Systematic Review

The 50 Most Cited Articles on Meniscus Injuries and Surgery from 2000 to 2019 Focus on Arthroscopic Repair or Removal, Originate from Institutions Within the United States and Were Published Before 2010

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Purpose: To identify the 50 most cited original articles on meniscus injury and surgery from 2000 to 2019, and to perform a bibliometric analysis of the identified articles. **Methods:** A Clarivate Web of Science search, completed in June 2020, generated a list of the most cited articles related to meniscus research. Articles were sorted by number of times cited, and review articles or those unrelated to the meniscus were removed. Articles were classified as basic science or assigned the appropriate level of evidence. Extracted data included title, authors, journal, year of publication, country/institution of origin, total number of citations, and number of citations per year. **Results:** The final list of 50 included articles with a range of 106 to 490 citations and a mean of 162.34 total or 11.91 citations per year. The most cited articles appeared in 8 of the most influential journals in the field per the Journal Citation Index. Twenty-nine (58%) originated from institutions within the United States, and only 13 (26%) were published in 2010 or later. Overall, 25 (50%) were classified as therapeutic, only 5 (10%) were therapeutic randomized controlled studies, and 17 (34%) were basic science. "Arthroscopic meniscal repair or meniscectomy" appeared most frequently, with 16 (32%) falling into this subclassification. **Conclusion:** This study of the most cited meniscus articles showed a strong predominance for therapeutic studies, studies generated and published within the United States, and studies focused on topics of arthroscopic repair or removal. Overwhelmingly, included articles were published before 2010, affirming the criticism that bibliometric analysis favors older articles. **Clinical relevance:** This study provides information about which articles are driving the field relating to meniscus injuries and meniscus surgery in the last two decades.

Introduction

The rise of evidence-based medicine and the desire to evaluate the quality of published articles ignited a trend in using bibliometric techniques to identify high-impact articles in various medical disciplines, including orthopaedic surgery as a whole and in more specialized topics within the discipline (e.g., bibliometric techniques applied to pediatric orthopaedic topics or shoulder arthroscopy Anterior Cruciate Ligament [ACL] tears).[1−5] Identification of objective measures to determine the impact of an original or review article is vitally important to determining influence in a field of study or in ranking high-impact works, but proves difficult to achieve in practice. Employing

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citation analysis, such as bibliometric studies, is one potentially effective method for examining impact and can be useful as an indicator of an article's significance to a specific subject area.[1–12]

The classic criticism of bibliometric analysis is that although an article may accumulate a large number of citations, this may not translate to higher quality or suggest a higher level of clinical importance.[13,14] Positive results, the journal publishing the article, and self-citation all bias the number of times an article is cited and cast doubt in the value of such analysis.[14–16] However, bibliometric analysis does provide a metric in the larger examination of overall quality and remains a useful tool.[1,4,5,7–12] Lee et al. determined that factors that correlate to higher methodological quality include those "published in journals whose articles are cited more frequently (higher citation rates and impact factors), read more widely (higher circulation) and scrutinized more carefully by editors and outside peer-reviewers (lower manuscript acceptance rates).[17]" Additionally, bibliometric reviews of the published literature help to make important financial decisions, such as being used by the United Kingdom National Institute for Health research panels as one aspect of the decision-making process when awarding research funding.[18]

Even though a recent bibliometric analysis was published on the overall knee and identified "Knee Arthroplasty" as the predominant theme,[19] the meniscus is an important topic in orthopaedic surgery and warrants its own bibliometric analysis. In the United States, the direct medical cost for meniscectomies is estimated at $4 billion per year, and 20.5% of ambulatory musculoskeletal surgeries were for arthroscopy of the knee (International Classification of Diseases [ICD]-Ninth Revision 80.2) or excision of semilunar cartilage of the knee (ICD-9 80.6).[20,21] An estimate published in 2020 based on the PearlDiver database suggests a decreasing incidence of isolated meniscectomies (28.3/10,000) and a stable incidence of isolated meniscus repairs (0.24/10,000).[22] Current estimates indicate that 45.7% of meniscal repair with ACL reconstruction occurred in patients aged 15–19 years, suggesting that ACL reconstruction may frequently occur simultaneously with meniscus surgery and justifies production of articles examining the outcomes of this dual surgery.[22–26] With a high rate of meniscal injuries in individuals under the age of 30, there is a sincere interest in research dedicated to tracking the development of knee osteoarthritis later in life and manners to prevent progression to osteoarthritis.[27–31]

With the high incidence of meniscal tears in younger patients, the associated cost to the health care system, and the potential for the development of osteoarthritis later in life, it is important to understand what original literature has been generated on the topic of meniscal injuries and how that literature is influencing the production and funding of research by others. The purposes of this study were to identify the 50 most cited original articles on meniscus injury and surgery from 2000 to 2019 and to perform a bibliometric analysis of the identified articles. Our hypothesis is that this snapshot of the past 20 years will contain a strong bias toward articles published in earlier years, will favor therapeutic studies (versus prognostic or diagnostic), will help to identify which topics are currently gaining the most attention (such as a rise in articles about meniscus transplant), and will uncover gaps in the existing research (such as a low proportion of randomized controlled trials).

Methods

A Clarivate Analytics Web of Science Citation Index Search was performed using the Science Core Collection Indices on June 18, 2020, to identify the 50 most cited articles related to the meniscus published on or after January 1, 2000, and on or before December 31, 2019. A Journal Citation Report most recently updated in 2018 ranked the 79 most influential journals in orthopaedic surgery by impact factor and determined which journals would be included in the initial Citation Index Search.[32] The following search terms were used: "Meniscectomy," "Meniscus Tear," "Meniscus Surgery," "Meniscus," "Meniscus Repair," "Meniscus Allograft," and "Meniscus Transplant." This resulted in 5,432 articles with 136,283 total citations and an average of 25.09 citations per article. Articles were removed if the original publication date was before January 1, 2000. Any articles that were deemed by the authors (A.B. and P.R.) not to focus on meniscus injury, basic science, or biomechanical evaluations of the meniscus, surgical interventions and/or outcomes, diagnostic methods directly related to meniscus injury, or complications of meniscus injury/surgery were excluded. Review for inclusion involved independent review of the full article by two authors. Removal mainly applied to articles on osteoarthritis or the ACL, which only had peripheral attention to the meniscus. All systematic review and meta-analyses (SRMs) were also excluded.

