

The 50 Most Cited Articles in Knee Medial Collateral Ligament Injury Research

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Background: Medial collateral ligament (MCL) injury is a common orthopaedic knee injury with a plethora of published articles regarding evaluation, treatment, and outcome.

Purpose: To perform a comprehensive bibliometric analysis of the 50 most cited articles in MCL research.

Study Design: Cross-sectional study.

Methods: We performed a keyword search of the Institute for Scientific Information's Web of Knowledge database for the identification of articles published before September 2021 encompassing the MCL. The conducted search yielded 9534 articles. The results were then filtered using predetermined guidelines and criteria, and the 50 most cited articles were selected for analysis. Extracted data included title, authors, citation count, year of publication, topic, journal, article type, country of origin, and level of evidence.

Results: The selected 50 articles ranged from 1976 to 2013. The largest proportion was classified as having level 4 evidence ($n = 12$; 24%). The majority of the articles were published in the decade from 2000 to 2009 ($n = 17$; 34%), followed by 1990 to 1999 ($n = 16$; 32%). The mean raw citation score per article was 133 (range, 74-422). The most popular topic discussed was surgical technique and outcome ($n = 14$; 28%), followed by anatomy and biomechanics ($n = 13$; 26%).

Conclusion: This study provides a comprehensive and objective measure of the most cited articles on MCL research. Knowledge of the characteristics of these most influential articles improves the understanding of MCL injury and can guide discussion for future research.

Keywords: bibliometric; analysis; medial collateral ligament; MCL injury; citation

The medial collateral ligament (MCL) is a major stabilizer as 1 of the 4 ligaments in the knee,¹ and it accounts for nearly 8% of all knee injuries.²³ These injuries are extremely common in athletic environments with an emphasis on sports such as judo, skiing, hockey, and rugby.¹⁵ MCL injuries tend to be more prevalent among male athletes and result in an average of approximately 23 days of lost time for minor injuries and significantly more for higher-grade injuries.^{21,27} Knowledge of the mechanism of injury, healing potential, treatment options, and patient outcomes is vital for clinicians to optimize outcomes in MCL injuries.

Bibliometric analysis is the statistical interpretation that quantifies the influence of published articles, books, or chapters on the scientific community, and it appraises the impact of an article by using the number of times that it has been cited by other authors.¹¹ Within the field of orthopaedic surgery, bibliometric analyses have been conducted to assess research conducted on topics such as meniscal

injuries, knee surgery, ankle surgery, and rotator cuff tears.^{4,6,19,35} However, no current analysis has been conducted on MCL injuries, pathology, and management.

The purpose of this review was to perform a thorough bibliometric analysis to comprehensively assess the 50 most cited articles in MCL research to illustrate the highest-impact articles regarding MCL injury, pathology, and management. This analysis aims to improve the understanding of the current research focuses of MCL pathology and the understanding of research insufficiencies to better guide the development of new research inquiries. We hypothesize that the most influential articles would predominantly focus on the mechanism of injury and surgical technique guides.

METHODS

In September 2021, we used the Institute for Scientific Information's Web of Knowledge database (also known as the Web of Science Core Collection, MEDLINE, BIOSIS Citation Index, Scielo Citation Index, KCI-Korean Journal Database, and Russian Science Citation Index) to identify articles

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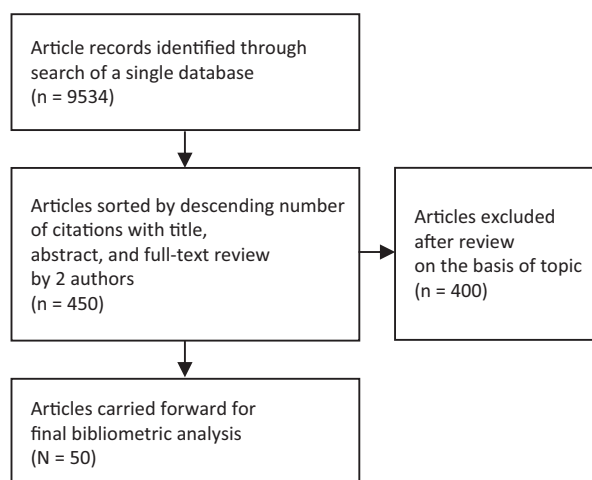


