

The 100 most cited papers in spinal deformity surgery: a bibliometric analysis

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Abstract

Spinal deformity is a condition that has been recognized for many millennia. There have been major advances in the treatment of spinal deformity in recent years and studies outlining new ideas can inspire others to further advance the speciality. The number of citations a paper receives may indicate the influence of that paper. It is therefore important that we evaluate and analyze the most cited works in our field. The aim of this study is to identify the 100 most cited papers relevant to spinal deformity surgery in the literature. A search through the Thomson Reuters Web of Science™ for citations related to spinal deformity surgery was performed. The number of citations, mean citation number (total number citations/years since publication), journal, authors, year of publication and country of origin of the top 100 papers was recorded. The top 100 papers were cited a combined 17,646 times, ranging from 453 to 112. The majority of papers originated from the United States (71) and were published in 20 different journals. The decade 1990-1999 was the most prolific, with 36 of the 100 papers published during this time. Papers pertaining to the management of scoliosis (49) were the most common. This study identifies the top 100 most cited papers in the field of spinal deformity surgery. While citation is not a specific marker of the scientific quality of a paper, it is a surrogate for the influence a paper has had on the orthopedic community. This list of papers provides an invaluable resource for both those in training and those actively practicing and involved in the further development of spinal deformity surgery.

Introduction

Spinal deformity is a condition that has been recognized for many millennia,¹ with documented attempts at scoliosis correction dating back at least 5000 years.² Our understanding of the development and progression of spinal deformity has increased significantly in recent years, along with major advancements in corrective

techniques for this debilitating condition. Undoubtedly, much is learned from those who went before us, with the published literature acting as an invaluable tool in the advancement of knowledge and innovation in a particular area. Ranking papers by the number of citations they receive allows us to develop a list of the most influential papers in our field of interest.

A citation is an acknowledgement by an author of another author's contribution to their work. Citations contribute to the impact factor a journal receives and therefore influences the journals that we read. Citation analysis, the bibliometric process analyzing citations credited to a given paper, directly determines the impact factor of journals. Impact factor is calculated by dividing the total number of citations of papers published in that journal over the past year divided by the total number of papers published by that journal over the past two years.³ There have been a number of recent publications examining the most influential papers as determined by citation analysis in orthopedic surgery,⁴ and the subspecialties of arthroscopy,⁵ foot and ankle,⁶ arthroplasty,⁷ and pediatric orthopedics.⁸ Similarly, lists of classic papers have been developed in other specialties such as general surgery,⁹ radiology,¹⁰ and plastic surgery.¹¹ One publication looked at the most cited articles in spine.¹² This publication devised the list based on the generality of spine surgery and limited their search to certain subject categories and journals. This is the first publication in the literature to devise a list of the most influential papers specific to spinal deformity surgery.

The aim of this study was to identify the 100 most cited papers relevant to spinal deformity surgery, by performing a bibliometric analysis of the literature using the Science Citation Index (SCI) database.

Materials and Methods

The top 100 most cited papers relevant to spinal deformity surgery were identified from a search of the SCI of the Institute for Scientific Information (ISI), using the Thomson Reuters Web of Science™ search engine from 1945-2014. The following search strategy was performed in March 2014: *Spinal deformity OR Scoliosis OR Kyphoscoliosis OR Kyphosis OR Lordosis OR Sagittal plane deformity OR Sagittal imbalance OR Coronal plane deformity OR Coronal imbalance OR spondylolisthesis*. No limitation was applied to the search in terms of subject category or journal. Results were listed by citation number and assessed by two independent authors (SCON and JSB) for relevance to spinal deformity surgery with complete agreement between authors required for inclusion of a paper.

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Key words: spinal deformity, citation analysis, most cited, scoliosis, bibliometric.

Contributions: SCON wrote the manuscript and completed the research; JSB contributed to the writing of the manuscript, aided in the selection of the articles and reviewed the manuscript; NMG contributed to the results section and reviewed the manuscript; ROL contributed to the methods and introduction section and reviewed the manuscript; KS edited the manuscript and contributed to the discussion section and reviewed the final manuscript.

Conflict of interests: the authors declare no potential conflict of interests.