The articles identified in the search were organized by the total number of times they were cited, and the data collected included article title, author names, journal of publication, year of publication, country of origin, total number of citations, and number of citations per year. Including "number of citations per year" recognizes the bias associated with articles published in earlier years appearing higher on the ranking list. Each article was then classified as basic science/lab controlled/cadaveric or assigned one of the four levels of evidence (LOE) based on review of the title and abstract by the authors as defined by "Updating the Assignment of Levels of

Table 1. Top 50 Most Cited Articles Related to Meniscus Injuries From 2000 to 2019

Rank	Title	Total Citations	Citations per Year	Category and LOE*
1	Glasson SS, Blanchet TJ, Morris EA. The surgical destabilization of the medial meniscus (DMM) model of osteoarthritis in the 129/SvEv mouse. *Osteoarthritis Cartilage* 2007;15:1061-1069.	490	35.00	Basic Science**
2	Allaire R, Muriuki M, Gilbertson L, Harner CD. Biomechanical consequences of a tear of the posterior root of the medial meniscus: Similar to total meniscectomy. *J Bone Joint Surg Am* 2008;90:1922-1931.	365	28.08	Basic Science
3	Lee SJ, Aadalen KJ, Malaviya P, et al. Tibiofemoral contact mechanics after serial medial meniscectomies in the human cadaveric knee. *Am J Sports Med* 2006;34:1334-1344.	241	16.07	Basic Science
4	Shelbourne KD, Gray T. Results of anterior cruciate ligament reconstruction based on meniscus and articular cartilage status at the time of surgery: Five- to fifteen-year evaluations. *Am J Sports Med* 2000;28:446-452.	235	11.19	Therapeutic IV
5	Allen CR, Wong EK, Livesay GA, Sakane M, Fu FH, Woo SL-Y. Importance of the medial meniscus in the anterior cruciate ligament-deficient knee. *J Orthop Res Ther* 2000;18:109-115.	225	10.71	Basic Science
6	Torres L, Dunlop DD, Peterfy C, et al. The relationship between specific tissue lesions and pain severity in persons with knee osteoarthritis. *Osteoarthritis Cartilage* 2006;14:1033-1040.	224	14.93	Diagnostic I
7	Prodromos CC, Joyce BT, Keller BL, Murphy BJ, Shi K. Magnetic resonance imaging measurement of the contralateral normal meniscus is a more accurate method of determining meniscal allograft size than radiographic measurement of the recipient tibial plateau. *Arthroscopy* 2007;23:1174-1179.	219	15.64	Diagnostic II
8	Verdonk PCM, Verstraete KL, Almqvist KF, et al. Meniscal allograft transplantation: Long-term clinical results with radiological and magnetic resonance imaging correlations. *Knee Surg Sports Traumatol Arthrosc* 2006;14:694-706.	212	14.13	Therapeutic IV
9	Herrlin S, Hållander M, Wange P, Weidenhielm L, Werner S. Arthroscopic or conservative treatment of degenerative medial meniscal tears: A prospective randomized trial. *Knee Surg Sports Traumatol Arthrosc* 2007;15:393-401.	195	13.93	Therapeutic I
10	Millett PJ, Willis AA, Warren RF. Associated injuries in pediatric and adolescent anterior cruciate ligament tears: Does a delay in treatment increase the risk of meniscal tear? *Arthrosc J Arthrosc Relat Surg* 2002;18:955-959.	193	10.16	Therapeutic IV
11	Verdonk PCM, Demurie A, Almqvist KF, Veys EM, Verbruggen G, Verdonk R. Transplantation of viable meniscal allograft: Survivorship analysis and clinical outcome of one hundred cases. *J Bone Joint Surg Am* 2005;87-A:715-724.	188	11.75	Therapeutic IV
12	Wirth CJ, Peters G, Milachowski KA, Weismeier KG, Kohn D. Long-term results of meniscal allograft transplantation. *Am J Sports Med* 2002;30:174-181.	188	9.89	Therapeutic III
13	Vangsness CT, Farr J, Boyd J, Dellaero DT, Mills CR, LeRoux-Williams M. Adult human mesenchymal stem cells delivered via intra-articular injection to the knee following partial medial meniscectomy: A randomized, double-blind, controlled study. *J Bone Joint Surg Am* 2014;96:90-98.	184	26.29	Therapeutic I
14	Stein T, Mehling AP, Welsch F, von Eisenhart-Rothe R, Jäger A. long-term outcome after arthroscopic meniscal repair versus arthroscopic partial meniscectomy for traumatic meniscal tears. *Am J Sports Med* 2010;38:1542-1548.	183	16.64	Therapeutic III
15	Briggs KK, Kocher MS, Rodkey WG, Steadman JR. Reliability, validity, and responsiveness of the Lysholm knee score and Tegner activity scale for patients with meniscal injury of the knee. *J Bone Joint Surg Am* 2006;88-A:698-705.	165	11.00	Diagnostic I
16	Yim J-H, Seon J-K, Song E-K, et al. A comparative study of meniscectomy and nonoperative treatment for degenerative horizontal tears of the medial meniscus. *Am Joint Sports Med* 2013;41:1565-1570.	158	19.75	Therapeutic I
17	Marzo JM, Gurske-DePerio J. Effects of medial meniscus posterior horn avulsion and repair on tibiofemoral contact area and peak contact pressure with clinical implications. *Am J Sports Med* 2009;37:124-129.	156	13.00	Basic Science
18	Tandogan RN, Taşer Ö, Kayaalp A, et al. Analysis of meniscal and chondral lesions accompanying anterior cruciate ligament tears: Relationship with age, time from injury, and level of sport. *Knee Surg Sports Traumatol Arthrosc* 2004;12:262-270.	154	9.06	Prognostic III
19	Musahl V, Citak M, O'Loughlin PF, Choi D, Bedi A, Pearle AD. The effect of medial versus lateral meniscectomy on the stability of the anterior cruciate ligament-deficient knee. *Am J Sports Med* 2010;38:1591-1597.	152	13.82	Basic Science
20	Papageorgiou CD, Gil JE, Kanamori A, Fenwick JA, Woo SL-Y, Fu FH. The biomechanical interdependence between the anterior cruciate ligament replacement graft and the medial meniscus. *Am J Sports Med* 2001;29:226-231.	151	7.55	Basic Science

(continued)

