Influential literatures in periprosthetic infection following joint arthroplasty: A bibliometric review

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Abstract
The objective of this bibliometric literature review was to identify and analyze the most frequently cited manuscripts on the topic of periprosthetic joint infection. Periprosthetic infection following joint arthroplasty is a complication leading to rising rates of mortality and increasing economic strain. No prior study has evaluated the most impactful literature on the topic of periprosthetic joint infection (“PJI”) in total hip and knee arthroplasty. Knowledge and appreciation of the most influential publications on this topic can guide and inspire future research endeavors. Using the Clarivate Analytics Web of Science database, the 50 most cited articles related to periprosthetic infection following joint arthroplasty were identified. Numerous metrics including citation frequency, year of publication, country of origin, level-of-evidence (LOE), article type, and contributing authors/institutions were recorded. The seven most cited articles (per year) during the past 10 years were also identified. The years of publication of the articles included in the final analysis ranged from 1969 to 2014. “Current concepts: Prosthetic-joint infections” by Zimmerli et al. was the most frequently cited article. Level of Evidence (“LOE”) of 2 and 3 were the most common. Clinical outcomes was the most common article type. Mayo Clinic and Thomas Jefferson University produced the most publications. Hanssen and Parvisi were the most productive authors. 2000–2009 (n = 25) was the most prolific decade in terms of number of publications. Using citation analysis as an indication of influence, the most influential articles on periprosthetic joint infection were highlighted. Analysis of the most recognized publication on PJI provides an enhanced understanding of the diagnosis, treatment, and future research of PJI.

Future studies may combine the search results of multiple databases including Scopus, Web of Science and PubMed to rectify any discrepancies in citation data and to capture additional literature on PJI.

Keywords
Total joint arthroplasty, periprosthetic joint infection, most influential, citation analysis, bibliometric study

Introduction
Total joint arthroplasty (TJA), including total hip arthroplasty (THA) and total knee arthroplasty (TKA), is a well-known treatment for osteoarthritis.1 With a large aging population, the demand for these procedures is projected to grow substantially. In 2009, 438,000 THAs and 686,000 TKAs were performed in the United States.2 A recent report by Singh et al. projected the annual number of primary THAs and TKAs done in the United States to grow by 284% (1.43 million) and 401% (3.42 million), respectively by the year 2040.3 As the rate of TJA increases, so do the number of associated complications.

Periprosthetic joint infection (PJI) continues to be a difficult to manage complication for both the patient and the

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orthopedic surgeon with rising rates. Data extrapolated from the Nationwide Inpatient Sample revealed that between 2001 and 2009 the annual incidence of PJI in the United States increased from 1.99% to 2.18% for THAs and 2.05% to 2.18% for TKAs. The economic strain of PJIs is substantial, costing the United States healthcare system $566 million in 2009 with a projected increase to $1.62 billion by 2020.4 Although the economic impact of PJIs is large, the burden falls heaviest on the patient. Studies have shown that mortality in patients undergoing revision arthroplasty for PJI (up to 25.9% at 5 years) is as much as five-fold greater than the mortality in patients receiving revision for aseptic failures.5

For treating orthopedic surgeons, a solid understanding of fundamental publications in PJI is crucial to adequately address this issue. A commonly used method for evaluating the level of influence of a publication is the number of citations. While there are other gauges of quality, citation frequency can establish “classic” articles which have greatly influenced practice and future research.6 In recent years, there has been an effort to identify the most relevant articles in medical specialties, such as orthopaedics, through identification of the most cited works in the field.7 Citation analysis has previously been used in various topics in orthopaedics, including hip and knee arthroplasty, ankle arthroplasty, elbow surgery, spine surgery, and sports medicine.8–14

At this time, there have been no studies investigating the most highly cited articles on the topic of PJI in total hip and knee arthroplasty.

The extensive impact of PJIs on patients and the economy, combined with the projected increase in TJA procedures and subsequent increase in PJIs in the future, has led to a recent escalation in PJI research. The objective of this study is to conduct a bibliometric analysis of the top 50 most cited scientific articles pertaining to PJIs after total hip or knee arthroplasty to identify which articles drive our current understanding, as well as identify potential knowledge gaps to direct future research.

