



# The 100 most influential spine fracture publications

Chester J. Donnally III<sup>1</sup>, Sebastian Rivera<sup>1</sup>, Augustus J. Rush III<sup>1</sup>, Kevin J. Bondar<sup>2</sup>, Allison L. Boden<sup>1</sup>, Michael Y. Wang<sup>3</sup>

<sup>1</sup>Department of Orthopaedic Surgery, University of Miami Hospital, Miami, FL, USA; <sup>2</sup>Department of Education, <sup>3</sup>Department of Neurological Surgery, The University of Miami Leonard M. Miller School of Medicine, Miami, FL, USA

**Contributions:** (I) Conception and design: CJ Donnally 3rd, AJ Rush 3rd, KJ Bondar, MY Wang; (II) Administrative support: CJ Donnally 3rd, KJ Bondar; (III) Provision of study materials or patients: KJ Bondar; (IV) Collection and assembly of data: KJ Bondar; (V) Data analysis and interpretation: CJ Donnally 3rd, S Rivera, AJ Rush 3rd, AL Boden; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

**Correspondence to:** Chester J. Donnally III, MD. Department of Orthopaedics, University of Miami Hospital, 1400 NW 12th Ave, Miami, FL 33136, USA. Email: Chester.Donnally@jhsmiami.org.

**Background:** Management of spine fractures has advanced considerably even over the past decade. A review of the current and historical literature can lead to a better appreciation of current management protocols. This is the first comprehensive review of the most influential articles related to spine fracture management. The purpose of this study is to identify and analyze the 100 most cited publications in spine fracture management.

**Methods:** Using the Clarivate Analytics Web of Science, search phrases were used to identify publications pertaining to spine fractures (110,809 publications). The 100 most cited articles were isolated. The frequency of citations, year of publication, country of origin, journal of publication, level-of-evidence (LOE), article type, and contributing authors/institutions were recorded. We also highlighted the ten most cited articles (per year) from the past decade.

**Results:** The publications included ranged from 1953–2010, with the majority published between 2000–2009 (n=41). Total citations ranged from 154 to 1,076. A LOE of IV had the plurality at 36%. The most cited article was “The 3 Column Spine and Its Significance in The Classification of Acute Thoracolumbar Spinal-Injuries” (*Spine* 1983) by F Denis. The majority of papers originated in the United States (n=65), and the highest number were published in *Spine* (n=27). Osteoporotic fractures were the specific topic in 34 publications. In the past decade, the article with the most citations/year was “A Randomized Trial of Vertebroplasty for Osteoporotic Spinal Fractures” by DF Kalmes in 2009.

**Conclusions:** Despite less time for citation than other decades, the 2000s contain the plurality of the influential publications. This may indicate that some of the most important changes to spine fracture management pertain to improved imaging modalities and surgical technologies. This review provides a guide for a comprehensive understanding of the historical and current literature pertaining to spine fracture management.

**Keywords:** Spine fracture; spine surgery; osteoporosis; citation analysis; bibliometric study

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## Introduction

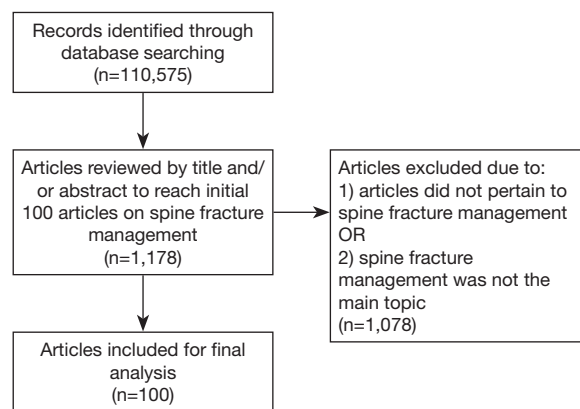
Given the importance and traction of evidence-based medicine in recent years, research studies are instrumental not only in the understanding and advancement of disease management, but in clinical decision-making. Unfortunately, the task of searching through medical literature can be daunting and overwhelming given the abundance of information available. While new studies are being published at increasing rates, few studies make lasting contributions to a field.

Citation analysis, also known as bibliometric study, is a quantitative analysis of written publications that has become a popular method to identify studies that have a high impact on a particular field of medicine (1). While many fields in medicine and multiple fields of orthopaedics have undergone extensive literature reviews to identify the most influential articles published, there is no comprehensive review of the most cited articles related to spine fracture management.

Advancements in the management of spine fracture have had a beneficial effect on the long-term prognosis of these potentially devastating injuries. Mismanagement of certain injury patterns could result in further injury to the patient. The goal of this study was to identify and analyze the 100 most cited publications related to spine fracture management through an extensive literature search method, used and validated in previous bibliometric analyses (2-6). An appreciation and understanding of these influential publications can help clinicians with treatment decisions as well as aid researchers in future project development.

## Methods

The Preferred Reporting Guidelines for Systematic Review (PRISMA) guidelines and checklist items were used to guide the methods. These items included stating our objectives and rationale (to isolate the most cited publications related to spine fracture), detailing search methods via Web of Science, eligibility criteria (peer-reviewed articles and review articles related to spine fracture), a multi-step screening of search results (*Figure 1*), and data collection. The search method was conducted as follows: three investigators determined the appropriate Boolean search statement and search parameters based on the intended objectives of the paper and Web of Science capabilities. Web of Science was utilized for the search because of its breadth of content and analytical capabilities. A Web of Science query was carried out on May 5, 2018. The query

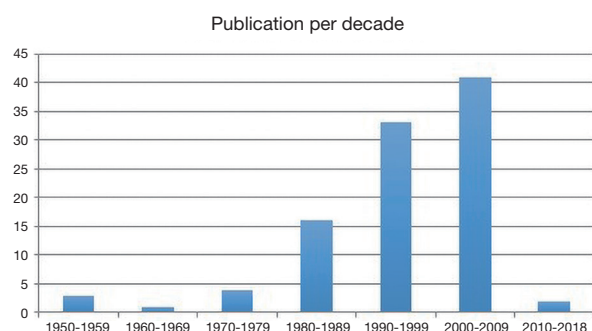


**Figure 1** Modified PRISMA flowchart.

involved the following search statement: ((Fracture OR rupture OR displacement OR fixation OR repair OR classification OR chance OR burst OR injury) AND (Spine OR vertebra\* OR cervical OR thoracic OR thoracolumbar OR lumbar OR lumbosacral OR sacral OR sacrum)). This search statement was utilized because it contains the various terms associated with: (I) the location (spine); and (II) the type of injury (fracture of any given classification); the investigators concluded that these search terms would appropriately narrow the search to the topic of interest while ideally capturing all articles related to spine fracture. The “\*” indicates all endings to this particular word are included in the search.