Table 1. Continued

Rank	Title	Total Citations	Citations per Year	Category and LOE*
21	Bin S-I, Kim J-M, Shin S-J. Radial tears of the posterior horn of the medial meniscus. *Arthroscopy* 2004;20:373-378.	150	8.82	Therapeutic IV
22	Herrlin SV, Wange PO, Lapidus G, Hållander M, Werner S, Weidenhielm L. Is arthroscopic surgery beneficial in treating non-traumatic, degenerative medial meniscal tears? A five year follow-up. *Knee Surg Sports Traumatol Arthrosc* 2013;21:358-364.	149	18.63	Therapeutic I
23	Pauli C, Grogan SP, Patil S, et al. Macroscopic and histopathologic analysis of human knee menisci in aging and osteoarthritis. *Osteoarthritis Cartilage* 2011;19:1132-1141.	149	14.90	Basic Science
24	Peña E, Calvo B, Martínez MA, Palanca D, Doblaré M. Finite element analysis of the effect of meniscal tears and meniscectomies on human knee biomechanics. *Clin Biomech* 2005;20:498-507.	148	9.25	Basic Science
25	Andersson-Molina H, Karlsson H, Rockborn P. Arthroscopic partial and total meniscectomy: A long-term follow-up study with matched controls. *Arthroscopy* 2002;18:183-189.	148	7.79	Therapeutic III
26	Abrams GD, Frank RM, Gupta AK, Harris JD, McCormick FM, Cole BJ. Trends in meniscus repair and meniscectomy in the United States, 2005-2011. *Am J Sports Med* 2013;41:2333-2339.	142	17.75	Prognostic IV
27	Bedi A, Kelly NH, Baad M, et al. Dynamic contact mechanics of the medial meniscus as a function of radial tear, repair, and partial meniscectomy: *J Bone Joint Surg Am* 2010;92:1398-1408.	142	12.91	Basic Science
28	Janusz MJ, Bendele AM, Brown KK, Taiwo YO, Hsieh L, Heitmeyer SA. Induction of osteoarthritis in the rat by surgical tear of the meniscus: Inhibition of joint damage by a matrix metalloproteinase inhibitor. *Osteoarthritis Cartilage* 2002;10:785-791.	141	7.42	Basic Science
29	Chatain F, Adeleine P, Chambat P, Neyret P. A comparative study of medial versus lateral arthroscopic partial meniscectomy on stable knees: 10-year minimum follow-up. *Arthroscopy* 2003;19:842-849.	139	7.72	Therapeutic III
30	Rodkey WG, DeHaven KE, Montgomery WH, et al. Comparison of the collagen meniscus implant with partial meniscectomy: A prospective randomized trial. *J Bone Joint Surg Am* 2008;90:1413-1426.	136	10.46	Therapeutic I
31	Rath E, Richmond JC, Yassir W, Albright JD, Gundogan F. Meniscal allograft transplantation: Two- to eight-year results. *Am J Sports Med* 2001;29:410-414.	136	6.80	Therapeutic IV
32	Stollsteimer GT, Shelton WR, Dukes A, Bomboy AL. Meniscal allograft transplantation: A 1- to 5-year follow-up of 22 patients. *Arthroscopy* 2000;16:343-347.	136	6.48	Therapeutic IV
33	Rodeo SA, Seneviratne A, Suzuki K, Felker K, Wickiewicz TL, Warren RF. Histological analysis of human meniscal allografts: A preliminary report. *J Bone Joint Surg Am* 2000;82:1071-1082.	135	6.43	Basic Science
34	McNicholas MJ, Rowley DI, McGurty D, et al. Total meniscectomy in adolescence: A Thirty-year follow-up. *J Bone Joint Surg Br* 2000;82-B:217-221.	135	6.43	Therapeutic IV
35	Segawa Y, Muneta T, Makino H, et al. Mesenchymal stem cells derived from synovium, meniscus, anterior cruciate ligament, and articular chondrocytes share similar gene expression profiles. *J Orthop Res Ther* 2009;27:435-441.	132	11.00	Basic Science
36	Roos EM, Östenberg A, Roos H, Ekdahl C, Lohmander LS. Long-term outcome of meniscectomy: Symptoms, function, and performance tests in patients with or without radiographic osteoarthritis compared to matched controls. *Osteoarthritis Cartilage* 2001;9:316-324.	129	6.45	Therapeutic III
37	van Arkel ERA, de Boer HH. Survival analysis of human meniscal transplantations. *J Bone Joint Surg Br* 2002;84-B:227-231.	127	6.68	Therapeutic IV
38	Smith JP, Barrett GR. Medial and lateral meniscal tear patterns in anterior cruciate ligament-deficient knees: A prospective analysis of 575 tears. *Am J Sports Med* 2001;29:415-419.	124	6.20	Prognostic IV
39	Chevrier A, Nelea M, Hurtig MB, Hoemann CD, Buschmann MD. Meniscus structure in human, sheep, and rabbit for animal models of meniscus repair. *J Orthop Res Ther* 2009;27:1197-1203.	121	10.08	Basic Science
40	Ozkoc G, Circi E, Gonc U, Irgit K, Pourbagher A, Tandogan RN. Radial tears in the root of the posterior horn of the medial meniscus. *Knee Surg Sports Traumatol Arthrosc* 2008;16:849-854.	118	9.08	Therapeutic IV
41	Kim SB, Ha JK, Lee SW, et al. Medial meniscus root tear refixation: Comparison of clinical, radiologic, and arthroscopic findings with medial meniscectomy. *Arthroscopy* 2011;27:346-354.	117	11.70	Therapeutic III

(continued)

Table 1. Continued

Rank	Title	Total Citations	Citations per Year	Category and LOE*
42	Verdonk PCM, Forsyth RG, Wang J, et al. Characterization of human knee meniscus cell phenotype. *Osteoarthritis Cartilage* 2005;13:548-560.	117	7.31	Basic Science
43	Noyes FR, Barber-Westin SD, Rankin M. Meniscal transplantation in symptomatic patients less than fifty years old. *J Bone Joint Surg Am* 2004;86-A:1392-1404.	113	6.65	Therapeutic IV
44	Cox CL, Huston LJ, Dunn WR, et al. Are articular cartilage lesions and meniscus tears predictive of IKDC, KOOS, and Marx activity level outcomes after anterior cruciate ligament reconstruction? A 6-year multicenter cohort study. *Am J Sports Med* 2014;42:1058-1067.	110	15.71	Prognostic I
45	Wu WH, Hackett T, Richmond JC. Effects of meniscal and articular surface status on knee stability, function, and symptoms after anterior cruciate ligament reconstruction: A long-term prospective study. *Am J Sports Med* 2002;30:845-850.	109	5.74	Therapeutic II
46	Verdonk R, Verdonk P, Huysse W, Forsyth R, Heinrichs E-L. Tissue ingrowth after implantation of a novel, biodegradable polyurethane scaffold for treatment of partial meniscal lesions. *Am J Sports Med* 2011;39:774-782.	108	10.80	Therapeutic IV
47	Zarins ZA, Bolbos RI, Pialat JB, et al. Cartilage and meniscus assessment using T1rho and T2 measurements in healthy subjects and patients with osteoarthritis. *Osteoarthritis Cartilage* 2010;18:1408-1416.	108	9.82	Diagnostic I
48	Steadman JR, Rodkey WG. Tissue-engineered collagen meniscus implants: 5- to 6-Year feasibility study results. *Arthroscopy* 2005;21:515-525.	107	6.69	Therapeutic IV
49	Peretti GM, Gill TJ, Xu J-W, Randolph MA, Morse KR, Zaleske DJ. Cell-based therapy for meniscal repair: A large animal study. *Am J Sports Med* 2004;32:146-158.	107	6.29	Basic Science
50	LaPrade CM, Jansson KS, Dornan G, Smith SD, Wijdicks CA, LaPrade RF. Altered tibiofemoral contact mechanics due to lateral meniscus posterior horn root avulsions and radial tears can be restored with in situ pull-out suture repairs. *J Bone Joint Surg Am* 2014;96:471-479.	106	15.14	Basic Science

*LOE: Level of Evidence.
**Basic Science: Basic Science, Lab Controlled or Cadaveric Study.