Figure 1. Modified PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) diagram detailing the collection of the top 50 most cited articles pertaining to knee medial collateral ligament injury.

related to MCL injuries. The following keywords were used: medial collateral ligament OR medial collateral ligament injury OR mcl injury OR unhappy triad OR valgus instability OR medial collateral ligament repair OR medial collateral ligament reconstruction OR mcl repair OR mcl reconstruction OR valgus stress test OR medial collateral ligament tear OR medial collateral ligament sprain OR tibial collateral ligament OR valgus deformity OR MCL instability.

The search was conducted by a trained medical student researcher (D.L.). Inclusion criteria were original peer-reviewed articles such as review articles, systematic reviews, meta-analyses, and guidelines. Articles were sorted by citation count and screened by title and abstract. Duplicates and articles that did not pertain to MCL injuries, pathology, healing, or management were excluded. Two medical student independent investigators reviewed the titles and abstracts of the articles to finalize the top 50 cited in our study (D.L., H.D.). An orthopaedic surgery resident (M.G.R.) and lead author (D.L.) reviewed each article to finalize the top 50 in the study. Any disagreements in article selection were reviewed by the principal investigator (M.G.B.), who had the final decision for article inclusion.

The following data were extracted from each article by 2 trained researchers (D.L., M.G.): title, source journal, study design, main topic, language, citations, year, institutional affiliation, country of origin, and level of evidence. The country of origin was determined by the address of the corresponding author's affiliated institution. The articles were

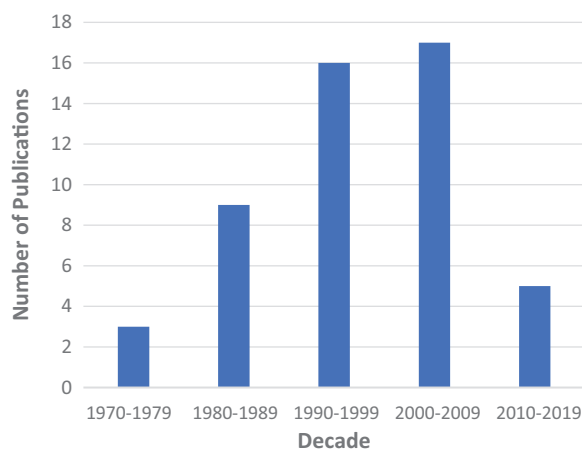


Figure 2. Distribution of highest cited articles according to decade, 1970s through 2010s.

ranked by the number of citations per article. If multiple articles had the same number of citations, the most recently published one received a prioritized ranking. The level of evidence was assigned either upon evaluation of the abstract or by full-text review using the guidelines of the *Journal of Bone and Joint Surgery*.³⁴ Many articles provided the level of evidence within the abstract. An investigator (D.L.) determined the article topic and category before the onset of the study. Article topic included anatomy and biomechanics, imaging, prevention and rehabilitation, surgical technique and outcome, tissue engineering, and epidemiology. Article category included clinic science and outcomes, basic science, and review and meta-analysis. Articles were placed into only 1 category via reviewer determination, and this most applicable category for that article was selected.

RESULTS

The conducted search yielded 9534 articles. The articles were ranked in descending order of citations. The first 450 results were reviewed, and 400 articles were then excluded by article topic. This left the remaining 50 articles (Figure 1).

The 50 most cited articles are listed in Appendix Table A1. The mean number of citations was 133 (range, 74-122; median, 105). All articles were published between 1976 and 2013. In terms of productivity by decade, most articles were published between 2000 and 2009 ($n = 17$) and between 1990 and 1999 ($n = 16$). The 1980s, 2010s, and 1970s had a lower number of contributions with 9, 5, and 3 publications, respectively (Figure 2). Of the top 10 most cited articles, the

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Ethical approval was not sought for the present study.