Regarding specific search filters and criteria, articles from both medical and non-medical journals were included. Only articles written in English were included. This search was not restricted to any particular data range. The search was restricted to peer-reviewed articles and review articles; thus, all other paper classifications such as letters, editorials, and conference papers were excluded. No restrictions on the time of publication were placed on the original search. No restrictions were placed on study type, such as clinical trials versus cohort studies versus cross-sectional studies. No restrictions were placed on the specific cohorts of included study. No restrictions were placed on authors, source titles, funding agencies, organizations, editors, research areas, regions of origin, or paper categories. The resulting articles were sorted by descending number of citations. The search results were saved and the first 12,000 results along with all corresponding citation and journal source data were exported to Endnote Online and Microsoft Excel for screening.

The screening process involved a multi-step approach.



**Figure 2** An analysis of articles published from 1950 to 2018.

Two investigators sequentially reviewed the results by title and abstract when necessary to gather only articles that pertained to the treatment, prognosis, or management of spine fractures. The initial screen was stopped when 100 articles were isolated for further review. The second screening step consisted of two investigators reviewing the abstracts of the 100 articles to ensure that all inclusion criteria were met. Full manuscripts were reviewed if necessary to verify if an article met inclusion criteria. Publications pertaining to injuries of the spinal cord, vertebrae, or cauda equina were permitted for inclusion. Additionally, studies pertaining to osteoporotic compression fractures were included as these fractures often result from minor traumas and potentially have the same treatment options as non-osteoporotic compression fractures. Articles that discussed treatments for other spinal conditions or injuries, such as tumors or infections, were excluded. Publications in question for inclusion were reviewed independently by the lead author (CJD). As a final screening step and a primary step of data collection, all included publications were reviewed by one investigator for LOE and article topic data. No articles were determined to fail to meet inclusion criteria; therefore, no articles were excluded in this final screen. Articles for which LOE or article type data was unclear were discussed with a second investigator.

The 100 most cited articles were isolated for additional analysis. The number of citations in the most recent year was used to systematically establish the order of articles when an equal total number of citations occurred. On May 22, 2018, 17 days after the initial search was conducted, the final 100 articles were further reviewed via Web of Science for the following: publication year, country of origin, journal of publication, article type, frequency of citations, average citations per year, citations in 2017, and authorship frequency. May 22, 2018 was effectively the last access date

as far as data collection.

Each publication's institutions of origin were determined by manual article review. This institutional information was cross-referenced with the Web of Science organizational information, and the combined data was utilized. The level of evidence and article type was assigned to each publication after careful review of the abstracts and manuscripts.

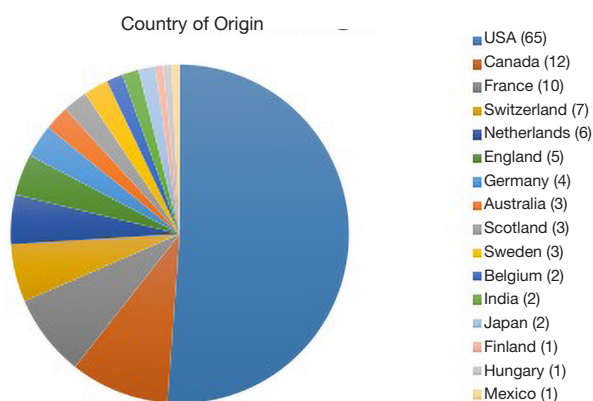
Our initial list is subject to bias in that the more recent articles had a shorter time window between the date of publication and the date of our search; therefore, these articles had a more limited opportunity for peer citation. In an attempt to mitigate this bias, we identified the top 10 most influential articles of the past decade. Our original Web of Science search results were refined to include only articles published between 2008 and 2018. Citation data for these articles was gathered, and the articles were sorted by decreasing number of average citations per year, as opposed to total citations.

## Results

The initial search yielded 110,809 publications that met the criteria of our search term statement. After sequentially reviewing the first 1,178 results, ordered by decreasing number of citations, we found 100 articles that specifically pertained to spine fracture management (*Figure 1*).

The most productive decade was 2000–2009 (41%); the second most prolific decade was 1990–1999 (31%). Between 1950 and 2010, a positive trend between the year of publication and the number of publications was noted (*Figure 2*). Based on our methods, we documented every country affiliated with a single publication, as opposed to the country of the first or last author only. In all, 16 countries contributed to these 100 publications with the United States as the greatest contributor ( $n=65$ ). The second greatest contributor was Canada ( $n=12$ ), followed by France ( $n=10$ ). Of note, 10 countries contributed to three or more articles (*Figure 3*).

The range of publication years for the 100 articles was 1953 to 2010. The articles were collectively cited a total of 30,129 times. The most cited paper was cited 1,076 times; the least cited paper was cited 156 times. The average number of citations in 2017 was 18.5. The average number of citations per year since the year of publication was 15.9. The average total number of total citations was 301 (*Table 1*). The first ranked article by F Denis from 1983 explores the middle osteoligamentous complex and classifies major and minor spinal injuries to discuss treatment based on a



**Figure 3** A summary of the countries of origin of the articles.

three-column approach. The second ranked article is “A Randomized Trial of Vertebroplasty for Osteoporotic Spinal Fractures” by DF Kalmes from 2009. The third ranked article is “A Randomized Trial of Vertebroplasty for Painful Osteoporotic Vertebral Fractures” by DF Buchbinder. The earliest publication is Cloward’s explanation of back pain associated with ruptured discs and the utility of spinal fusions for this condition (Table 1).

*Spine* contained the most articles, accounting for 27% of the publications. The second most recurring journal was the *Journal of Bone and Joint Surgery- American Volume*, accounting for 13% of the publications. *Journal of Neurosurgery* and *New England Journal of Medicine* were tied