Evidence" published in 2014 in the *Journal of Bone and Joint Surgery* (*JBJS*).[33] LOE analysis was verified by two authors independently, and 33 articles were sorted into the following categories: diagnostic, prognostic, therapeutic, and economic. Our study included LOE to identify articles with important clinical applications that direct clinicians toward answering a clinical question with the best evidence available.[33] As such, the LOE system is not used here as an independent variable defining study caliber, and LOE V was excluded as it corresponds to SRMs.

Finally, the articles were assigned a subclassification: arthroscopic meniscus repair or meniscectomy, meniscal allograft transplant or replacement tissues, biomechanics, meniscal injury with ACL reconstruction, meniscal injury, cell science, meniscal injury with development of osteoarthritis, or meniscectomy with ACL reconstruction. "Meniscal injury" was defined as studies related to the mechanics of injury or assessment of the meniscal injury and "replacement tissues" consisted of allograft-derived tissues, scaffolding, and hydrogel meniscus materials. The authors developed the subclassifications, and two authors independently assigned articles based on review of the abstract and keywords. Any discrepancies in subclassification were resolved by joint review of the entire article.

In an effort to recognize bias related to recency of publication, a second analysis of the initial Web of Science data was conducted. The raw Web of Science search was sorted by "citations per year," and the same authors independently reviewed the titles and abstract of each article. The inclusion and exclusion criteria remained the same, except for eliminating the requirement that the article be published on or after January 1, 2000. In contrast to the list of top cited articles from the last 20 years, this list was organized by ranking "number of citations per year" and included article title, authors, journal of publication, year of publication, total number of times cited, and number of citations per year.

Results

The top 50 articles related to meniscus injuries from 2000 to 2019 were published in 8 of the top 79 most influential journals and were cited a total of 8,117 times (Table 1). A total of 5,432 articles were found in the initial search. After exclusions were applied, 212 articles remained from which to generate the final list of 50 articles. Of the top 50 articles, only 13 (26%) were published in 2010 or later (Fig 1). The article with the highest number of citations appeared in *Osteoarthritis and Cartilage* in 2007, with 490 total citations, and was a basic science article focused on medial meniscus instability and osteoarthritis.[34] Overall, the number of citations ranged from 106 to 490 (median number of citations 384) and had a mean of 162.34 total citations.

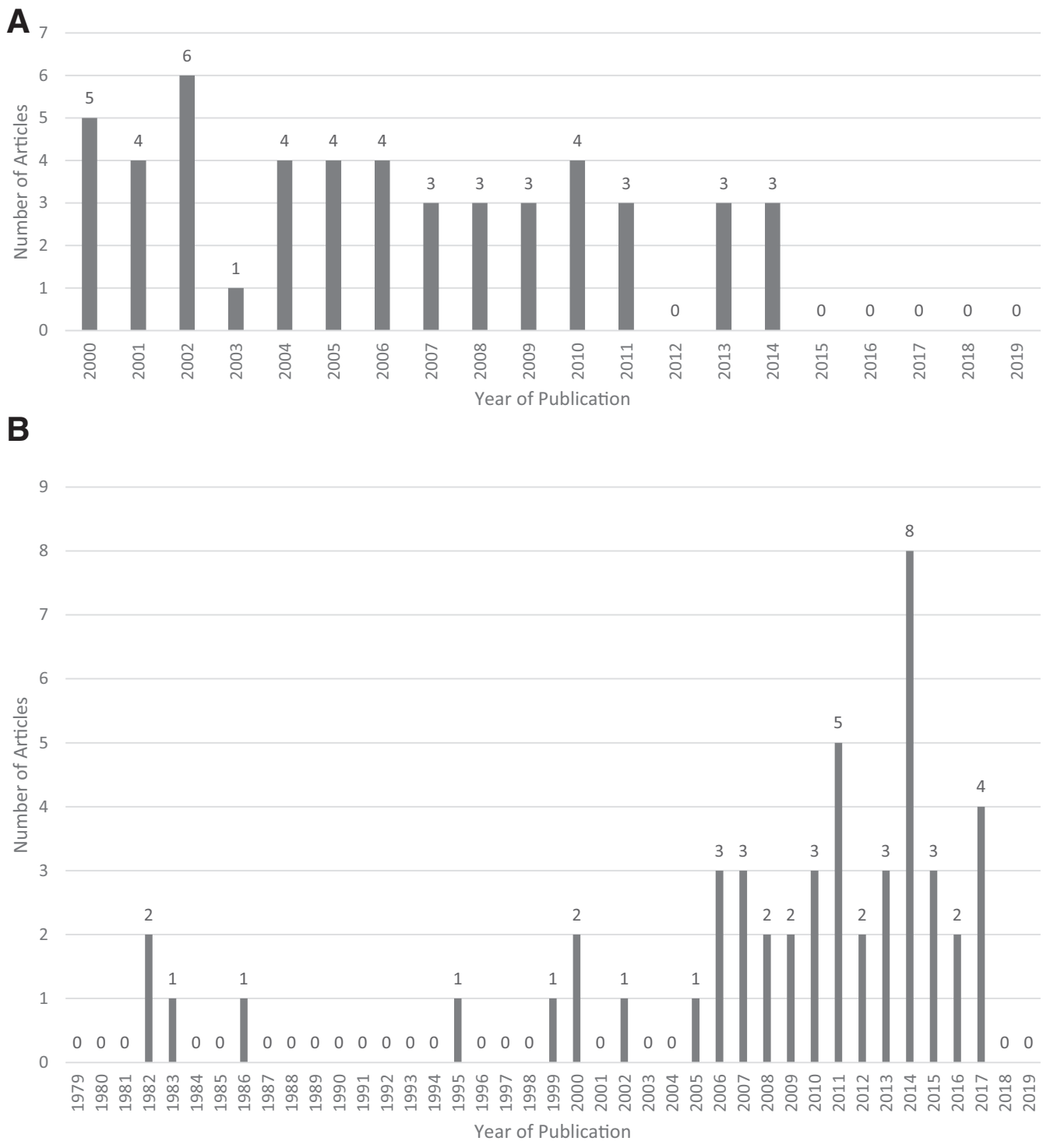

Fig 1. Number of Top 50 Cited Articles by Year Published. (A) Year of publication for top 50 articles from 2000 to 2019. The year 2002 produced the most publications for the articles that make the top 50 cited articles from 2000 to 2019. This is followed by 2000 as the second highest producer and a tie between five different years for the third highest producer. No articles younger than 2014 made the list. (B) Year of publication for the top 50 articles from 1976 to 2019. 2014, followed by 2011 and 2017 were the most productive years of publication for articles on the list of top 50 cited from 1976 to 2019. Additionally, two large gaps, 1987-1994 and 1996-1998, exist in the data where no articles published in those years made the list of top 50 cited.