Methods

Clarivate Analytics Web of Science is a comprehensive indexing database containing citation data. Web of Science contains an expansive collection of articles from over 18,000 journals, and clinical medicine is the domain with the most citations. The database calculates citation data, which allows authors to assess the relative influences of specific journals and journal articles.15,16 There are numerous alternative databases containing medical research articles such as PubMed, Google Scholar, and Scopus. Both Scopus and Web of Science contain detailed citation data and scientometric analytical capabilities. However, Web of Science covers articles published within the largest time frame, ranging from 1900 to present. Web of Science contains analysis capabilities on article information including country of origin, institution of origin, article classifications, journal names, and funding agencies.16,17

A Web of Science query was conducted to accumulate the most highly cited journal articles pertaining to infection following hip or knee arthroplasty. An initial search was conducted on April 4, 2019 using the following search terms: (“Arthro**” OR “Total Joint” AND “Hip” AND “Knee” AND “Infection”). The authors realized that the search terms limited the results to articles pertaining to both the hip and the knee. After discussion among authors, the search terms were adjusted in order to encompass publications related to either the hip, or the knee, or both, thus, yielding more exhaustive search results. The search terms of the second search were as follows: (“Arthro**” OR “Total Joint” AND “Hip” OR “Knee” AND “Infection”). This second search was conducted on April 9, 2019. The results of the first and second searches were combined in the same Excel file for further analysis. The results consisted of a total of 151,260 publications. Filters were placed on the search results such that all publications were limited to peer-reviewed articles written in English. No additional filters were implemented. The results were sorted by descending number of citations, excluding self-citations.

The article titles were screened sequentially for inclusion using a multi-step, two-author screening process. Step 1 consisted of sorting articles by descending number of citations and then sequentially reviewing the title and abstracts of the search results until 60 articles related to PJI were identified. A total of 763 citations underwent initial screening review, 703 out of 763 articles were excluded based on article topic, leaving 60 articles for full review. Step 2 consisted of abstract and manuscript review of the 60 articles retained in Step 1. The 50 most cited articles pertaining to total hip and knee arthroplasty infection were isolated for full bibliometric analysis (Figure 1).

Level of evidence (LOE) and article types were assigned for each article by author review. Article type categories consisted of the following: Surgical technique, Clinical outcomes, Anatomy (Cadaver), Natural history, Epidemiology, Clinical description, Classification, Conservative therapy, Clinical guidelines, Imaging, Genetics, Questionnaire Development, Physical Examination, Technique, Pathogenesis, and Biomechanics. Articles were assigned to one category by two independent reviewers. Uncertainties within the data were discussed and rectified by a third independent reviewer.

Numerous additional characteristics were analyzed: citation frequency per year, citation frequency in the calendar year prior to the search (2018), publication year and decade, journal sources and associated Cite Scores, authorship, institutional contribution, and country of origin. Cite Score is a citation metric used to rank journals and is determined by the number of citations of articles published within a journal in a given time period and the number of papers published by that journal in the same time period.18
Order of authorship was not considered in the analysis of author contribution. Authors and institutions that contributed to at least three papers within the top 50 list were reported.

Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines and checklist items were followed in guiding the various steps of our methods: defining our criteria, sourcing data, designing a search strategy, removing duplicate results, specifying screening criteria, and reviewing search results using a multi-step author review.

**Results**

Publications ranged from 1969 to 2014 (Table 1). The peak years that produced the most articles were 2006 ($n = 5$) and 2008 ($n = 4$). The total number of citations of all articles within the list was 16,586, with a mean of 331.7 citations per article. The average number of citations per year for a given article, calculated from the year of publication until 2019, was 22.6. “Current concepts: Prosthetic-joint infections” by Zimmerli et al. and published in the *New England Journal of Medicine*, contained both the highest number of total citations at 1,384, and the highest average number of citations per year at 86.5. The second ranked article was “Sonication of removed hip and knee prostheses for diagnosis of infection” by Trampuz et al., with 641 total citations. The third most cited article was “An in vitro assessment of the antibacterial properties and cytotoxicity of nanoparticulate silver bone cement” by Alt et al., with 570 total citations.