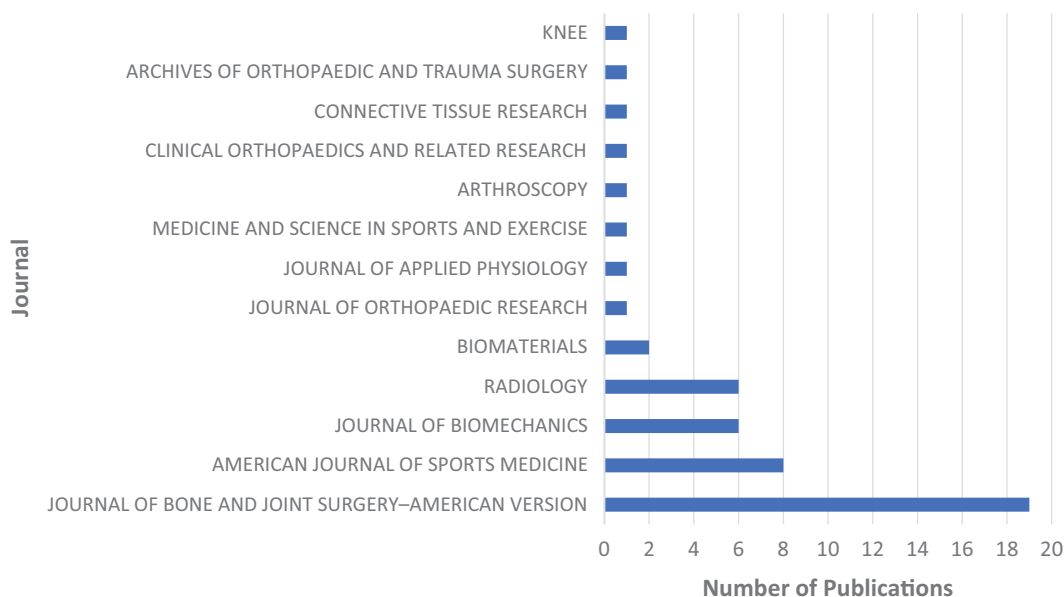


Figure 3. Distribution of highest cited articles according to journal.

most productive period for publishing was 2000 to 2009, with 5 articles.

Regarding the number of publications per journal, the greatest contribution was from the *Journal of Bone and Joint Surgery—American Volume* (n = 19), followed by the *American Journal of Sports Medicine* (n = 8), *Journal of Biomechanics* (n = 6), and *Radiology* (n = 6). All other journals contributed <5 articles (Figure 3). The majority were published in the United States (n = 40). Canada published the second most (n = 3), with Switzerland, Finland, China, Japan, and Denmark each producing <3 publications.

Of the top 50 most cited articles, 24 were categorized as foundational research and therefore did not receive a level of evidence score. Of the publications receiving a level of evidence, most were level 4 studies (n = 12), followed by level 3 studies (n = 8). The largest proportion of articles focused on clinical science and outcomes (n = 27), followed by basic science research (n = 20) (Figure 4). The remaining articles were categorized as review and meta-analysis (n = 3). Within our list, the most frequently studied topic was surgical technique and outcomes (n = 14) (Figure 5). There was also a significant proportion of anatomy and biomechanics (n = 13), prevention and rehabilitation (n = 7), and tissue engineering studies (n = 7).

DISCUSSION

This bibliometric analysis highlights the most important articles frequently referenced by the scientific community when researching topics concerning MCL injury, pathology, healing, and management. The majority were low-level evidence studies (level 4, n = 12; level 3, n = 8), and most publications came from research groups in the United States (n = 40).