Received for publication: 3 August 2014.
Accepted for publication: 19 August 2014.

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Orthopedic Reviews 2014; 6:5584
doi:10.4081/or.2014.5584

Papers not relevant to the topic were excluded. The resulting most cited 100 papers were then assessed for; title, journal, number of citations, mean citation number (total number citations/years since publication), authors, year of publication and country of origin.

Results

The top 100 papers in spinal deformity surgery have been cited a combined 17,646 times. The top 100 papers and the number of citations are presented in Table 1.¹³⁻¹¹¹ The most cited paper was by Harrington with 453 citations,¹³ while the 100th paper by Lee *et al.* was cited 112 times.¹⁰⁷ The mean number of citations was 176, with a mean citation number of 8.33/year.

The oldest paper included in the list was by Ponseti *et al.* *Prognosis in idiopathic scoliosis* published in 1950 with the most recent published in 2007 by Weinstein *et al.*

The 1990s accounted for the most number of papers (36) with the 20 years between 1990-2010 accounting for 58% of the top 100 papers. Citations increased exponentially decade by decade with 79 in the 1950s and 8359 in the 2000s. The number of papers listed by decade published is presented in Figure 1.

Overall twelve countries contributed papers. The majority of the top 100 papers originated from the United States (71), followed by United Kingdom, France and Sweden (5 papers each); South Korea (4 papers); Australia, Canada, Germany (2 papers each); Switzerland, Japan, Denmark and Scotland (1 paper each).

Sixty-nine separate institutions contributed papers to the list. Washington University contributed the most papers (8), with the University of Iowa contributing 5. The Long Beach Memorial Medical Center contributed 4 studies, while other 9 papers were published by The Royal National Orthopedic Hospital, Stanmore, London (3 papers), the University of Louisville (3 papers) and the University of Gothenburg (3 papers).

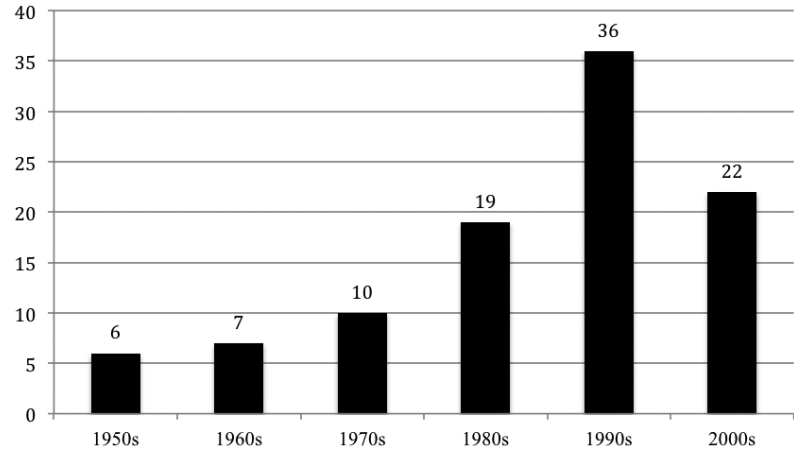


Figure 1. Publication number by decade.

Table 1. The top 100 most cited papers.