The most common Level of Evidence (LOE) was Level II ($n = 20$) and Level III ($n = 19$). The breakdown of the

Figure 1. Modified PRISMA flowchart.
| Rank | Publication                                                                                                                                                                                                 | Total citations | Citations/year of publication until 2019 | Citations in 2018 |
|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|----------------------------------------|------------------|
| 1    | Zimmerli W, Trampuz A, Ochsner PE. Current concepts: Prosthetic-joint infections. *New England Journal of Medicine* 351(16): 1645, 2004                                                                         | 1384            | 86.5                                    | 136              |
| 2    | Trampuz A, Piper KE, Jacobson MJ, Hanssen AD, Unni KK, Osmon DR, Mandrekar JN, Cockerill FR, Steckelberg JM, Greenleaf JF, Patel R. Sonication of removed hip and knee prostheses for diagnosis of infection. *New England Journal of Medicine* 357(7): 654, 2007 | 641             | 49.31                                   | 73               |
| 3    | Alt V, Bechert T, Steinrucke P, Wagener M, Seidel P, Dingeldein E, Domann E, Schnettler R. An in vitro assessment of the antibacterial properties and cytotoxicity of nanoparticulate silver bone cement. *Biomaterials* 25(18): 4383, 2004 | 570             | 35.63                                   | 30               |
| 4    | Osmon DR, Berbari EF, Berendt AR, Lew D, Zimmerli W, Steckelberg JM, Rao N, Hanssen A, Wilson WR. Diagnosis and Management of Prosthetic Joint Infection: Clinical Practice Guidelines by the Infectious Diseases Society of America. *Clinical Infectious Diseases* 56(1): 1, 2013 | 531             | 75.86                                   | 115              |
| 5    | Pulido L, Ghanem E, Joshi A, Purtill JJ, Parvizi J. Periprosthetic joint infection: The incidence, timing, and predisposing factors. *Clinical Orthopaedics and Related Research* 466(7): 1710, 2008       | 528             | 44                                      | 78               |
| 6    | Tsukayama DT, Estrada R, Gustilo RB. Infection after total hip arthroplasty—a study of the treatment of one hundred and six infections. *Journal of Bone and Joint Surgery-American Volume* 78A(4): 512, 1996 | 486             | 20.25                                   | 23               |
| 7    | Kurtz SM, Lau E, Watson H, Schmier JK, Parvizi J. Economic Burden of Periprosthetic Joint Infection in the United States. *Journal of Arthroplasty* 27(8): 61, 2012                                        | 464             | 58                                      | 120              |
| 8    | Kurtz SM, Lau E, Schmier J, Ong KL, Zhao K, Parvizi J. Infection burden for hip and knee arthroplasty in the United States. *Journal of Arthroplasty* 23(7): 984, 2008                                      | 455             | 37.92                                   | 59               |
| 9    | Spangehl MJ, Masri BA, O'Connell JX, Duncan CP. Prospective analysis of prooperative and intraoperative investigations for the diagnosis of infection at the sites of two hundred and two revision total hip arthroplasties. *Journal of Bone and Joint Surgery-American Volume* 81A(5): 672, 1999 | 452             | 21.52                                   | 20               |