Treatment was the primary focus of these articles, as new techniques and interventions are being introduced to

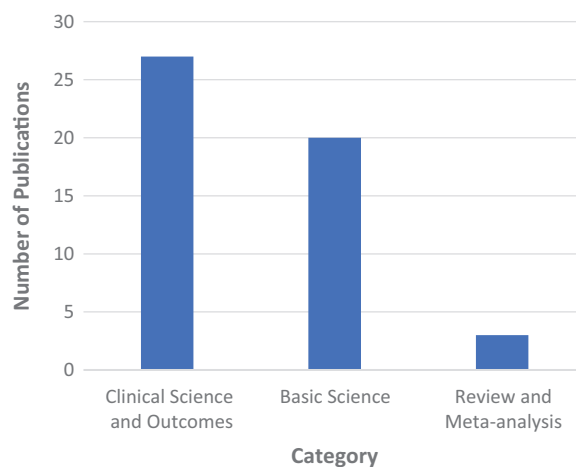


Figure 4. Distribution of highest cited articles according to category.

provide innovative ways to restore affected structures to normal function. Because MCL injuries are the most common ligamentous knee injuries, research has shown that a well-guided rehabilitation program is crucial to achieving excellent functional outcomes in the majority of patients.¹⁷ Most MCL injuries—grade 1, 2, and 3 tears without valgus instability—are managed nonsurgically with a special emphasis on brace protection, range of motion, and gait training before return to activity.¹⁵ However, for the small subset of patients who do require surgical management, quick and effective identification and treatment of these patients signify a better outcome.^{5,22} As a result, improvement in outcomes, interventions, and technique is a very popular topic of MCL research, thus explaining the predominance of articles found under this subcategory.

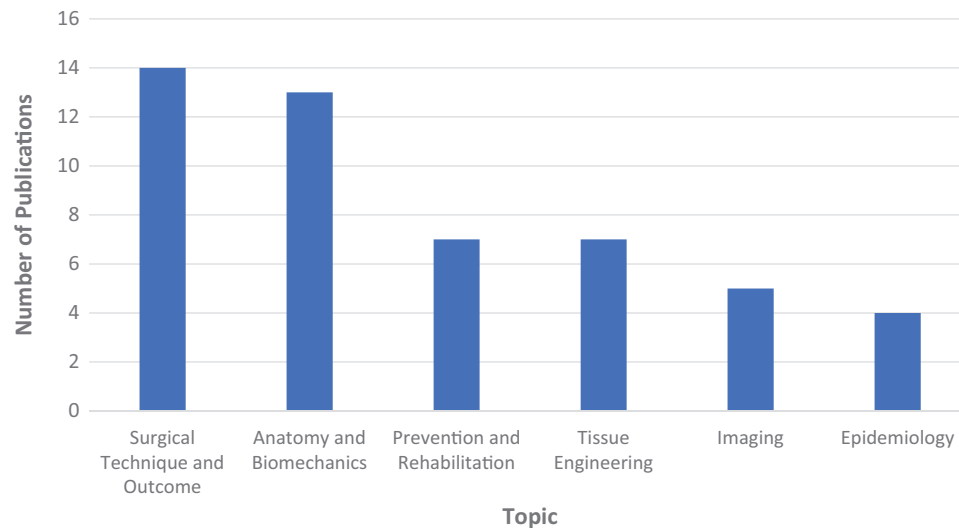


Figure 5. Distribution of highest cited articles according to topic researched.

Another popular topic among the most cited studies was anatomy and biomechanics.[‡] As such, this topic is important for thoroughly understanding the role that the injury mechanisms play in reconstruction.¹⁰ MCL injuries are usually the result of valgus stress on a stationary knee.¹⁵ Minor trauma and major trauma of the MCL are managed differently, as they typically result in different aspects of the MCL being torn. Minor injuries of the MCL often affect the superficial portion of the ligament and are managed with nonoperative treatment and early rehabilitation. Major injuries of the MCL, however, affect the superficial and deep layers of the ligament and are surgically managed through repair, augmentation, or reconstruction.²⁴ Knowledge of the injury mechanism facilitates expedient diagnosis and helps guide management; additionally, it lends insight into potential associated structures that may be affected by the same injury.¹