**Table 1** 100 most cited spine fracture publications

Rank	Publication	Total citations	Citations/year of publication until 2018	Citations in 2017
1	Denis F. The 3 Column Spine and Its Significance in The Classification of Acute Thoracolumbar Spinal-Injuries. <i>Spine</i> 1983;8(8):817-831	1,076	29.89	62
2	Kallmes DF, Comstock BA, Heagerty PJ, et al. A Randomized Trial of Vertebroplasty for Osteoporotic Spinal Fractures. <i>New England Journal of Medicine</i> 2009;361(6):569-579	677	67.7	52
3	Buchbinder R, Osborne RH, Ebeling PR, et al. A Randomized Trial of Vertebroplasty for Painful Osteoporotic Vertebral Fractures. <i>New England Journal of Medicine</i> 2009;361(6):557-568	664	66.4	56
4	Harms J, Melcher RP. Posterior C1-C2 fusion with polyaxial screw and rod fixation. <i>Spine</i> 2001;26(22):2467-2471	647	35.94	72
5	Garfin SR, Yuan HA, Reiley MA. New technologies in spine - Kyphoplasty and vertebroplasty for the treatment of painful osteoporotic compression fractures. <i>Spine</i> 2001;26(14):1511-1515	603	33.5	29
6	Hoffman JR, Mower WR, Wolfson AB, Todd KH, Zucker MI, Natl Emergency XRUSG. Validity of a set of clinical criteria to rule out injury to the cervical spine in patients with blunt trauma. <i>New England Journal of Medicine</i> 2000;343(2):94-99	589	31	47
7	Lieberman IH, Dudeney S, Reinhardt MK, Bell G. Initial outcome and efficacy of “kyphoplasty” in the treatment of painful osteoporotic vertebral compression fractures. <i>Spine</i> 2001;26(14):1631-1637	564	31.33	22
8	Stiell IG, Wells GA, Vandemheen KL, et al. The Canadian C-spine rule for radiography in alert and stable trauma patients. <i>JAMA-Journal of the American Medical Association</i> 2001;286(15):1841-1848	511	28.39	43
9	Barr JD, Barr MS, Lemley TJ, McCann RM. Percutaneous vertebroplasty for pain relief and spinal stabilization. <i>Spine</i> 2000;25(8):923-928	496	26.11	14
10	Holdsworth F. Fractures, Dislocations, And Fracture-Dislocations of Spine. <i>Journal of Bone and Joint Surgery-American Volume</i> 1970;52(8):1534-51.	467	9.53	15
11	Goel A, Laheri V. Plate and Screw Fixation for Atlantoaxial Subluxation. <i>Acta Neurochirurgica</i> 1994;129(1-2):47-53	463	18.52	55
12	Eastell R, Cedel SI, Wahner HW, Riggs BL, Melton LJ. Classification of Vertebral Fractures. <i>Journal of Bone and Mineral Research</i> 1991;6(3):207-215	448	16	8
13	Bohlman HH. Acute Fractures and Dislocations of the Cervical-Spine - Analysis of 300 Hospitalized-Patients and Review of the Literature. <i>Journal of Bone and Joint Surgery-American Volume</i> 1979;61(8):1119-1142	423	10.58	15

**Table 1** (continued)

Table 1 (continued)

Rank	Publication	Total citations	Citations/year of publication until 2018	Citations in 2017
14	Grados F, Depriester C, Cayrolle G, Hardy N, Deramond H, Fardellone P. Long-Term Observations of Vertebral Osteoporotic Fractures Treated by Percutaneous Vertebroplasty. <i>Rheumatology</i> 2000;39(12):1410-1414	399	21	10
15	Dumont RJ, Okonkwo DO, Verma RS, <i>et al.</i> Acute spinal cord injury, part I: Pathophysiologic mechanisms. <i>Clinical Neuropharmacology</i> 2001;24(5):254-264	392	21.78	46
16	Wardlaw D, Cummings SR, Van Meirhaeghe J, <i>et al.</i> Efficacy and safety of balloon kyphoplasty compared with non-surgical care for vertebral compression fracture (FREE): a randomised controlled trial. <i>Lancet</i> 2009;373(9668):1016-1024	391	39.1	31
17	Hulme PA, Krebs J, Ferguson SJ, Berlemann U. Vertebroplasty and kyphoplasty: A systematic review of 69 clinical studies. <i>Spine</i> 2006;31(17):1983-2001	388	29.85	34
18	Klazen CAH, Lohle PNM, de Vries J, <i>et al.</i> Vertebroplasty versus conservative treatment in acute osteoporotic vertebral compression fractures (Vertos II): an open-label randomised trial. <i>Lancet</i> 2010;376(9746):1085-1092	370	41.11	40
19	Denis F, Davis S, Comfort T. Sacral Fractures - An Important Problem - Retrospective Analysis Of 236 Cases. <i>Clinical Orthopaedics and Related Research</i> 1988(227):67-81	353	11.39	22
20	Geisler FH, Dorsey FC, Coleman WP. Recovery of Motor Function After Spinal-Cord Injury - A Randomized, Placebo-Controlled Trial with Gm-1 Ganglioside. <i>New England Journal of Medicine</i> 1991;324(26):1829-1838	348	12.43	11
21	Cotten A, Boutry N, Cortet B, <i>et al.</i> Percutaneous vertebroplasty: State of the art. <i>Radiographics</i> 1998;18(2):311-320	343	16.33	7
22	Mccormack T, Karaikovic E, Gaines RW. The Load Sharing Classification of Spine Fractures. <i>Spine</i> 1994;19(15):1741-1744	340	13.6	32
23	Mcbroom RJ, Hayes WC, Edwards WT, Goldberg RP, White AA. Prediction of Vertebral Body Compressive Fracture Using Quantitative Computed-Tomography. <i>Journal of Bone and Joint Surgery-American Volume</i> 1985;67a(8):1206-1214	339	9.97	8
24	Cloward RB. The Treatment of Ruptured Lumbar Intervertebral Discs by Vertebral Body Fusion .1. Indications, Operative Technique, After Care. <i>Journal of Neurosurgery</i> 1953;10(2):154-168	330	5	14
25	Uppin AA, Hirsch JA, Centenera LV, Pfiefer BA, Pazianos AG, Choi IS. Occurrence of new vertebral body fracture after percutaneous vertebroplasty in patients with osteoporosis. <i>Radiology</i> 2003;226(1):119-124	328	20.5	14
26	Cortet B, Cotten A, Boutry N, <i>et al.</i> Percutaneous vertebroplasty in the treatment of osteoporotic vertebral compression fractures: An open prospective study. <i>Journal of Rheumatology</i> 1999;26(10):2222-2228	328	16.4	5
27	Fountas KN, Kapsalaki EZ, Nikolakakos LG, <i>et al.</i> Anterior cervical Discectomy and fusion associated complications. <i>Spine</i> 2007;32(21):2310-2317	325	27.08	65
28	Cann CE, Genant HK, Kolb FO, Ettinger B. Quantitative Computed-Tomography for Prediction of Vertebral Fracture Risk. <i>Bone</i> 1985;6(1):1-7	323	9.5	4
29	Allen BL, Ferguson RL, Lehmann TR, O'Brien RP. A Mechanistic Classification of Closed, Indirect Fractures and Dislocations of the Lower Cervical-Spine. <i>Spine</i> 1982;7(1):1-27	314	8.49	22
30	Scheff SW, Rabchevsky AG, Fugaccia I, Main JA, Lumpp JE. Experimental modeling of spinal cord injury: Characterization of a force-defined injury device. <i>Journal of Neurotrauma</i> 2003;20(2):179-193	312	19.5	21
31	Schneider RC, Cherry G, Pantek H. The Syndrome of Acute Central Cervical Spinal Cord Injury - With Special Reference to The Mechanisms Involved in Hyperextension Injuries of Cervical Spine. <i>Journal of Neurosurgery</i> 1954;11(6):546-577	312	4.8	18

