focused on ESS. Over the past 2 decades, although ESS has garnered increased attention from spine surgeons and their patients, due to the limited indications of ESS, the acceptance of ESS by some spine surgeons was still relatively limited. Moreover, inexperienced young spine surgeon without formal training are unable to perform ESS well due to the relatively steep and long learning curve compared with classical open surgery. Finally, as a relatively new field, less people participate in the basic research of this surgical technique. As a result, a total of 408 articles only were identified between 1997 and 2018.²⁶

There is no doubt that the publishing date can affect citation numbers, the longer the time period after the article publication, the greater chance the article could be cited. Our study showed that the most productive periods were 2001 to 2005 and 2006 to 2010, with a total of 65 articles. However, there were only 6 articles (with 300 citations in total) published from 2011

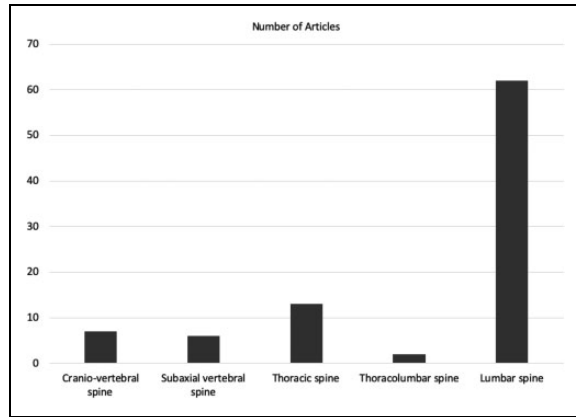


Figure 4. Application of the top 100 cited articles on endoscopic spine surgery.

to 2015, because the recently released articles still need time to be cited widely.

In total, 28 different journals published the top 100 most-cited studies, with the *Spine* contributing most studies, followed by *Neurosurgery*, which is inconsistent with previous report.²⁶ The reason why *Spine* was the most productive journal and highest cited journal may be related to the fact that *Spine* is a top journal sought after in spine surgery publications, and its articles have a high influence. A recent study showed that the top 3 journals with the highest number of articles were *World Neurosurgery*, *Pain Physician*, and *Spine*. The underlined reason for the difference could be their focus only on full-ESS.

Overall, 10 countries contributed to the 100 articles, and the most productive country was the United States, which was consistent to other bibliometric studies in the field of spine surgery.^{33,34} The reasons for this could be closely related to the country's investment in scientific research and the efforts of researchers. In contrast, Asian countries make a relatively small contribution to the 100 most-cited articles, which indicated that there is still a large gap of scientific studies between Asian countries and Western developed countries. This could partially be attributed to non-English language studies were excluded by our study. However, a recent study showed that if all articles published for full-ESS are considered, the largest number of articles was from China, followed by South Korea and the United States. It could be due to the relative lower quantity and late start of Asian countries.²⁶

In counting the authors who contributed to the 100 top-cited articles on ESS, we counted both first and last authors. Since the first author usually contributed most and the last author usually was the senior author, counting both authors will be better for elucidation the contribution of the researchers in this field. The authors listed in Table 4 have made a significant contribution to the development of the ESS; however, it does not mean that the contributions of the authors who are not on the list is any less. Although P. Kambin has only 1 article on the list of the 100 top cited articles, he was the pioneer who proposed the concept of endoscopic lumbar discectomy in 1988 for the first time.³² The worldwide used triangular safe zone

contoured by the anterior exiting root, the medial traversing root and the upper endplate of the lower lumbar spine was described and named after Dr P. Kambin too.

There are several limitations to our study. The date for literature search was March 15, 2019, which could theoretically affect the citation numbers by the time. However, the trends are unlikely to change dramatically. Moreover, although the method of bibliometrics is widely used in various research fields, the number of citations does not fully reflect the influence of the articles. It may be affected by many factors, such as the time of publication, the influence of journal, and the field of study. Furthermore, not only will the article be cited when praising an article, but it will still be cited when criticizing the article, and yet increase the citation rate of the article. Finally, since the 100 top-cited articles selected in this study are limited to English, we might have missed out some high-impact articles in other languages.