| 10   | Berbari EF, Hanssen AD, Duffy MC, Steckelberg JM, Ilstrup DM, Harmsen WS, Osmon DR. Risk factors for prosthetic joint infection: Case-control study. *Clinical Infectious Diseases* 27(5): 1247, 1998 | 444             | 20.18                                   | 19               |
| 11   | Lidwell OM, Lowbury EJL, Whyte W, Blowers R, Stanley SJ, Lowe D. Effect of ultraclean air in operating-rooms on dep sepsis in the joint after total hip or knee replacement – a randomized study. *British Medical Journal* 285(6334): 10, 1982 | 436             | 11.47                                   | 20               |
| 12   | Peersman G, Laskin R, Davis J, Peterson M. The Insall Award paper—infecion in total knee replacement—a retrospective review of 6489 total knee replacements. *Clinical Orthopaedics and Related Research* (392): 15, 2001 | 420             | 22.11                                   | 37               |
| 13   | Del Pozo JL, Patel R. Infection Associated with Prosthetic Joints. *New England Journal of Medicine* 361(8): 787, 2009                                                                                  | 378             | 34.36                                   | 34               |
| 14   | Atkins BL, Athanasou N, Deeks JJ, Crook DW, Simpson H, Peto TEA, McLardy-Smith P, Berendt AR, Grp OCS. Prospective evaluation of criteria for microbiological diagnosis of prosthetic-joint infection at revision arthroplasty. *Journal of Clinical Microbiology* 36(10): 2932, 1998 | 367             | 16.68                                   | 25               |
| 15   | Parvizi J, Jacovides C, Zmistowski B, Jung KA. Definition of Periprosthetic Joint Infection: Is There a Consensus? *Clinical Orthopaedics and Related Research* 469(11): 3022, 2011                                 | 358             | 39.78                                   | 122              |
| 16   | Fitzgerald RH, Nolan DR, Ilstrup DM, Vanscoy RE, Washington JA, Coventry MB. Deep wound sepsis following total hip arthroplasty. *Journal of Bone and Joint Surgery-American Volume* 59(7): 847, 1977 | 357             | 8.3                                     | 8                |
| 17   | Charney J, Eftekhar N. Postoperative infection in total prosthetic replacement arthroplasty of hip-joint with special reference to bacterial content in air of operating room. *British Journal of Surgery* 56(9): 641, 1969 | 336             | 6.59                                    | 11               |
| 18   | Garvin KL, Hanssen AD. Current concepts review infection after total hip-arthroplasty past, present, and future. *Journal of Bone and Joint Surgery-American Volume* 77(10): 1576, 1995                        | 311             | 12.44                                   | 17               |
| 19   | Tunney MM, Patrick S, Curran MD, Ramage G, Hanna D, Nixon JR, Gorman SP, Davis RI, Anderson N. Detection of prosthetic hip infection at revision arthroplasty by immunofluorescence microscopy and PCR amplification of the bacterial 16 S rRNA gene. *Journal of Clinical Microbiology* 37(10): 3281, 1999 | 309             | 14.71                                   | 15               |