Table 1 (continued)



Table 1 (continued)

Rank	Publication	Total citations	Citations/year of publication until 2018	Citations in 2017
32	Mayer TG, Gatchel RJ, Kishino N, <i>et al.</i> Objective Assessment of Spine Function Following Industrial Injury - A Prospective-Study with Comparison Group and One-Year Follow-Up. <i>Spine</i> 1985;10(6):482-493	310	9.12	4
33	Madawi AA, Casey ATH, Solanki GA, Tuite G, Veres R, Crockard HA. Radiological and anatomical evaluation of the atlantoaxial transarticular screw fixation technique. <i>Journal of Neurosurgery</i> 1997;86(6):961-968	309	14.05	12
34	Panjabi MM. Clinical spinal instability and low back pain. <i>Journal of Electromyography and Kinesiology</i> 2003;13(4):371-379	307	19.19	32
35	Belkoff SM, Mathis JM, Jasper LE, Deramond H. The biomechanics of vertebroplasty - The effect of cement volume on mechanical behavior. <i>Spine</i> 2001;26(14):1537-1541	307	17.06	11
36	Delmas PD, Genant HK, Crans GG, <i>et al.</i> Severity of prevalent vertebral fractures and the risk of subsequent vertebral and nonvertebral fractures: results from the MORE trial. <i>Bone</i> 2003;33(4):522-532	301	18.81	17
37	Melton LJ, Atkinson EJ, Cooper C, O'Fallon WM, Riggs BL. Vertebral fractures predict subsequent fractures. <i>Osteoporosis International</i> 1999;10(3):214-221	301	15.05	8
38	McLain RF, Sparling E, Benson DR. Early Failure of Short-Segment Pedicle Instrumentation for Thoracolumbar Fractures. <i>Journal of Bone and Joint Surgery-American Volume</i> 1993;75A(2):162-167	297	11.42	21
39	Roycammille R, Saillant G, Mazel C. Internal-Fixation of The Lumbar Spine with Pedicle Screw Plating. <i>Clinical Orthopaedics and Related Research</i> 1986(203):7-17	297	9	21
40	Mathis JM, Barr JD, Belkoff SM, Barr MS, Jensen ME, Deramond H. Percutaneous vertebroplasty: A developing standard of care for vertebral compression fractures. <i>American Journal of Neuroradiology</i> 2001;22(2):373-381	295	16.39	10
41	Goel A, Desai KI, Muzumdar DP. Atlantoaxial fixation using, plate and screw method: A report of 160 treated patients. <i>Neurosurgery</i> 2002;51(6):1351-1356	294	17.29	33
42	Panjabi MM, Oxland TR, Yamamoto I, Crisco JJ. Mechanical-Behavior of The Human Lumbar and Lumbosacral Spine as Shown by 3-Dimensional Load-Displacement Curves. <i>Journal of Bone and Joint Surgery-American Volume</i> 1994;76A(3):413-424	290	11.6	19
43	Schlaich C, Minne HW, Bruckner T, <i>et al.</i> Reduced pulmonary function in patients with spinal osteoporotic fractures. <i>Osteoporosis International</i> 1998;8(3):261-267	288	13.71	10
44	Center JR, Bliue D, Nguyen TV, Eisman JA. Risk of subsequent fracture after low-trauma fracture in men and women. <i>JAMA-Journal of the American Medical Association</i> 2007;297(4):387-394	287	23.92	28
45	Heini PF, Walchli B, Berlemann U. Percutaneous transpedicular vertebroplasty with PMMA: operative technique and early results - A prospective study for the treatment of osteoporotic compression fractures. <i>European Spine Journal</i> 2000;9(5):445-450	285	15	8
46	Gangi A, Kastler BA, Dietemann JL. Percutaneous Vertebroplasty Guided by A Combination of CT and Fluoroscopy. <i>American Journal of Neuroradiology</i> 1994;15(1):83-86	285	11.4	7
47	Vaccaro AR, Rizzolo SJ, Balderston RA, <i>et al.</i> Placement of Pedicle Screws in The Thoracic Spine .2. An Anatomical and Radiographic Assessment. <i>Journal of Bone and Joint Surgery-American Volume</i> 1995;77A(8):1200-1206	280	11.67	14
48	Berlemann U, Ferguson SJ, Nolte LP, Hein PF. Adjacent vertebral failure after vertebroplasty - A biomechanical investigation. <i>Journal of Bone and Joint Surgery-British Volume</i> 2002;84B(5):748-752	276	16.24	13
49	Chapman JR, Harrington RM, Lee KM, Anderson PA, Tencer AF, Kowalski D. Factors affecting the pullout strength of cancellous bone screws. <i>Journal of Biomechanical Engineering-Transactions of the Asme</i> 1996;118(3):391-398	276	12	19
50	Vaccaro AR, Lehman RA, Hurlbert J, <i>et al.</i> A new classification of thoracolumbar injuries - The importance of injury morphology, the integrity of the posterior ligamentous complex, and neurologic status. <i>Spine</i> 2005;30(20):2325-2333	275	19.64	26

Table 1 (continued)

Table 1 (continued)