In summary, despite its limitations, bibliometric analysis is still one of the best tools to quantify the impact of scientific publications in some specific field, and it is also a common tool to quantify the contributions of researchers and their origins. We believe that the current research represents a valuable summary on the topic of ESS, which establishes another scientific milestone in the field of spinal surgery. Our study identified historical milestones and research hotspots of ESS, with its aim to highlight the contribution of responsible researchers and countries. Moreover, this bibliometric analysis also provides interesting research directions for researchers dedicated to the study of ESS in the future.

Conclusions

This bibliometric study is meant to propose a list of intellectual milestones in the field of ESS. The 100 most-cited publications in ESS were searched and analyzed, and the contribution of the authors and their origins were identified. Concepts will also continue to evolve, as new endoscopes, instrumentation, philosophies of surgical spine care, researchers, and surgeons may use the work of our predecessors to guide future ESS-related research.


Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This study was supported by grants from Zhejiang Provincial Health Bureau Science Foundation of China (2018KY017).

ORCID iD

Jun Zhang, MD  <https://orcid.org/0000-0001-5193-9155>

References

1. Fehlings MG, Tetreault L, Nater A. The aging of the global population: the changing epidemiology of disease and spinal disorders. *Neurosurgery*. 2015;77(suppl 4):S1-S5.
2. Ruetten S, Komp M, Godolias G. 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. *Spine (Phila Pa 1976)*. 2005;30:2570-2578.
3. Ahn Y. Transforaminal percutaneous endoscopic lumbar discectomy: technical tips to prevent complications. *Expert Rev Med Devices*. 2012;9:361-366.
4. Krugluger J, Knahr K. Minimally invasive disc surgery: a review. *Int Orthop*. 2001;24:303-306.
5. Chang X, Chen B, Li HY, Han XB, Zhou Y, Li CQ. The safety and efficacy of minimally invasive discectomy: a meta-analysis of prospective randomized controlled trials. *Int Orthop*. 2014;38:1225-1234.
6. Ahn Y. Percutaneous endoscopic decompression for lumbar spinal stenosis. *Expert Rev Med Devices*. 2014;11:605-616.
7. Kim JH, Kim HS, Kapoor A, et al. Feasibility of full endoscopic spine surgery in patients over the age of 70 years with degenerative lumbar spine disease. *Neurospine*. 2018;15:131-137.
8. Middleton SD, Wagner R, Gibson JNA. Multi-level spine endoscopy: a review of available evidence and case report. *EFORT Open Rev*. 2017;2:317-323.
9. Wang H, Huang B, Li C, et al. Learning curve for percutaneous endoscopic lumbar discectomy depending on the surgeon's training level of minimally invasive spine surgery. *Clin Neurol Neurosurg*. 2013;115:1987-1991.
10. Heo DH, Choi WS, Park CK, Kim JS. Minimally invasive oblique lumbar interbody fusion with spinal endoscope assistance: a technical note. *World Neurosurg*. 2016;96:530-536.
11. Kambin P, O'Brien E, Zhou L, Schaffer JL. Arthroscopic microdiscectomy and selective fragmentectomy. *Clin Orthop Relat Res*. 1998;347:150-167.
12. Yeung AT, Tsou PM. Posterolateral endoscopic excision for lumbar disc herniation: surgical technique, outcome, and complications in 307 consecutive cases. *Spine (Phila Pa 1976)*. 2002;27:722-731.
13. Wolinsky JP, Sciubba DM, Suk I, Gokaslan ZL. Endoscopic image-guided odontoidectomy for decompression of basilar invagination via a standard anterior cervical approach. Technical note. *J Neurosurg Spine*. 2007;6:184-191.
14. Cavallo LM, Cappabianca P, Messina A, et al. The extended endoscopic endonasal approach to the clivus and cranio-vertebral junction: anatomical study. *Childs Nerv Syst*. 2007;23:665-671.