(continued)
| Rank | Publication                                                                                                                                                                                                 | Total citations | Citations/year of publication until 2019 | Citations in 2018 |
|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|----------------------------------------|------------------|
| 20   | Wilson MG, Kelley K, Thornhill TS. Infection as a complication of total knee-replacement arthroplasty – risk-factors and treatment in 67 cases. *Journal of Bone and Joint Surgery-American Volume* 72A(6): 878, 1990     | 295             | 9.83                                   | 9                |
| 21   | Bozic KJ, Ries MD. The impact of infection after total hip arthroplasty on hospital and surgeon resource utilization. *Journal of Bone and Joint Surgery-American Volume* 87A(8): 1746, 2005                  | 289             | 19.27                                  | 25               |
| 22   | Trampuz A, Hanssen AD, Osmon DR, Mandrekar J, Steckelberg JM, Patel R. Synovial fluid leukocyte count and differential for the diagnosis of prosthetic knee infection. *American Journal of Medicine* 117(8): 556, 2004            | 289             | 18.06                                  | 26               |
| 23   | Insall JN, Thompson FM, Brause BD. 2-Stage reimplantation for the salvage of infected total knee arthroplasty. *Journal of Bone and Joint Surgery-American Volume* 65(8): 1087, 1983                                                                   | 281             | 7.56                                   | 8                |
| 24   | Phillips JE, Crane TP, Noy M, Elliott TSJ, Grimer RJ. The incidence of deep prosthetic infections in specialist orthopaedic hospital—a 15-year prospective survey. *Journal of Bone and Joint Surgery-British Volume* 88B(7): 943, 2006 | 272             | 19.43                                  | 22               |
| 25   | Kurtz SM, Ong KL, Lau E, Bozic KJ, Berry D, Parvizi J. Prosthetic Joint Infection Risk after TKA in the Medicare Population. *Clinical Orthopaedics and Related Research* 468(1): 52, 2010                           | 270             | 27                                     | 43               |
| 26   | Tande AJ, Patel R. Prosthetic Joint Infection. *Clinical Microbiology Reviews* 27(2): 302, 2014                                                                                                              | 264             | 44                                     | 96               |
| 27   | Parvizi J, Zmistowski B, Berbari EF, Bauer TW, Springer BD, Della Valle CJ, Garvin KL, Mont MA, Wongworawat MD, Zalavras CG. New Definition for Periprosthetic Joint Infection: From the Workgroup of the Musculoskeletal Infection Society. *Clinical Orthopaedics and Related Research* 469(11): 2992, 2011 | 251             | 17.93                                  | 21               |
| 28   | Segawa H, Tsukayama DT, Kyle RF, Becker DA, Gustilo RB. Infection after total knee arthroplasty—a retrospective study of the treatment of eighty-one infections. *Journal of Bone and Joint Surgery-American Volume* 81A(10): 1434, 1999 | 257             | 12.24                                  | 5                |
| 29   | Marculescu CE, Berbari EF, Hanssen AD, Steckelberg JM, Harmsen SW, Mandrekar JN, Osmon DR. Outcome of prosthetic joint infections treated with debridement and retention of components. *Clinical Infectious Diseases* 42(4): 471, 2006                           | 251             | 17.93                                  | 21               |
| 30   | Ridgeway S, Wilson J, Charlet A, Kafatos G, Pearson A, Coello R. Infection of the surgical site after arthroplasty of the hip. *Journal of Bone and Joint Surgery-British Volume* 87B(6): 844, 2005                                               | 247             | 16.47                                  | 20               |
| 31   | Patel VP, Walsh M, Sehgal B, Preston C, Dewal H, Di Cesare PE. Factors associated with prolonged wound drainage after primary total hip and knee arthroplasty. *Journal of Bone and Joint Surgery-American Volume* 89A(1): 33, 2007 | 242             | 18.62                                  | 27               |
| 32   | Schinskey MF, Della Valle CJ, Sporer SM, Paprosky VG. Perioperative testing for joint infection in patients undergoing revision total hip arthroplasty. *Journal of Bone and Joint Surgery-American Volume* 90A(9): 1869, 2008 | 237             | 19.75                                  | 23               |
| 33   | Shi ZL, Neoh KG, Kang ET, Wang W. Antibacterial and mechanical properties of bone cement impregnated with chitosan nanoparticles. *Biomaterials* 27(11): 2440, 2006                                                                 | 234             | 16.71                                  | 14               |
| 34   | Lentino JR. Prosthetic joint infections: Bane of orthopedists, challenge for infectious disease specialists. *Clinical Infectious Diseases* 36(9): 1157, 2003                                                                 |
| 35   | Schafer P, Fink B, Sandow D, Margull A, Berger I, Frommelt L. Prolonged Bacterial Culture to Identify Late Periprosthetic Joint Infection: A Promising Strategy. *Clinical Infectious Diseases* 47(11): 1403, 2008 |
| 36   | Brandt CM, Sistrunk WW, Duffy MC, Hanssen AD, Steckelberg JM, Ilstrup DM, Osmon DR. *Staphylococcus aureus* prosthetic joint infection treated with debridement and prosthes. *Clinical Infectious Diseases* 24(5): 914, 1997 |
| 37   | Bauer TW, Parvizi J, Kobayashi N, Krebs V. Diagnosis of periprosthetic infection. *Journal of Bone and Joint Surgery-American Volume* 88A(4): 869, 2006                                                                 | 227             | 16.21                                  | 13               |
| 38   | Tunney MM, Patrick S, Gorman SP, Nixon JR, Anderson N, Davis RJ, Hanna D, Ramage G. Improved detection of infection in hip replacements—a currently underestimated problem. *Journal of Bone and Joint Surgery-British Volume* 80B(4): 568, 1998 |
| 39   | Rohde H, Burandt EC, Siemssen N, Frommelt L, Burdelski C, Wurster S, Scherpe S, Davies AP, Harris LG, Horstkotte MA, Knobloch JK, Ragunath C, Kaplan JB, Mack D. Polysaccharide intercellular adhesin or protein factors in biofilm accumulation of | 225             | 17.31                                  | 12               |