The most cited study out of the 50 collected for this analysis was “Epidemiology of Athletic Knee Injuries: A 10-Year Study” by Majewski et al,²¹ published in *The Knee*. This article discusses the type and frequency of knee injuries to aid in prevention, diagnosis, and treatment of knee injuries. The study comprised 17,397 patients with 19,530 sport injuries over a 10-year period. The authors found that MCL injuries occurred at a rate of 7.9% among athletes with knee injuries and were sustained predominantly during activities such as judo and skiing.²¹ The popularity of this article is based on its epidemiological nature, which serves to provide fundamental statistics that quantify the prevalence of knee injuries. This study is also extremely impactful because it provides the background data and support needed for common research studies regarding a variety of knee injuries including the MCL.

The second- and third-most cited studies were published in the *Journal of Bone and Joint Surgery–American Volume* and *American Journal of Sports Medicine*, respectively,

which were the 2 most productive journals. The second-most cited article, “Tension Studies of Human Knee Ligaments: Yield Point, Ultimate Failure, and Disruption of the Cruciate and Tibial Collateral Ligaments,” was a basic science study that was published in 1976. This study was important for researchers and clinicians because it showed how microscopic failure of the collagen fibrils in macroscopically intact knee ligaments plays a key role in clinical knee instability.¹⁴ The third-most cited article, “Medial Collateral Ligament Healing: A Multidisciplinary Assessment in Rabbits,” was also a basic science study.⁷ This study demonstrated that an injured MCL can begin to heal without treatment. However, the healing process does plateau, and the ensuing scar formation causes chemical and mechanical abnormalities in the ligament at long-term follow-up.⁷

The majority of the top 50 most cited articles on MCL research were generated in the United States (80%), and all were published in English. This finding is consistent with the observation that a majority of orthopaedic surgery research is conducted in the United States, a trend confirmed by several other bibliometric analyses.^{2,13,18} Most articles were published in the *Journal of Bone and Joint Surgery–American Volume* (n = 19), followed by the *American Journal of Sports Medicine* (n = 8) and *Radiology* (n = 6), all of which are published in the United States as well as *The Journal of Biomechanics* (n = 6) which is not published in the United States (Figure 3).

Within our bibliometric analysis, the largest proportion of articles were clinical science and outcomes studies (54%), followed by basic science (40%) (Figure 4). Since basic science research is considered foundational, these articles did not receive a numerical level of evidence score.³⁴ Regardless, most studies within the clinical science and outcomes category are considered high impact, with level 2 evidence. Clinical and basic science research is generally more demanding to execute and publish, so these findings are not entirely unexpected. However, our findings imply that level of evidence does not necessarily correlate with citation

[‡]References 3, 8, 9, 14, 16, 20, 25, 26, 29–33.

density or impact—considering that (1) every level 1 evidence study within these 2 more prevalent categories was cited less frequently than corresponding level 2 articles and (2) a large proportion of our highest-impact studies were in fact basic science articles.

The primary limitation of our bibliometric search is that, by definition, it includes only the most frequently cited works on the topic of MCL research. Given that the number of absolute citations was the metric through which we selected and organized our top 50 articles, high-impact studies published since 2013 as well as those published in a foreign language may have been excluded.^{12,28} Moreover, articles published in textbooks and nonindexed journals, as well as articles privately cited, could not be included, as they are not available on the public domain. As is common to all bibliometric analyses, the number of absolute citations per article may be inflated by self-citations and sub-publications, 2 factors that are difficult to control for. Historical articles that have been available in the public domain for a greater length of time are often cited more frequently than those published relatively recently, simply because of the increased exposure time; however, this observation was not witnessed in our study, considering that our top 15 articles with the highest citation density were all published within the past 2 decades. Additionally, the total number of citations does not necessarily reflect an article's clinical utility. Nonetheless, bibliometric analysis by total number of citations still provides important insight on the scientific relevance and demand for research in a specific field or clinical subspecialty.