As a way of addressing the bias favoring older articles, the average citations per year was also analyzed and determined to be an average of 11.91 citations per year. The top article did not change and has been cited an average of 35 times per year since its publication in 2007.[34] The least cited article overall and the least cited

Table 2A. Journals Ranked by Number of Top 50 Cited Articles on Meniscus Injuries: Top 50 Articles from 2000 to 2019

Journal	Country	Number of Cited Articles in Top 50	InCites Journal Citation Report Rank**	Journal Impact Factor*	Total Cites
The American Journal of Sports Medicine	United States	15	1	6.093	35,110
The Journal of Bone & Joint Surgery — American Volume	United States	9	4	4.716	46,190
Arthroscopy	United States	8	5	4.433	17.057
Osteoarthritis and Cartilage	United Kingdom	7	3	4.879	16,264
Knee Surgery, Sports Traumatology, Arthroscopy	Germany	5	13	3.149	14,500
Journal of Orthopedic Research	United States	3	16	3.043	14,813
The Journal of Bone & Joint Surgery — British Volume	United Kingdom	2	6	4.301	5,865
Clinical Biomechanics	United Kingdom	1	35	1.977	8,724

*Journal Impact Factor identifies the frequency of citations per year of an average article in that journal.
**InCites Journal Citation Report Rank is based on that Impact Factor.

article per year did show variability. The article that had been cited the least number of times per year (5.74) had been cited 109 times overall since it was published in 2002 (35). The least cited article overall has 106 total citations but an impressive 15.14 citations per year since its publication in 2014.[36]

The *American Journal of Sports Medicine* (*AJSM*) and the *JBJS — American Version* published the most articles related to this topic, with 15 (30%) and 9 (18%) articles, respectively (Table 2A). Of the 8 journals represented in the top 50, 5 of the journals rank in the top 6 by journal impact factor in the 2018 InCites Journal Citation Report, and all 8 are ranked in the top 35.[32] In concordance with having the highest number of articles in the top 50, *AJSM* was ranked number 1 with a journal impact factor of 6.093 in 2018 (Table 2A). Twenty-five (50%) of the top 50 cited articles were therapeutic, with 6 (14%) classified as Level III and 13 (26%) classified as Level IV (Table 1). Four (8%) articles were classified as diagnostic and 4 (8%) were prognostic. Seventeen (34%) of the studies were basic science research or lab controlled, which does not fall into the LOE clinical article classification system.

The most productive years for frequently cited articles were 2002 (n = 6, 12%)[35,37–41] and 2000 (n = 5, 10%),[25,42–45] and an average of 3.33 articles were published per year (Fig 1). The most recent article included in this study was published in May 2014 and has been cited 110 times since its publication (Fig 1).[46] The top 50 cited articles were further classified into 8 general subtopics related to the treatment and diagnosis of meniscal injuries (Table 3). Of the 50 articles, 16 (32%) focused on arthroscopic procedures for meniscus repair and/or meniscectomy, and 13 (26%) articles evaluated the use of meniscal allograft transplants or other replacement tissues.

Seventy-one different institutions or organizations of origin were identified from the top 50 cited articles and represented 14 different countries (Fig 2). Three articles showed research collaborations between more than one country. McNicholas et al.[45] is a collaboration between Scotland and Sweden, Zarins et al.[47] is a collaboration between France and the United States, and Peretti et al.[48] is a collaboration between China, Italy, and the United States. Twenty-nine (58%) articles originated from institutions in the United States, which is an interesting finding, as only four of the eight publishing journals are in the United States (Table 2A). The United Kingdom (3) and Germany (1) publish the other four journals on the top 50 list, but combined the two nations only produced 2 of the articles. Of the contributing institutions, Ghent University Hospital (Ghent, Belgium), Steadman Hawkins Research Foundation (Vail, CO, USA), and The Hospital for Special Surgery (New York, NY, USA) contributed the highest number of articles with 4 each. In the United States, the articles originate from 10 different medical schools and 5 of those medical schools currently receive enough National Institute of Health (NIH) funding to hold a spot among the top 40 funded medical schools in the United States.[49]

Table 2B. Journals Ranked by Number of Top 50 Cited Articles on Meniscus Injuries: Top 50 Articles From 1976 to 2019

Journal	Country	Number of Cited Articles in Top 50	InCites Journal Citation Report Rank	Journal Impact Factor	Total Cites
The American Journal of Sports Medicine	United States	23	1	6.093	35,110
The Journal of Bone & Joint Surgery — American Volume	United States	8	4	4.716	46,190
Osteoarthritis and Cartilage	United Kingdom	7	3	4.879	16,264
Knee Surgery, Sports Traumatology, Arthroscopy	Germany	6	13	3.149	14,500
Arthroscopy	United States	3	5	4.433	17.057
Journal of Orthopedic Research	United States	2	16	3.043	14,813
Acta Orthopedica	United Kingdom	1	11	3.217	8,685

Table 3. Most Common Subclassifications of Top 50 Cited Articles

Subclassification	Number of Articles
Arthroscopic Meniscus Repair or Meniscectomy	16
Meniscal Allograft Transplant or Replacement Tissues	13
Biomechanics	6
Meniscal Injury with Anterior Cruciate Ligament Reconstruction	4
Meniscal Injury - Mechanism of meniscal injury - Assessment of the meniscal injury	3
Cell Science	3
Meniscal Injury with the Development of Osteoarthritis	3
Meniscectomy with Anterior Cruciate Ligament Reconstruction	1

Table 4 lists the articles by "number of citations per year" and eliminates the exclusion criteria of publication date. The top 2 articles did not change, and only 6 articles published before 2000 made the second list. In the list of the 50 most cited (Table 1), 2014 was the most recent publication year, but changing to citations per year allowed for inclusion of 9 articles published in the timeframe of 2015 to 2017 (Table 4).[50–58] *AJSM* remained the most frequent journal of publication, and the top 6 journals did not change (Table 2B).

Discussion

This study identified the 50 most cited articles related to meniscus injury published from 2000 to 2019. As predicted, our study found a strong skew toward articles published in earlier years with 74% published before 2010, along with a predominance of therapeutic studies (50%). Only 5 (10%) of the identified studies made use of a therapeutic controlled trial study design. We anticipated that "meniscal allograft transplant or other replacement tissues" would occupy the top spot on the list of subclassifications because our list focused on more recent publication years and potentially the inclusion of a high percentage of articles related to tissue engineering or transplant improvement. In opposition to our original projection, the most abundant article subclassification was "arthroscopic meniscus repair or meniscectomy" (32%), followed closely by "meniscal allograft transplant or other replacement tissues" with 26%.