Rank	Publication	Total citations	Citations/year of publication until 2018	Citations in 2017
51	Wallach S, Cohen S, Reid DM, <i>et al.</i> Effects of risedronate treatment on bone density and vertebral fracture in patients on corticosteroid therapy. <i>Calcified Tissue International</i> 2000;67(4):277-285	272	14.32	4
52	Stiell IG, Clement CM, McKnight RD, <i>et al.</i> The canadian C-spine rule versus the NEXUS low-risk criteria in patients with trauma. <i>New England Journal of Medicine</i> 2003;349(26):2510-2518	266	16.63	30
53	Vaccaro AR, Lehman RA, Hurlbert J, <i>et al.</i> A new classification of thoracolumbar injuries - The importance of injury morphology, the integrity of the posterior ligamentous complex, and neurologic status. <i>Spine</i> 2005;30(20):2325-2333	264	10.15	8
54	Baur A, Stabler A, Bruning R, <i>et al.</i> Diffusion-weighted MR imaging of bone marrow: Differentiation of benign versus pathologic compression fractures. <i>Radiology</i> 1998;207(2):349-356	256	12.19	11
55	Sharma M, Langrana NA, Rodriguez J. Role of Ligaments and Facets in Lumbar Spinal Stability. <i>Spine</i> 1995;20(8):887-900	254	10.58	16
56	Jeanneret B, Magerl F. Primary Posterior Fusion-C1/2 In Odontoid Fractures - Indications, Technique, And Results of Transarticular Screw Fixation. <i>Journal of Spinal Disorders</i> 1992;5(4):464-475	254	9.41	18
57	Evans AJ, Jensen ME, Kip KE, <i>et al.</i> Vertebral compression fractures: Pain reduction and improvement in functional mobility after percutaneous polymethylmethacrylate vertebroplasty-retrospective report of 245 cases. <i>Radiology</i> 2003;226(2):366-372	253	15.81	10
58	Mumford J, Weinstein JN, Spratt KF, Goel VK. Thoracolumbar Burst Fractures - The Clinical Efficacy and Outcome of Nonoperative Management. <i>Spine</i> 1993;18(8):955-970	253	9.73	10
59	Lips P, Cooper C, Agnusdei D, <i>et al.</i> Quality of life in patients with vertebral fractures: Validation of the quality of life questionnaire of the European Foundation for Osteoporosis (QUALEFFO). <i>Osteoporosis International</i> 1999;10(2):150-160	252	12.6	5
60	Delmas PD, van de Langerijt L, Watts NB, <i>et al.</i> Underdiagnosis of vertebral fractures is a worldwide problem: The IMPACT study. <i>Journal of Bone and Mineral Research</i> 2005;20(4):557-563	251	17.93	19
61	Lin EP, Ekholm S, Hiwatashi A, Westesson PL. Vertebroplasty: Cement leakage into the disc increases the risk of new fracture of adjacent vertebral body. <i>American Journal of Neuroradiology</i> 2004;25(2):175-180	251	16.73	16
62	Grob D, Crisco JJ, Panjabi MM, Wang P, Dvorak J. Biomechanical Evaluation of 4 Different Posterior Atlantoaxial Fixation Techniques. <i>Spine</i> 1992;17(5):480-490	250	9.26	11
63	Liebschner MAK, Rosenberg WS, Keaveny TM. Effects of bone cement volume and distribution on vertebral stiffness after vertebroplasty. <i>Spine</i> 2001;26(14):1547-1554	248	13.78	14
64	Davis JW, Phreaner DL, Hoyt DB, Mackersie RC. The Etiology of Missed Cervical-Spine Injuries. <i>Journal of Trauma-Injury Infection and Critical Care</i> 1993;34(3):342-346	248	9.54	9
65	McAfee PC, Yuan HA, Fredrickson BE, Lubicky JP. The Value of Computed-Tomography in Thoracolumbar Fractures - An Analysis of 100 Consecutive Cases and A New Classification. <i>Journal of Bone and Joint Surgery-American Volume</i> 1983;65(4):461-473	248	6.89	11
66	Fehlings MG, Vaccaro A, Wilson JR, <i>et al.</i> Early versus Delayed Decompression for Traumatic Cervical Spinal Cord Injury: Results of the Surgical Timing in Acute Spinal Cord Injury Study (STASCIS). <i>Plos One</i> 2012;7(2)	244	34.86	63
67	Jones EL, Heller JG, Silcox DH, Hutton WC. Cervical pedicle screws versus lateral mass screws - Anatomic feasibility and biomechanical comparison. <i>Spine</i> 1997;22(9):977-982	243	11.05	15
68	Goel VK, Monroe BT, Gilbertson LG, Brinckmann P, Nat R. Interlaminar Shear Stresses and Laminae Separation in A Disc - Finite-Element Analysis of the L3-L4 Motion Segment Subjected to Axial Compressive Loads. <i>Spine</i> 1995;20(6):689-698	242	10.08	14
69	Silverman SL. The Clinical Consequences of Vertebral Compression Fracture. <i>Bone</i> 1992;13:S27-S31	242	8.96	11

Table 1 (continued)

Table 1 (continued)

Rank	Publication	Total citations	Citations/year of publication until 2018	Citations in 2017
70	Reid DC, Henderson R, Saboe L, Miller JDR. Etiology and Clinical Course of Missed Spine Fractures. <i>Journal of Trauma-Injury Infection and Critical Care</i> 1987;27(9):980-986	242	7.56	7
71	Wood K, Buttermann G, Mehbod A, Garvey T, Jhanjee R, Sechriest V. Operative compared with nonoperative treatment of a thoracolumbar burst fracture without neurological deficit - A prospective, randomized study. <i>Journal of Bone and Joint Surgery-American Volume</i> 2003;85A(5):773-781	240	15	17
72	Vaccaro AR, Falatyn SP, Scuderi GJ, <i>et al.</i> Early failure of long segment anterior cervical plate fixation. <i>Journal of Spinal Disorders</i> 1998;11(5):410-415	238	10.86	17
73	Grob D, Jeanneret B, Aebi M, Markwalder TM. Atlantoaxial Fusion with Transarticular Screw Fixation. <i>Journal of Bone and Joint Surgery-British Volume</i> 1991;73(6):972-976	231	8.25	9
74	Zoarski GH, Snow P, Olan WJ, <i>et al.</i> Percutaneous vertebroplasty for osteoporotic compression fractures: Quantitative prospective evaluation of long-term outcomes. <i>Journal of Vascular and Interventional Radiology</i> 2002;13(2):139-148	224	13.18	4
75	Wright NM. Posterior C2 fixation using bilateral, crossing C2 laminar screws - Case series and technical note. <i>Journal of Spinal Disorders &amp; Techniques</i> 2004;17(2):158-162	223	14.87	16
76	Fribourg D, Tang C, Delamarter R, Bae H. Incidence of subsequent vertebral fracture after kyphoplasty. <i>Spine</i> 2004;29(20):2270-2276	222	14.8	10
77	Rogers WA. Fractures and Dislocations of the Cervical Spine - An End-Result Study. <i>Journal of Bone and Joint Surgery-American Volume</i> 1957;39(2):341-376	217	3.5	1
78	Magerl FP. Stabilization of The Lower Thoracic and Lumbar Spine with External Skeletal Fixation. <i>Clinical Orthopaedics and Related Research</i> 1984(189):125-141	213	6.09	14
79	Hadley MN, Zabramski JM, Browner CM, Rekate H, Sonntag VKH. Pediatric Spinal Trauma - Review of 122 Cases of Spinal-Cord and Vertebral Column Injuries. <i>Journal of Neurosurgery</i> 1988;68(1):18-24	210	6.77	11
80	Verlaan JJ, Diekerhof CH, Buskens E, <i>et al.</i> Surgical treatment of traumatic fractures of the thoracic and lumbar spine - A systematic review of the literature on techniques, complications, and outcome. <i>Spine</i> 2004;29(7):803-814	209	13.93	22
81	Gertzbein SD. Scoliosis-Research-Society - Multicenter Spine Fracture Study. <i>Spine</i> 1992;17(5):528-540	209	7.74	10
82	Dickson JH, Harrington PR, Erwin WD. Results of Reduction and Stabilization of Severely Fractured Thoracic and Lumbar Spine. <i>Journal of Bone and Joint Surgery-American Volume</i> 1978;60(6):799-805	208	5.07	2
83	Hu R, Mustard CA, Burns C. Epidemiology of incident spinal fracture in a complete population. <i>Spine</i> 1996;21(4):492-499	192	8.35	12
84	Parker JW, Lane JR, Karaikovic EE, Gaines RW. Successful short-segment instrumentation and fusion for thoracolumbar spine fractures - A consecutive 4(1)/(2)-year series. <i>Spine</i> 2000;25(9):1157-1169	190	10	17
85	Denis F, Armstrong GWD, Searls K, Matta L. ACUTE Thoracolumbar Burst Fractures in The Absence of Neurologic Deficit - A Comparison Between Operative and Nonoperative Treatment. <i>Clinical Orthopaedics and Related Research</i> 1984(189):142-149	185	5.29	5
86	Westerveld LA, Verlaan JJ, Oner FC. Spinal fractures in patients with ankylosing spinal disorders: a systematic review of the literature on treatment, neurological status and complications. <i>European Spine Journal</i> 2009;18(2):145-156	177	17.7	34
87	Hoffman JR, Wolfson AB, Todd K, Mower WR, Grp N. Selective cervical spine radiography in blunt trauma: Methodology of the National Emergency X-Radiography Utilization Study (NEXUS). <i>Annals of Emergency Medicine</i> 1998;32(4):461-469	177	8.43	10
88	Schneider RC, Livingston KE, Cave AJE, Hamilton G. Hangmans Fracture of Cervical Spine. <i>Journal of Neurosurgery</i> 1965;22(2):141-54	172	3.19	6