15. Morera VA, Fernandez-Miranda JC, , Prevedello DM, et al. "Far-medial" expanded endonasal approach to the inferior third of the clivus: the transcondylar and transjugular tubercle approaches. *Neurosurgery*. 2010;66(6 suppl):211-219.
16. Nayak JV, Gardner PA, Vescan AD, Carrau RL, Kassam AB, Snyderman CH. Experience with the expanded endonasal approach for resection of the odontoid process in rheumatoid disease. *Am J Rhinol*. 2007;21:601-606.
17. Moon ASM, Manoharan SRR. Endoscopic spine surgery: current state of art and the future perspective. *Asian Spine J*. 2018;12:1-2.
18. Yeung A, Roberts A, Zhu L, Qi L, Zhang J, Lewandrowski KU. Treatment of soft tissue and bony spinal stenosis by a visualized endoscopic transforaminal technique under local anesthesia. *Neurospine*. 2019;16:52-62.
19. Burke TG, Caputy A. Microendoscopic posterior cervical foraminotomy: a cadaveric model and clinical application for cervical radiculopathy. *J Neurosurg*. 2000;93(1 suppl):126-129.
20. Ahn Y, Lee SH, Park WM, Lee HY, Shin SW, Kang HY. Percutaneous endoscopic lumbar discectomy for recurrent disc herniation: Surgical technique, outcome, and prognostic factors of 43 consecutive cases. *Spine (Phila Pa 1976)*. 2004;29:E326-E332.
21. Ruetten S, Komp M, Godolias G. A new full-endoscopic technique for the interlaminar operation of lumbar disc herniations using 6-mm endoscopes: prospective 2-year results of 331 patients. *Minim Invasive Neurosurg*. 2006;49:80-87.
22. Ito M, Abumi K, Kotani Y, Kadoya K, Minami A. Clinical outcome of posterolateral endoscopic surgery for pyogenic spondylodiscitis—results of 15 patients with serious comorbid conditions. *Spine (Phila Pa 1976)*. 2007;32:200-206.
23. Ruetten S, Komp M, Merk H, Godolias G. Full-endoscopic cervical posterior foraminotomy for the operation of lateral disc herniations using 5.9-mm endoscopes. A prospective, randomized, controlled study. *Spine (Phila Pa 1976)*. 2008;33:940-948.
24. Anichini G, Landi A, Caporlingua F, et al. Lumbar endoscopic microdiscectomy: where are we now? An updated literature review focused on clinical outcome, complications, and rate of recurrence. *Biomed Res Int*. 2015;2015:417801.
25. Li XC, Zhong CF, Deng GB, Liang RW, Huang CM. Full-endoscopic procedures versus traditional discectomy surgery for discectomy: a systematic review and meta-analysis of current global clinical trials. *Pain Physician*. 2016;19:103-118.
26. Lin GX, Kotheeranurak V, Mahatthanatrakul A, et al. Worldwide research productivity in the field of full-endoscopic spine surgery: a bibliometric study. *Eur Spine J*. 2019;29:153-160.
27. Murray MR, Wang T, Schroeder GD, Hsu WK. The 100 most cited spine articles. *Eur Spine J*. 2012;21:2059-2069.
28. Huang W, Wang L, Wang B, Yu L, Yu X. Top 100 cited articles on back pain research: a citation analysis. *Spine (Phila Pa 1976)*. 2016;41:1683-1692.
29. Rügsegger N, Ahmad SS, Benneker LM, Berlemann U, Keel MJ, Hoppe S. The 100 most influential publications in cervical spine research. *Spine (Phila Pa 1976)*. 2016;41:538-548.
30. Badhiwala JH, Nassiri F, Witiw CD, et al. Highly cited works in spinal disorders: the top 100 most cited papers published in spine journals. *Spine (Phila Pa 1976)*. 2018;43:1746-1755.
31. Virk SS, Yu E. The top 50 articles on minimally invasive spine surgery. *Spine (Phila Pa 1976)*. 2017;42:513-519.
32. Kambin P, Nixon JE, Chait A, Schaffer JL. Annular protrusion: pathophysiology and roentgenographic appearance. *Spine (Phila Pa 1976)*. 1988;13:671-675.
33. Held M, Castelein S, Bruins MF, et al. Most influential literature in spinal tuberculosis: a global disease without global evidence. *Global Spine J*. 2018;8:84-94.
34. Lee YC, Brooks F, Sandler S, Yau YH, Selby M., Freeman B. Most cited publications in cervical spine surgery. *Int J Spine Surg*. 2017;11:19.