Similar to other bibliometric analyses in orthopaedic surgery, most of the 50 most cited articles for meniscal injuries were classified as Level IV, specifically Level IV therapeutic studies.[1,4,6,11,59] Our analysis identified 9 (18%) Level I therapeutic studies (Table 1), which is higher than in previous bibliometric reviews in the field of orthopaedics and shows variance among topics within the specialty. Lefaivre et al.[12] demonstrated that 5% of the top 100 most cited articles in orthopaedic trauma surgery were Level I studies and Namdari

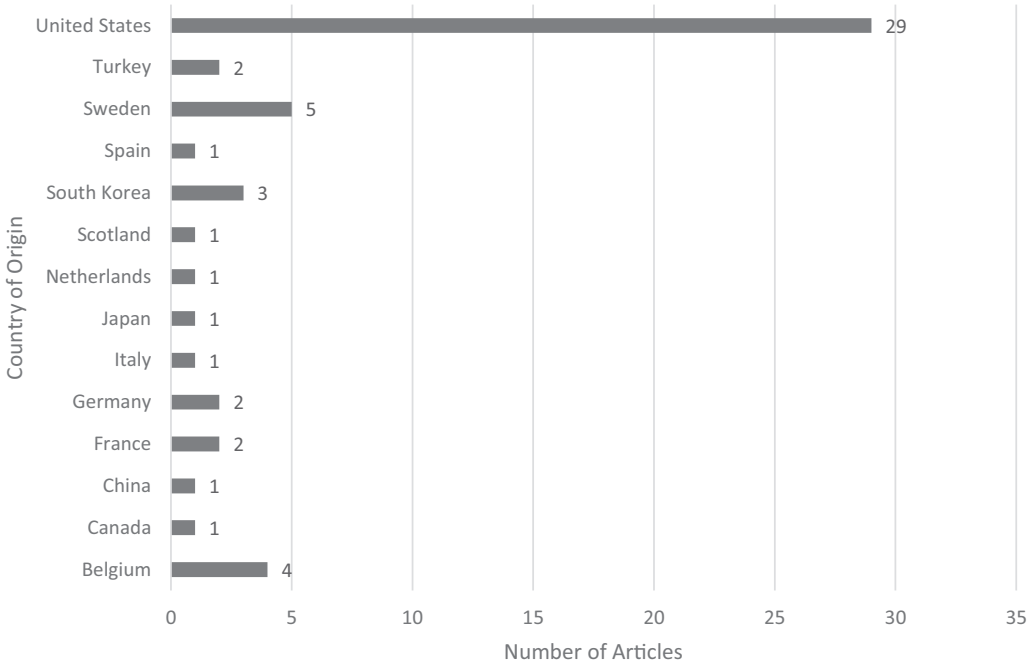

Fig 2. Number of articles by country of origin for contributing institutions. 14 nations of origin are shown for each of the 50 articles that appear on the list of top 50 cited articles on meniscus injuries from 2000 to 2019. Academic centers and other institutions within the United States produced 29 of the articles on the list, followed in second by Sweden (5) and Belgium (4) in third.

Table 4. Top 50 Articles by Citation per Year from 1976 to 2019

Rank	Title	Total Citations	Citations per Year
1	Glasson SS, Blanchet TJ, Morris EA. The surgical destabilization of the medial meniscus (DMM) model of osteoarthritis in the 129/SvEv mouse. *Osteoarthritis Cartilage* 2007;15:1061-1069.	490	35.00
2	Allaire R, Muriuki M, Gilbertson L, Harner CD. Biomechanical consequences of a tear of the posterior root of the medial meniscus: Similar to total meniscectomy. *J Bone Joint Surg Am* 2008;90:1922-1931.	365	28.08
3	Vangsness CT, Farr J, Boyd J, Dellaero DT, Mills CR, LeRoux-Williams M. Adult human mesenchymal stem cells delivered via intra articular injection to the knee following partial medial meniscectomy: A randomized, double-blind, controlled study. *J Bone Joint Surg Am* 2014;96:90-98.	184	26.29
4	Yim J-H, Seon J-K, Song E-K, et al. A comparative study of meniscectomy and nonoperative treatment for degenerative horizontal tears of the medial meniscus. *Am J Sports Med* 2013;41:1565-1570.	158	19.75
5	Herrlin SV, Wange PO, Lapidus G, Hållander M, Werner S, Weidenhielm L. Is arthroscopic surgery beneficial in treating non-traumatic, degenerative medial meniscal tears? A five year follow-up. *Knee Surg Sports Traumatol Arthrosc* 2013;21:358-364.	149	18.63
6	Stein T, Mehling AP, Welsch F, von Eisenhart-Rothe R, Jäger A. Long-term outcome after arthroscopic meniscal repair versus arthroscopic partial meniscectomy for traumatic meniscal tears. *Am J Sports Med* 2010;38:1542-1548.	183	16.64
7	Lee SJ, Aadalen KJ, Malaviya P, et al. Tibiofemoral contact mechanics after serial medial meniscectomies in the human cadaveric knee. *Am J Sports Med* 2006;34:1334-1344.	241	16.07
8	Prodromos CC, Joyce BT, Keller BL, Murphy BJ, Shi K. Magnetic resonance imaging measurement of the contralateral normal meniscus is a more accurate method of determining meniscal allograft size than radiographic measurement of the recipient tibial plateau. *Arthroscopy* 2007;23:1174-1179.	219	15.64
9	Cox CL, Huston LJ, Dunn WR, et al. Are articular cartilage lesions and meniscus tears predictive of IKDC, KOOS, and Marx activity level outcomes after anterior cruciate ligament reconstruction? A 6-year multicenter cohort study. *Am J Sports Med* 2014;42:1058-1067.	110	15.71
10	Anderson AF, Anderson CN. Correlation of meniscal and articular cartilage injuries in children and adolescents with timing of anterior cruciate ligament reconstruction. *Am J Sports Med* 2015;43:275-281.	94	15.67
11	Stephen JM, Halewood C, Kittl C, Bollen SR, Williams A, Amis AA. Posteromedial meniscocapsular lesions increase tibiofemoral joint laxity with anterior cruciate ligament deficiency, and their repair reduces laxity. *Am J Sports Med* 2016;44:400-408.	78	15.60
12	LaPrade CM, Jansson KS, Dornan G, Smith SD, Wijdicks CA, LaPrade RF. Altered tibiofemoral contact mechanics due to lateral meniscus posterior horn root avulsions and radial tears can be restored with in situ pull-out suture repairs. *J Bone Joint Surg Am* 2014;96:471-479.	106	15.14
13	Pauli C, Grogan SP, Patil S, et al. Macroscopic and histopathologic analysis of human knee menisci in aging and osteoarthritis. *Osteoarthritis Cartilage* 2011;19:1132-1141.	149	14.90
14	Arnoczky SP, Warren RF. Microvasculature of the human meniscus. *Am J Sports Med* 1982;10:90-95.	567	14.54
15	Musahl V, Rahnemai-Azar AA, Costello J, et al. The influence of meniscal and anterolateral capsular injury on knee laxity in patients with anterior cruciate ligament injuries. *Am J Sports Med* 2016;44:3126-3131.	72	14.40
16	Beaufils P, Becker R, Kopf S, et al. Surgical management of degenerative meniscus lesions: The 2016 ESSKA meniscus consensus. *Knee Surg Sports Traumatol Arthrosc* 2017;25:335-346.	57	14.25
17	Verdonk PCM, Verstraete KL, Almqvist KF, et al. Meniscal allograft transplantation: Long-term clinical results with radiological and magnetic resonance imaging correlations. *Knee Surg Sports Traumatol Arthrosc* 2006;14:694-706	212	14.13
18	Herrlin S, Hållander M, Wange P, Weidenhielm L, Werner S. Arthroscopic or conservative treatment of degenerative medial meniscal tears: A prospective randomized trial. *Knee Surg Sports Traumatol Arthrosc* 2007;15:393-401.	195	13.93
19	Musahl V, Citak M, O'Loughlin PF, Choi D, Bedi A, Pearle AD. The effect of medial versus lateral meniscectomy on the stability of the anterior cruciate ligament-deficient knee. *Am J Sports Med* 2010;38:1591-1597.	152	13.82
20	Baratz ME, Fu FH, Mengato R. Meniscal tears: The effect of meniscectomy and of repair on intraarticular contact areas and stress in the human knee. *Am J Sports Med* 1986;14:270-275.	480	13.71
21	Padalecki JR, Jansson KS, Smith SD, et al. Biomechanical consequences of a complete radial tear adjacent to the medial meniscus posterior root attachment site: In situ pull-out repair restores derangement of joint mechanics. *Am J Sports Med* 2014;42:699-707.	96	13.71