1 st author	Citations	1 st author	Citations	1 st author	Citations
Harrington ¹³	453	Hahe ¹⁴	183	Lowe ¹⁵	131
Lenke ¹⁶	408	Stokes ¹⁷	182	Aebi ¹⁸	130
King ¹⁹	391	Suk ²⁰	181	Bunnell ²¹	129
O'sullivan ²²	388	Kumar ²³	176	Kim ²⁴	128
Herkowitz ²⁵	347	Weinstein ²⁶	175	Gill ²⁷	128
Fischgrund ²⁸	346	Collis ²⁹	174	Asher ³⁰	127
Lonstein ³¹	337	Weinstein ³²	172	West ³³	126
Beutler ³⁴	310	Weinstein ³⁵	165	Suk ³⁶	124
Jackson ³⁷	274	Betz ³⁸	162	Albert ³⁹	121
Bergofsky ⁴⁰	269	Dickson ⁴¹	155	Mack ⁴²	121
Nuwer ⁴³	261	Vialle ⁴⁴	151	Riseborough ⁴⁵	121
Suk ⁴⁶	259	Wiltse ⁴⁷	151	Gaines ⁴⁸	120
Stagnara ⁴⁹	251	McMaster ⁵⁰	150	McDonnell ⁵¹	120
Wiltse ⁴⁷	245	Etebar ⁵²	149	Rosenberg ⁵³	120
Nachemson ⁵⁴	239	Aris ⁵⁵	148	Moller ⁵⁶	119
Warren ⁵⁷	238	Wiltse ⁵⁸	148	Black ⁵⁹	119
Boyd ⁶⁰	233	Kim ⁶¹	146	Benzel ⁶²	119
Macewen ⁶³	225	Mardjetko ⁶⁴	146	Roussouly ⁶⁵	118
Gelb ⁶⁶	224	Wiltse ⁶⁷	145	Myers ⁶⁸	118
Bridwell ⁶⁹	223	Brooks ⁷⁰	145	Katsuura ⁷¹	117
Ponseti ⁷²	222	Lenke ⁷³	143	Nilsonne ⁷⁴	116
Cochran ⁷⁵	218	Vaz ⁷⁶	142	Vedantam ⁷⁷	115
Kim ⁷⁸	216	Brodke ⁷⁹	141	Ransford ⁸⁰	115
Thomsen ⁸¹	209	Ponseti ⁸²	140	Fon ⁸³	115
Boxall ⁸⁴	207	Rowe ⁸⁵	139	Asher ⁸⁶	114
Morrissy ⁸⁷	206	Emans ⁸⁸	139	Herman ⁸⁹	114
Glassman ⁹⁰	201	Lonstein ⁹¹	138	Collier ⁹²	114
Glassman ⁹³	201	Bunnell ⁹⁴	138	Dwyer ⁹⁵	114
Carman ⁹⁶	200	Engler ⁹⁷	138	Theodorou ⁹⁸	113
Liljenqvist ⁹⁹	196	Winter ¹⁰⁰	138	Levine ¹⁰¹	113
Rogala ¹⁰²	194	Nachemson ¹⁰³	138	James ¹⁰⁴	113
Sharma ¹⁰⁵	192	Zdeblick ¹⁰⁶	137	Lee ¹⁰⁷	112
Newman ¹⁰⁸	186	Shands ¹⁰⁹	135	Jackson ¹¹⁰	112
		Campbell ¹¹¹	131		

The top 100 papers were published in 20 different journals, which represented orthopedic, general and other sub-specialty interests. *The journal of bone and joint surgery - American volume* published the greatest number of papers (39), followed closely by *Spine* journal (32), *The journal of bone and joint surgery - British volume* (5) and the *European Spine Journal* (4). A complete list of journals can be found in Table 2.

A number of authors were represented on multiple papers in the top 100. Lenke and Bridwell both appeared on 8 of the papers on the list, with Ponseti and Winter appearing on 5. Wiltse published the greatest number of papers as first author (4). Suk, Nachemson, Moe, Kim, Herkowitz, Glassman, Dimar, Bunnell and Bradford appear in 3 papers each.

While a variety of spinal deformity topics are represented in the top 100, papers specifically relating to scoliosis management (49) were the most common topic.

Discussion

In our study, the Science Citation Index was interrogated to assess the most cited papers in spinal deformity surgery in order to attempt to produce a list of citation *classics* in the field. It provides an insight into some of the most influential papers in the area of spinal deformity surgery and chronicles the practice-changing work

that has been published over the past 70 years.

The most cited paper was *Treatment of scoliosis - correction and internal fixation by spine instrumentation* by Harrington in 1962, which was cited 453 times.¹³ The paper described a new operative technique for the treatment of scoliosis. Harrington described the use of internal fixation and distraction using rods to correct the deformity. While his initial results were mixed it marked the beginning of a new era in the surgical treatment of scoliotic deformity. Numerous alterations were made to Harrington's instrumentation and innovation in internal fixation for scoliosis correction continues today.