Table 1 (continued)



Table 1 (continued)

Rank	Publication	Total citations	Citations/year of publication until 2018	Citations in 2017
89	Brown RL, Brunn MA, Garcia VF. Cervical spine injuries in children: A review of 103 patients treated consecutively at a level 1 pediatric trauma center. <i>Journal of Pediatric Surgery</i> 2001;36(8):1107-1114	170	9.44	11
90	McAfee PC, Bohlman HH, Yuan HA. Anterior Decompression of Traumatic Thoracolumbar Fractures With Incomplete Neurological Deficit Using A Retroperitoneal Approach. <i>Journal of Bone and Joint Surgery-American Volume</i> 1985;67A(1):89-104	168	4.94	3
91	Miyajiri F, Furlan JC, Aarabi B, Arnold PM, Fehlings MG. Acute cervical traumatic spinal cord injury: MR Imaging findings correlated with neurologic outcome - Prospective study with 100 consecutive patients. <i>Radiology</i> 2007;243(3):820-827	164	13.67	26
92	Weinstein JN, Collalto P, Lehmann TR. Thoracolumbar Burst Fractures Treated Conservatively - A Long-Term Follow-Up. <i>Spine</i> 1988;13(1):33-38	163	5.26	6
93	Vaccaro AR, Hulbert J, Patel AA, <i>et al.</i> The subaxial cervical spine injury classification system. <i>Spine</i> 2007;32(21):2365-2374	161	13.42	23
94	Berne JD, Velmahos GC, El-Tawil Q, <i>et al.</i> Value of complete cervical helical computed tomographic scanning in identifying cervical spine injury in the unevaluable blunt trauma patient with multiple injuries: A prospective study. <i>Journal of Trauma-Injury Infection and Critical Care</i> 1999;47(5):896-902	161	8.05	2
94	Kaneda K, Abumi K, Fujiya M. Burst Fractures with Neurologic Deficits of The Thoracolumbar-Lumbar Spine - Results Of Anterior Decompression And Stabilization With Anterior Instrumentation. <i>Spine</i> 1984;9(8):788-795	161	4.6	2
96	Flesch JR, Leider LL, Erickson DL, Chou SN, Bradford DS. Harrington Instrumentation and Spine Fusion for Unstable Fractures and Fracture-Dislocations of Thoracic and Lumbar Spine. <i>Journal of Bone and Joint Surgery-American Volume</i> 1977;59(2):143-153	161	3.83	0
97	Delamarter RB, Sherman J, Carr JB. Pathophysiology of Spinal-Cord Injury - Recovery After Immediate and Delayed Decompression. <i>Journal of Bone and Joint Surgery-American Volume</i> 1995;77A(7):1042-1049	158	6.58	10
98	Woodring JH, Lee C. Limitations of Cervical Radiography in The Evaluation of Acute Cervical Trauma. <i>Journal of Trauma-Injury Infection and Critical Care</i> 1993;34(1):32-39	157	6.04	3
99	Kokoska ER, Keller MS, Rallo MC, Weber TR. Characteristics of pediatric cervical spine injuries. <i>Journal of Pediatric Surgery</i> 2001;36(1):100-105	156	8.67	11
100	Roycamille R, Saillant G, Gagna G, Mazel C. Transverse Fracture of the Upper Sacrum - Suicidal Jumpers Fracture. <i>Spine</i> 1985;10(9):838-845	156	4.59	13

as the third most recurring journal, each accounting for 5% of the articles. Interestingly, articles within the list are associated with 32 different journals (Table 2). We of Science provided the impact factor of each listed journal.

The most common level of evidence was IV (n=36). Within this article list the following numbers of articles were at each level of evidence: 9 (level I), 11 (level II), 16 (level III), 36 (level IV), and 28 (level V) (Figure 4).

Regarding types of articles, clinical outcomes (n=39; 39%) was the most common. Surgical technique (13%) was the second most common article type, and 10 articles

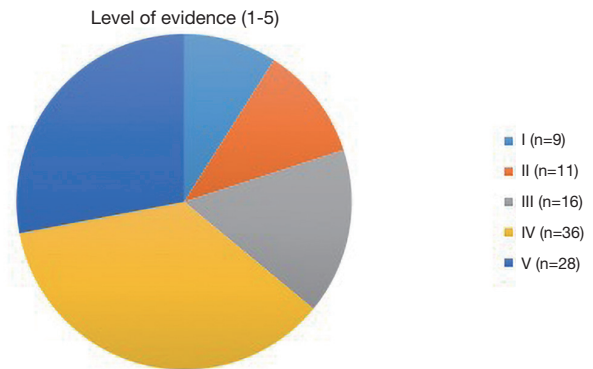
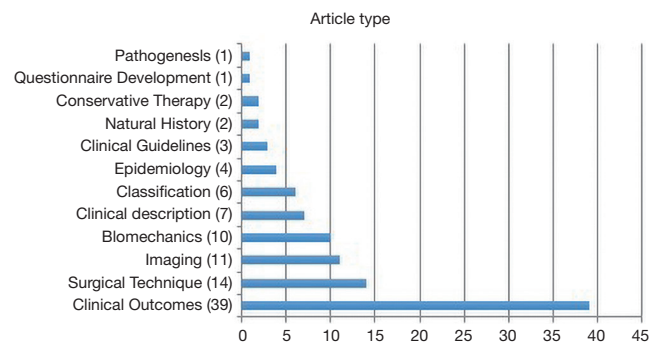
pertained specifically to biomechanics (Figure 5). There were 13 authors contributing to at least 3 publications in this list. H Deramond (n=4; 4%) and A Vaccaro (n=4; 4%) were tied as the most productive author (Table 3).