Regardless of these limitations, our bibliometric citation analysis of MCL research remains a valuable tool for evaluating the impact of scientific articles published on this topic. Through our analysis of article citation density, level of evidence, and demographic makeup of the top 50 most cited articles, this work provides a comprehensive overview on the quality and content of MCL research. This study can therefore help guide scientific researchers on deciding which topic to explore and what level of impact they intend to have concerning MCL research.

CONCLUSION

This study provides a comprehensive and objective measure of the most cited articles on MCL research. Knowledge of the characteristics of these most influential articles improves the understanding of MCL injury and can guide discussion for future research.

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APPENDIX

APPENDIX TABLE A1
Top 50 Most Cited Articles in Knee Medial Collateral Ligament Injury Research

Rank	Publication Information	No. of Citations
1	Majewski M, Susanne H, Klaus S. Epidemiology of athletic knee injuries: a 10-year study. <i>Knee</i> . 2006;13(3):184-188.	422
2	Kennedy JC, Hawkins RJ, Willis RB, Danylchuck KD. Tension studies of human knee ligaments: yield point, ultimate failure, and disruption of the cruciate and tibial collateral ligaments. <i>J Bone Joint Surg Am</i> . 1976;58(3):350-355.	315
3	Frank C, Woo SL, Amiel D, Harwood F, Gomez M, Akeson W. Medial collateral ligament healing: a multidisciplinary assessment in rabbits. <i>Am J Sports Med</i> . 1983;11(6):379-389.	266
4	Woo SL, Gomez MA, Sites TJ, Newton PO, Orlando CA, Akeson WH. The biomechanical and morphological changes in the medial collateral ligament of the rabbit after immobilization and remobilization. <i>J Bone Joint Surg Am</i> . 1987;69(8):1200-1211.	244
5	Woo SL, Abramowitch SD, Kilger R, Liang R. Biomechanics of knee ligaments: injury, healing, and repair. <i>J Biomech</i> . 2006;39(1):1-20.	238
6	Indelicato PA. Non-operative treatment of complete tears of the medial collateral ligament of the knee. <i>J Bone Joint Surg Am</i> . 1983;65(3):323-329.	195
7	Kijowski R, Davis KW, Woods MA, et al. Knee joint: comprehensive assessment with 3D isotropic resolution fast spin-echo MR imaging—diagnostic performance compared with that of conventional MR imaging at 3.0 T. <i>Radiology</i> . 2009;252(2):486-495.	195
8	Hildebrand KA, Woo SLY, Smith DW, et al. The effects of platelet-derived growth factor-BB on healing of the rabbit medial collateral ligament: an in vivo study. <i>Am J Sports Med</i> . 1998;26(4):549-554.	186
9	Chen X, Qi YY, Wang LL, et al. Ligament regeneration using a knitted silk scaffold combined with collagen matrix. <i>Biomaterials</i> . 2008;29(27):3683-3692.	175
10	Flik K, Lyman S, Marx RG. American collegiate men's ice hockey: an analysis of injuries. <i>Am J Sports Med</i> . 2005;33(2):183-187.	167
11	Marui T, Niyibizi C, Georgescu HI, et al. Effect of growth factors on matrix synthesis by ligament fibroblasts. <i>J Orthop Res</i> . 1997;15(1):18-23.	167
12	Provenzano PP, Heisey D, Hayashi K, Lakes R, Vanderby R. Subfailure damage in ligament: a structural and cellular evaluation. <i>J Appl Physiol</i> . 2002;92(1):362-371.	149
13	Swenson DM, Collins CL, Best TM, Flanigan DC, Fields SK, Comstock D. Epidemiology of knee injuries among US high school athletes, 2005/2006-2010/2011. <i>Med Sci Sports Exerc</i> . 2013;45(3):462-469.	148
14	Woo SL-Y, Inoue M, McGurk-Burleson E, Gomez MA. Treatment of the medial collateral ligament injury. II. structure and function of canine knees in response to differing treatment regimens. <i>Am J Sports Med</i> . 1987;15(1):22-29.	144
15	Schmidt CC, Georgescu HI, Kwok CK, et al. Effect of growth factors on the proliferation of fibroblasts from the medial collateral and anterior cruciate ligaments. <i>J Orthop Res</i> . 1995;13(2):184-190.	143
16	Wijdicks CA, Griffith CJ, Johansen S, Engebretsen L, LaPrade RE. Injuries to the medial collateral ligament and associated medial structures of the knee. <i>J Bone Joint Surg Am</i> . 2010;92(5):1266-1280.	139
17	Fanelli GC, Orcutt DR, Edson CJ. The multiple-ligament injured knee: evaluation, treatment, and results. <i>Arthroscopy</i> . 2005;21(4):471-486.	139
18	Schweitzer ME, Tran D, Deely DM, Hume EL. Medial collateral ligament injuries—evaluation of multiple signs, prevalence and location of associated bone bruises, and assessment with MR imaging. <i>Radiology</i> . 1995;194(3):825-829.	133