(continued)

Table 4. Continued

Rank	Title	Total Citations	Citations per Year
22	Roos H, Adalberth T, Dahlberg L, Lohmander LS. Osteoarthritis of the knee after injury to the anterior cruciate ligament or meniscus: The influence of time and age. *Osteoarthritis Cartilage* 1995;3:261-267.	355	13.65
23	Marzo JM, Gurske-DePerio J. Effects of medial meniscus posterior horn avulsion and repair on tibiofemoral contact area and peak contact pressure with clinical implications. *Am J Sports Med* 2009;37:124-129.	156	13.00
24	Shybut TB, Vega CE, Haddad J, et al. Effect of lateral meniscal root tear on the stability of the anterior cruciate ligament-deficient knee. *Am J Sports Med* 2015;43:905-911.	78	13.00
25	Bedi A, Kelly NH, Baad M, et al. Dynamic contact mechanics of the medial meniscus as a function of radial tear, repair, and partial meniscectomy. *J Bone Joint Surg Am* 2010;92:1398-1408.	142	12.91
26	Gauffin H, Tagesson S, Meunier A, Magnusson H, Kvist J. Knee arthroscopic surgery is beneficial to middle-aged patients with meniscal symptoms: A prospective, randomized, single-blinded study. *Osteoarthritis Cartilage* 2014;22:1808-1816.	90	12.86
27	Krych AJ, Reardon PJ, Johnson NR, et al. Non-operative management of medial meniscus posterior horn root tears is associated with worsening arthritis and poor clinical outcome at 5-year follow-up. *Knee Surg Sports Traumatol Arthrosc* 2017;25:383-389.	50	12.50
28	LaPrade CM, James EW, Cram TR, Feagin JA, Engebretsen L, LaPrade RF. Meniscal root tears: A classification system based on tear morphology. *Arthroscopy* 2015;43:363-369.	74	12.33
29	Levy IM, Torzilli PA, Warren RF. The effect of medial meniscectomy on anterior-posterior motion of the knee. *J Bone Joint Surg Am* 1982;64-A:883-888.	480	12.31
30	Thorlund JB, Hare KB, Lohmander LS. Large increase in arthroscopic meniscus surgery in the middle-aged and older population in Denmark from 2000 to 2011. *Acta Orthop* 2014;85:287-292.	86	12.29
31	Sonnery-Cottet B, Conteduca J, Thaunat M, Gunepin FX, Seil R. Hidden lesions of the posterior horn of the medial meniscus: A systematic arthroscopic exploration of the concealed portion of the knee. *Am J Sports Med* 2014;42:921-926.	84	12.00
32	Verdonk PCM, Demurie A, Almqvist KF, Veys EM, Verbruggen G, Verdonk R. Transplantation of viable meniscal allograft: Survivorship analysis and clinical outcome of one hundred cases. *J Bone Joint Surg Am* 2005;87-A:715-724.	188	11.75
33	Kim SB, Ha JK, Lee SW, et al. Medial meniscus root tear refixation: Comparison of clinical, radiologic, and arthroscopic findings with medial meniscectomy. *Arthroscopy* 2011;27:346-354.	117	11.70
34	Zhang Z-Z, Wang S-J, Zhang J-Y, et al. 3D-Printed poly(ε-caprolactone) scaffold augmented with mesenchymal stem cells for total meniscal substitution: A 12- and 24-week animal study in a rabbit model. *Am J Sports Med* 2017;45:1497-1511.	46	11.50
35	Hatsushika D, Muneta T, Nakamura T, et al. Repetitive allogeneic intraarticular injections of synovial mesenchymal stem cells promote meniscus regeneration in a porcine massive meniscus defect model. *Osteoarthritis Cartilage* 2014;22:941-950.	80	11.43
36	LaPrade RF, Matheny LM, Moulton SG, James EW, Dean CS. Posterior meniscal root repairs: Outcomes of an anatomic transtibial pull-out technique. *Am J Sports Med* 2017;45:884-891.	45	11.25
37	Shelbourne KD, Gray T. Results of anterior cruciate ligament reconstruction based on meniscus and articular cartilage status at the time of surgery: Five- to fifteen-year evaluations. *Am J Sports Med* 2000;28:446-452.	235	11.19
38	Briggs KK, Kocher MS, Rodkey WG, Steadman JR. Reliability, validity, and responsiveness of the Lysholm knee score and Tegner activity scale for patients with meniscal injury of the knee. *J Bone Joint Surg Am* 2006;88-A:698-705.	165	11.00
39	Segawa Y, Muneta T, Makino H, et al. Mesenchymal stem cells derived from synovium, meniscus, anterior cruciate ligament, and articular chondrocytes share similar gene expression profiles. *J Orthop Res Ther* 2009;27:435-441.	132	11.00
40	Gale DR, Chaisson CE, Totterman SMS, Schwartz RK, Gale ME, Felson D. Meniscal subluxation: Association with osteoarthritis and joint space narrowing. *Osteoarthritis Cartilage* 1999;7:526-532.	241	10.95
41	Johannsen AM, Civitarese DM, Padalecki JR, Goldsmith MT, Wijdicks CA, LaPrade RF. Qualitative and quantitative anatomic analysis of the posterior root attachments of the medial and lateral menisci. *Am J Sports Med* 2012;40:2342-2347.	98	10.89
42	Badlani JT, Borrero C, Golla S, Harner CD, Irrgang JJ. The effects of meniscus injury on the development of knee osteoarthritis: Data from the osteoarthritis initiative. *Am J Sports Med* 2013;41:1238-1244.	87	10.88
43	Verdonk R, Verdonk P, Huysse W, Forsyth R, Heinrichs E-L. Tissue ingrowth after implantation of a novel, biodegradable polyurethane scaffold for treatment of partial meniscal lesions. *Am J Sports Med* 2011;39:774-782	108	10.80
44	Allen CR, Wong EK, Livesay GA, Sakane M, Fu FH, Woo SL-Y. Importance of the medial meniscus in the anterior cruciate ligament-deficient knee. *J Orthop Res Ther* 2000;18:109-115.	225	10.71

(continued)