Moreover, 10 institutions contributed to at least four articles on the list. University of Maryland and University of Toronto, accounted for the largest contributors with seven articles each. The next most contributive institution was University of British Columbia with six articles (Table 4). Two particular special topics were discussed in 41% of our top 100 articles: osteoporosis (n=34) and pedicle screws (n=7).

**Table 2** Journal of origin

Journal name	Impact factor*	Number of publications
<i>Spine</i>	2.79	27
<i>Journal of Bone and Joint Surgery-American Volume</i>	4.58	13
<i>Journal of Neurosurgery</i>	4.32	5
<i>New England Journal Of Medicine</i>	79.26	5
<i>Clinical Orthopaedics and Related Research</i>	4.09	4
<i>Journal of Trauma and Acute Care Surgery (formerly Journal of Trauma Injury Infection and Critical Care)</i>	3.70	4
<i>Radiology</i>	7.47	4
<i>American Journal of Neuroradiology</i>	3.65	3
<i>Bone</i>	4.46	3
<i>Osteoporosis International</i>	3.86	3
<i>European Spine Journal</i>	2.63	2
<i>Journal of The American Medical Association</i>	47.66	2
<i>Journal of Bone and Joint Surgery-British Volume</i>	3.31	2
<i>Journal of Bone and Mineral Research</i>	6.31	2
<i>Journal of Pediatric Surgery</i>	2.13	2
<i>Journal of Spinal Disorders</i>	2.31	2
<i>Lancet</i>	53.25	2
<i>Acta Neurochirurgica</i>	1.93	1
<i>American Journal of Medicine</i>	5.12	1
<i>Annals of Emergency Medicine</i>	5.01	1
<i>Calcified Tissue International</i>	3.29	1
<i>Clinical Neuropharmacology</i>	1.37	1
<i>Journal of Biomechanical Engineering</i>	1.92	1
<i>Journal of Electromyography And Kinesiology</i>	1.57	1
<i>Journal of Neurotrauma</i>	5.00	1
<i>Journal of Rheumatology</i>	3.47	1
<i>Journal of Spinal Disorders &amp; Techniques</i>	2.31	1
<i>Journal of Vascular and Interventional Radiology</i>	2.76	1
<i>Neurosurgery</i>	4.48	1
<i>Plos One</i>	2.77	1
<i>Radiographics</i>	3.25	1
<i>Rheumatology</i>	5.25	1

\*, impact factor per Clarivate Analytics (the parent company of Web of Science) accessed December 2018.

**Figure 4** Number of articles at each level of evidence.**Figure 5** Frequency of each article type.**Table 3** Author frequency

Author	Number of papers
Deramond H	4
Vaccaro A	4
Aarabi B	3
Berlemann U	3
Denis F	3
Dvorak M	3
Eastell R	3
Fehlings M	3
Fisher C	3
Garfin S	3
Oner F	3
Panjabi M	3
Yuan H	3

Authors with 3 or more contributions are included.

**Table 4** Contributing institution

Name of institution	Location of institution	Number of articles
University of Maryland	Baltimore, MD, USA	7
University of Toronto	Toronto, Ontario, Canada	7
University of British Columbia	Vancouver, British Columbia, Canada	6
University of California-San Francisco	San Francisco, California, USA	5
Centre Hospitalier Universitaire-Amiens	Amiens, France	4
Thomas Jefferson University	Philadelphia, Pennsylvania, USA	4
University of Bern	Bern, Switzerland	4
University of California-Los Angeles	Los Angeles, California, USA	4
University of Virginia	Charlottesville, Virginia, USA	4
Utrecht University	Utrecht, Netherlands	4

Institutions with 4 or more contributions are included.

Web of Science assigned one or more publication categories to each article. According to this analysis, 51 articles were related to orthopaedics; 45 articles were related to clinical neurology; 32 articles were related to surgery.

With regards to the second search, which was focused on publications from the past decade relating to spine fractures, the highest number of citations per year was “A Randomized Trial of Vertebroplasty for Osteoporotic Spinal Fractures” by DF Kallmes in 2009. The second ranked article was “A Randomized Trial of Vertebroplasty for Painful Osteoporotic Vertebral Fractures” by DF Buchbinder from 2009. The third ranked article was “Mortality Risk Associated with Low-Trauma Osteoporotic Fracture and Subsequent Fracture in Men and Women” by D Bliuc in 2009 (Table 5). Interestingly, the first and second ranked articles in the second search list were ranked second and third in the original search list (Table 1), indicating that these two articles had both a very high number of total citations and a very high number of average citations per year.

## Discussion

This study highlights the articles and authors that have had some the greatest impact on spine fractures in the last century and the beginning of this century. The findings of this study identify many of the articles responsible for the development of current management strategies for spine fractures, including biomechanical concerns. The most cited paper in spine fracture literature is the classic work of Denis from 1983, which established the 3-column

model of the spine (7). This paper introduces the middle osteoligamentous complex and classifies major and minor spinal injuries to discuss treatment based on a three-column approach. This model is often used to characterize fractures as stable or unstable injuries, depending on the involvement of 2 or more columns.

The second most cited work is from Kallmes *et al.* within the last decade involving a randomized controlled trial of vertebroplasty for osteoporotic spinal fractures (8). In this study, 131 patients were randomized to either vertebroplasty or simulated vertebroplasty without introduction of polymethylmethacrylate (PMMA). The findings were remarkable that both groups showed clinical improvement with regards to pain and disability, which were sustained at one month, without statistical significant differences between the groups. These results lead authors to conclude that factors outside of injection of PMMA in osteoporotic fractures may account for the clinical improvements observed in the placebo group.

Similarly, the third most referenced paper, Buchbinder *et al.*, is another randomized trial of vertebroplasty for painful osteoporotic fractures published within the last decade (9). This study evaluated 71 patients who were randomized to vertebroplasty versus sham procedure. This study and the findings were similar to Kallmes *et al.* with the major difference being in study design (length of follow up of 6 months) (10). This article also failed to show significant difference of pain reduction in vertebroplasty versus sham procedure.