(continued)

APPENDIX TABLE A1 (continued)

Rank	Publication Information	No. of Citations
19	Lind M, Jakobsen BW, Lund B, Hansen MS, Abdallah O, Christiansen SE. Anatomical reconstruction of the medial collateral ligament and posteromedial corner of the knee in patients with chronic medial collateral ligament instability. <i>Am J Sports Med.</i> 2009;37(6):1116-1122.	131
20	Sims WF, Jacobson KE. The posteromedial corner of the knee—medial-sided injury patterns revisited. <i>Am J Sports Med.</i> 2004;32(2):337-345.	123
21	Griffith CJ, LaPrade RF, Johansen S, Armitag EB, Wijdicks C, Engebretsen L. Medial knee injury: part 1, static function of the individual components of the main medial knee structures. <i>Am J Sports Med.</i> 2009;37(9):1762-1770.	122
22	Fetto JF, Marshall JL. Medial collateral ligament injuries of the knee—rationale for treatment. <i>Clin Orthop Relat Res.</i> 1978;132:206-218.	119
23	Woo SL, Peterson RH, Ohland KJ, Sites TJ, Danto MI. The effects of strain rate on the properties of the medial collateral ligament in skeletally immature and mature rabbits—a biomechanical and histological study. <i>J Orthop Res.</i> 1990;8(5):712-721.	114
24	Musahl V, Abramowitch SD, Gilbert TW, et al. The use of porcine small intestinal submucosa to enhance the healing of the medial collateral ligament—a functional tissue engineering study in rabbits. <i>J Orthop Res.</i> 2004;22(1):214-220.	113
25	Weiss JA, Woo SLY, Ohland KJ, Horibe S, Newton PO. Evaluation of a new injury model to study medial collateral ligament healing—primary repair versus nonoperative treatment. <i>J Orthop Res.</i> 1991;9(4):516-528.	105
26	Halinen J, Lindahl J, Hirvensalo E, Santavirta S. Operative and nonoperative treatments of medial collateral ligament rupture with early anterior cruciate ligament reconstruction—a prospective randomized study. <i>Am J Sports Med.</i> 2006;34(7):1134-1140.	105
27	Wijdicks CA, Griffith CJ, LaPrade RF, et al. Radiographic identification of the primary medial knee structures. <i>J Bone Joint Surg Am.</i> 2009;91(3):521-529.	102
28	Woo SL, Orlando CA, Gomez MA, Frank CB, Akeson WH. Tensile properties of the medial collateral ligament as a function of age. <i>J Orthop Res.</i> 1986;4(2):133-141.	102
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(continued)

APPENDIX TABLE A1 (continued)

Rank	Publication Information	No. of Citations
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