Table 4. Continued

Rank	Title	Total Citations	Citations per Year
45	Horie M, Choi H, Lee RH, et al. Intra-articular injection of human mesenchymal stem cells (MSCs) promote rat meniscal regeneration by being activated to express Indian hedgehog that enhances expression of type II collagen. *Osteoarthritis Cartilage* 2012;20:1197-1207.	96	10.67
46	Rodkey WG, DeHaven KE, Montgomery WH, et al. Comparison of the collagen meniscus implant with partial meniscectomy: A prospective randomized trial. *J Bone Joint Surg Am* 2008;90:1413-1426.	136	10.46
47	Arnoczky SP, Warren RF. The microvasculature of the meniscus and its response to injury: An experimental study in the dog. *Am J Sports Med* 1983;11:131-141.	396	10.42
48	Trojani C, Sbihi A, Djian P, et al. Causes for failure of ACL reconstruction and influence of meniscectomies after revision. *Knee Surg Sports Traumatol Arthrosc* 2011;19:196-201.	104	10.40
49	Millett PJ, Willis AA, Warren RF. Associated injuries in pediatric and adolescent anterior cruciate ligament tears: Does a delay in treatment increase the risk of meniscal tear? *Arthroscopy* 2002;18:955-959.	193	10.16
50	Zaffagnini S, Marcheggiani Muccioli GM, Lopomo N, et al. Prospective long-term outcomes of the medial collagen meniscus implant versus partial medial meniscectomy: A minimum 10-year follow-up study. *Am J Sports Med* 2011;39:977-985.	101	10.10

et al.[59] found no Level I studies in an analysis of the 50 most cited articles related to orthopaedic shoulder surgery. Five of 9 (55.5%) Level I studies identified in our search were therapeutic controlled trials, 3 (33.3%) were testing previously developed diagnostic criteria, and the last was a Level I prognostic study. The development and execution of Level I randomized controlled trials remain difficult in the field of orthopaedic surgery and help explain the low number of Level I studies. As with any surgical intervention, scars often eliminate blinding when comparing surgical techniques, and sham surgeries are widely viewed as unethical, which makes comparing surgical to nonsurgical techniques difficult to blind. Compared to medical therapy or medication trials, orthopaedic surgery often lacks the ability to administer a placebo, provide a washout period, or easily analyze data when a patient assigned a nonsurgical treatment group decides to undergo surgical management.[60,61]

There was a lack of economic and decision analysis studies found in this review. Economic studies are an established study design within the *JBJS* LOE hierarchical rating system and range from computer simulation models in Levels I-III to decision tree analyses in Levels IV-V.[33] This work is being done but has not reached a point where these articles are being highly cited by other authors, most likely due to the nature of becoming quickly outdated as technology advances, research evolves, and reimbursement changes. For example, although cited only 3 times, Bendich et al. in 2018 found that meniscal allograft transplant was about 1/3 more effective at delaying osteoarthritis and represents the most cost-effective treatment.[62] Economic studies may be important in the clinical decision-making or treatment planning process but fail to reach a threshold for inclusion in a bibliometric analysis such as this study.[63]

Over half (58%) of the articles identified in our list originated in the United States (Fig 2), which agrees with previous bibliometric studies in both orthopaedic surgery and other specialties, including the fields of plastic and general surgery.[11,64-66] This could suggest that American authors hold an advantage within publishing, or it demonstrates the importance of meniscal research generated in the United States, or it could simply reflect the high presence of articles from *AJSM* on our list. Most likely, this finding represents some combination of all of these factors.

One major source of exclusion for our list involved removing articles with a primary focus on ACL injury or reconstruction, and even with this exclusion, we found that 5 (10%) of the highest cited articles also addressed the ACL in the subclassifications (Table 3). Goljan et al. provided the ideal comparison article because it examined the 30 most highly cited articles related to ACL injuries from 1994 to 2014, a similar 20-year time frame.[2] The major similarity between the two bibliometric reviews was that *AJSM* published the majority of the articles, with 16 of 30 (53%) for the ACL and 15 of 50 (30%) for the meniscus. A striking difference between the studies was that the list presented in Goljan et al. contained no articles with a dual focus on ACL and meniscus injury/surgery. Also, the most highly cited ACL article had 611 citations, while the lowest number of citations was 188, and an overall average of 283.87 per article. Our most cited article has a total of 490 citations, while the least cited article has 106 citations, and an overall article average of 162.34 times. This suggests a stronger focus on ACL injury and reconstruction in the literature, especially as both analyses involved a similar 20-year timeframe. Additionally, 5 of 30 (17%) top cited ACL articles focused on gender differences and 2 of 30 (7%) focused on the

prevention of ACL injuries, areas of investigation missing in our article analysis. [2]

Limitations

There are several limitations to this study. First, the study relies on the Web of Science Citation Index to identify the top 50 most cited articles and will only include articles captured in the Web of Science database. Second, a higher level of evidence according to the *JBJS* LOE classification system typically signifies a higher-quality study.[33] This classification system, as well as just counting the number of citations, does not necessarily reflect the direct clinical relevance or the impact the article makes on daily practice. For example, the number of times cited may become inflated by self-citation or bias in the selection of supporting evidence for a new article.[14] Unfortunately, there is currently no way to completely eliminate this bias; therefore, physicians must evaluate the articles individually for relevance or impact before adopting new clinical practices.

Although removing the SRMs allows for more inclusion of the original studies, attention must be paid as to how this practice creates bias, especially as systematic reviews currently receive a Level V in the *JBJS* LOE system and are highly cited by other authors.[33,67] One study identified that SRMs, when compared to original articles, received higher ratings for relevance, with high marks for review articles providing the "bottom line," but significantly lower marks for newsworthiness or novelty, accounting for more of the "cutting-edge" side of medical research.[68] This suggests that within the bibliometric analysis genre of articles, SRMs and original articles should potentially be analyzed separately to allow for comparison between more similar article types.

We acknowledge that a bias exists in ranking articles by total number of citations (vs. number of citations per year) and that this manipulation of the list may eliminate articles published more recently but with a high rate of recent citation. Inclusion of Table 4 and the subsequent analysis of those results attempted to highlight how this bias influences the bibliometric analysis genre of research. Another finding in Table 4 that points to an inherent bias in this kind of analysis is the inclusion of 6 articles published before 2000. These 6 publications combined have been cited 2,519 times (ranging from 567 to 241 times).[30,69–73] Compared to the highest cited article in Table 4, cited 35.0 times per year, the highest cited article from before 2000 was published in 1982 and only computes to 14.5 citations per year.[34,69] A bibliometric analysis like this is unable to parse apart whether these older articles continue to be heavily referenced by authors today or had such high numbers of citations in the past that they continue to show a strong presence on lists of top cited articles. If the latter is true, these articles would be projected to eventually fall off a list produced with bibliometric techniques.

Conclusion

This study of most-cited meniscus articles showed a strong predominance of therapeutic studies that were generated and published within the United States and focused on topics of arthroscopic repair or removal. Overwhelmingly, included articles were published before 2010, which confirms the criticism that bibliometric analysis favors older articles.

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