Osteoporosis was the most common topic in the top

**Table 5** Most cited publications per year from the past 10 years

Rank	Publication	Citations/year of publication until 2018	Total citations	Citations in 2017
1	Kallmes DF, Comstock BA, Heagerty PJ, <i>et al.</i> A Randomized Trial of Vertebroplasty for Osteoporotic Spinal Fractures. <i>New England Journal of Medicine</i> 2009;361(6):569-579	68.3	683	52
2	Buchbinder R, Osborne RH, Ebeling PR, <i>et al.</i> A Randomized Trial of Vertebroplasty for Painful Osteoporotic Vertebral Fractures. <i>New England Journal of Medicine</i> 2009;361(6):557-568	67.1	671	56
3	Bliuc D, Nguyen ND, Milch VE, Nguyen TV, Eisman JA, Center JR. Mortality Risk Associated with Low-Trauma Osteoporotic Fracture and Subsequent Fracture in Men and Women. <i>JAMA-Journal of the American Medical Association</i> 2009;301(5):513-521	58.1	581	66
4	Wright NC, Looker AC, Saag KG, <i>et al.</i> The Recent Prevalence of Osteoporosis and Low Bone Mass in the United States Based on Bone Mineral Density at the Femoral Neck or Lumbar Spine. <i>Journal of Bone and Mineral Research</i> 2014;29(11):2520-2526	46.4	232	84
5	Klazen CAH, Lohle PNM, de Vries J, <i>et al.</i> Vertebroplasty versus Conservative Treatment in Acute Osteoporotic Vertebral Compression Fractures (Vertos II): an open-label randomised trial. <i>Lancet</i> 2010;376(9746):1085-1092	41.6	374	40
6	Wardlaw D, Cummings SR, Van Meirhaeghe J, <i>et al.</i> Efficacy And Safety Of Balloon Kyphoplasty Compared with Non-Surgical Care for Vertebral Compression Fracture (FREE): A Randomised Controlled Trial. <i>Lancet</i> 2009;373(9668):1016-1024	39.3	393	31
7	Huber-Wagner S, Lefering R, Qvick LM, <i>et al.</i> Effect of Whole-body CT during Trauma Resuscitation on Survival: a Retrospective, Multicentre study. <i>Lancet</i> 2009;373(9673):1455-1461	37.9	379	44
8	Fehlings MG, Vaccaro A, Wilson JR, <i>et al.</i> Early versus Delayed Decompression for Traumatic Cervical Spinal Cord Injury: Results of the Surgical Timing in Acute Spinal Cord Injury Study (STASCIS). <i>Plos One</i> 2012;7(2)	35.3	247	63
9	DeVivo MJ. Epidemiology of Traumatic Spinal Cord Injury: trends and future implications. <i>Spinal Cord</i> 2012;50(5):365-372	32.7	229	57
10	Vaccaro AR, Oner C, Kepler CK, <i>et al.</i> AOSpine Thoracolumbar Spine Injury Classification System Fracture Description, Neurological Status, and Key Modifiers. <i>Spine</i> 2013;38(23):2028-2037	19.8	119	42

100 papers, with 34 publications focused on the topic. Osteoporotic vertebral fractures are widespread in the population with an estimated 550,000 to 700,000 fracture occurring annually (9,11). These fractures have a vast economic implication on the population as the prevalence is expected to continue to increase with the aging population. Burge *et al.* estimated cost of vertebral compression fractures to account for about 1.1 billion dollars in 2005, with estimated growth of approximately 50% by 2025 (1). Two of the most cited papers in our top 100 focused on the controversial issue of vertebroplasty versus conservative treatment for vertebral compression fractures. These papers have had dramatic impact on the rate of vertebroplasty, which has decreased since these papers were published in 2009 according to two large database studies (12,13).

Our study has various limitations. Primarily, we used the total number of citations as the main surrogate for

article importance. This is a controversial measure for the impact a paper has as it can over- or underestimate the true impact of a study (14,15). An additional limitation of our study involves the discussion of spinal fracture classification systems. We could not thoroughly discuss the most common classification systems such as AO, Magerl, and McAfee as the publications within our list were from a large timespan over which classification systems changed significantly due to the increased use of imaging techniques such as CT and MRI. Lastly, older publications have a greater opportunity to be cited more frequently; hence, these publications may be inaccurately viewed to be of greater importance. To account for this limitation, we included a separate list of the most important citations of the last ten years with average citations per year since publication to eliminate this bias. Furthermore, it is evident from our overall list that the oldest papers were, in fact, not the most cited papers.

## Conclusions

This study is the first to identify the most cited spine fracture papers. It provides insight that the 2000s contain the plurality of the influential publications indicating how some of the most important changes to spine fracture management pertain to better imaging modalities and surgical technologies. Knowledge of the influential publications can serve as a guide for a comprehensive understanding of the historical and current literature pertaining to spine fractures.

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## Footnote

*Conflicts of Interest:* The authors have no conflicts of interest to declare.

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1. Burge R, Dawson-Hughes B, Solomon DH, et al. Incidence and economic burden of osteoporosis-related fractures in the United States, 2005-2025. *J Bone Miner Res* 2007;22:465-75.
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3. Steinberger J, Skovrlj B, Caridi JM, et al. The top 100 classic papers in lumbar spine surgery. *Spine (Phila Pa 1976)* 2015;40:740-7.
4. Eshraghi A, Osman NA, Gholizadeh H, et al. 100 top-cited scientific papers in limb prosthetics. *Biomed Eng Online* 2013;12:119.
5. Skovrlj B, Steinberger J, Guzman JZ, et al. The 100 Most Influential Articles in Cervical Spine Surgery. *Global Spine J* 2016;6:69-79.
6. De la Garza-Ramos R, Benvenuti-Regato M, Caro-Osorio E. The 100 most-cited articles in spinal oncology. *J Neurosurg Spine* 2016;24:810-23.
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8. Denis F. The three column spine and its significance in the classification of acute thoracolumbar spinal injuries. *Spine (Phila Pa 1976)* 1983;8:817-31.
9. Buchbinder R, Osborne RH, Ebeling PR, et al. A randomized trial of vertebroplasty for painful osteoporotic vertebral fractures. *N Engl J Med* 2009;361:557-68.
10. Kallmes DF, Comstock BA, Heagerty PJ, et al. A randomized trial of vertebroplasty for osteoporotic spinal fractures. *N Engl J Med* 2009;361:569-79.
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13. Sayari AJ, Liu Y, Cohen JR, et al. Trends in vertebroplasty and kyphoplasty after thoracolumbar osteoporotic fracture: A large database study from 2005 to 2012. *J Orthop* 2015;12:S217-22.
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