The second most cited paper was by Lenke *et al.* *Adolescent idiopathic scoliosis* published in 2001, cited 408 times. This paper proposed a new two-dimensional classification system for adolescent idiopathic scoliosis that attempted to determine the level of fusion required at the time of surgery. It sought to improve upon the limitations of the existing classification proposed by King *et al.*,¹⁹ a paper which has been cited 391 times and is the third most cited paper in our study. Comparative studies have shown the new classification system by Lenke *et al.* to be more reproducible and reliable than King *et al.* There is a significant time period between the publication year of the 1st and 2nd paper on our list. Although Harrington's paper has more citations in absolute terms, this has been achieved over a 50-year period. In contrast to this, Lenke *et al.* published 13 years

ago and thus the mean number of citations per year of this paper is 29.14, which is significantly higher than the mean citation of 8.55 for Harrington. This finding suggests that the mean citation number may be useful in assessing the immediacy of the impact a paper has, when comparing publications from different time periods.

A total of 12 countries contributed papers to the top 100 most cited papers in spinal deformity surgery. All countries are from the developed world with a high degree of health care expenditure. The United States contributed 71 papers to the list, which is more than twice the number of all the other countries combined. This is in keeping with other similar studies across a number of medical specialties,^{7,8,11} and correlates to the volume of orthopedic practice and research output that exists in the United States. In terms of decade of publication, 77 of the top 100 papers have been published since the 1980s, with 1990s the most prolific period for publication, accounting for 36 papers. High impact factor orthopedic journals dominated the list with *The journal of bone and joint surgery - American volume* and *Spine* publishing the most articles, emphasizing the prestige and influence these journals exert in the field of orthopedic surgery. From our analysis, it would appear that for an author to achieve a highly cited paper, it is most likely to be published from a United States, English speaking institution and published in a high impact journal.

There are a number of inherent limitations to this form of citation analysis, which have been highlighted in previous papers using similar methods.¹¹ The SCI citation database was searched in this study using the Thomson Reuters Web of Science™ search engine. The ISI began collecting citation information in 1945 and therefore articles published prior to this were not included in this study. Previous studies limited the search to journals within specific subject categories. We placed no restriction on our search and feel this resulted in less likelihood of excluding potentially relevant articles and therefore achieving a more representative list of articles for analysis. It has been suggested that more recent papers are at a disadvantage with older papers more likely to be cited.¹² The use of mean citation number (total number citations/years since publication) in our analysis takes into account year of publication and allows a relative comparison of citation to be made between recent and more historic papers.

Self-citation, journal bias and language bias were not controlled for in this study. Articles published in high impact journals are more likely to reach a wider audience and therefore have a greater potential for citation. All papers in the top 100 were written in the English language. There are also a number of phenomenon that can influence citation analysis.

Table 2. Journals of publication.

Journal	Papers
Journal of Bone and Joint Surgery-American Volume	39
Spine	32
Journal of Bone and Joint Surgery-British Volume	5
European Spine Journal	4
New England Journal of Medicine	2
Journal of Spinal Disorders	2
Journal of Neurosurgery	2
Acta Orthopaedica Scandinavica	2
Medicine	1
Evoked Potentials-Electroencephalography and Clinical Neurophysiology	1
Journal of Neurology Neurosurgery and Psychiatry	1
American Journal of Pathology	1
Annals of Internal Medicine	1
Clinical Orthopaedics and Related Research	1
International Orthopaedics	1
Annals of Thoracic Surgery	1
Journal of Bone and Mineral Research	1
American Journal of Roentgenology	1
Radiology	1
Clinical Imaging	1

Obliteration by incorporation is one such phenomenon. It describes the observation that some highly influential or classic papers become so ingrained into common knowledge that they are no longer deemed necessary to cite.¹¹³ *Incomplete citing* can also occur. It describes the situation when citations are made by the author to persuade the reader rather than to give accurate acknowledgement to those that influenced their work.¹¹⁴

Conclusions

This study identifies the top 100 most cited papers in the field of spinal deformity surgery. While citation is not a specific marker of the scientific quality of a paper, it is a surrogate for the influence a paper has had on the orthopedic community. This present study provides a list of some of the most influential papers that have helped shape the speciality over the past 70 years. This list of papers provides an invaluable resource for both those in training and those actively practicing and involved in the further development of spinal deformity surgery.

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