(continued)
LOE are the following Level I (n = 2), Level II (n = 20), Level III (n = 19), Level IV (n = 5), and N/A (n = 4) (Figure 2). The four articles classified under N/A were comprised of basic science literature that did not fit LOE guidelines set forth by the Oxford Centre of Evidence-based Medicine guidelines. Articles were also assessed by article topic. From the 8 categories of article type, clinical outcome articles (n = 19) were the most frequent, followed by review articles (n = 9), and clinical guideline papers (n = 8) (Figure 3).

The United States of America was the major contributor to the most cited articles in total hip and knee arthroplasty infection (n = 34). Other countries with at least 3 article contributions were the United Kingdom (n = 9), Switzerland (n = 4), and Germany (n = 3) (Figure 4). A total of 10 different countries contributed to our top 50 list. Analysis of contributing institutions indicated that Mayo Clinic (n = 15) produced the most publications, followed by Thomas Jefferson University/Rothman Institute (n = 11). Two institutions that came in third, each with four article contributions, were Exponent Inc. and University of Basel (Table 2). Overall, 9 institutions were associated with at least 3 publication contributions in our top 50 list. Further, the most productive authors included A.D. Hanssen (n = 9), J. Parvizi (n = 8), and D.R. Osmon (n = 7). Fourteen authors contributed to 3 or more papers within the top 50 list (Table 3).

After filtering the articles published within the last 10 years from our top 50 list, “Diagnosis and Management of Prosthetic Joint Infection: Clinical Practice Guidelines by the Infectious Diseases Society of America” by Osmon et al. (75.9 citations/year) and “Economic Burden of

| Rank | Publication | Total citations | Citations/year of publication until 2019 | Citations in 2018 |
|------|-------------|-----------------|------------------------------------------|-------------------|
| 40   | Jiranek WA, Hanssen AD, Greenwald AS. Antibiotic-loaded bone cement for infection prophylaxis in total joint replacement. *Journal of Bone and Joint Surgery-American Volume* 88A(11): 2487, 2006 | 222 | 15.86 | 18 |
| 41   | Trampuz A, Zimmerli W. Prosthetic joint infections: update in diagnosis and treatment. *Swiss Medical Weekly* 135(17–18): 243, 2005 | 222 | 14.8 | 18 |
| 42   | Jamsen E, Hultala H, Puolakka T, Molanen T. Risk Factors for Infection After Knee Arthroplasty. *A Register-Based Analysis of 43.149 Cases. Journal of Bone and Joint Surgery-American Volume* 91A(1): 38, 2009 | 217 | 19.73 | 20 |
| 43   | Zimmerli W, Ochsner PE. Management of infection associated with prosthetic joints. *Infection* 31(2): 99, 2003 | 217 | 12.76 | 12 |
| 44   | Ong KL, Kurtz SM, Lau E, Bozic KJ, Berry DJ, Parvizi J. Prosthetic Joint Infection Risk After Total Hip Arthroplasty in the Medicare Population. *Journal of Arthroplasty* 24(6): 105, 2009 | 212 | 19.27 | 26 |
| 45   | Windsor RE, Insall JN, Urs WK, Miller DV, Brause BD. 2-Stage reimplantation for the salvage of total knee arthroplasty complicated by infection – further follow-up and refinement of indications. *Journal of Bone and Joint Surgery-American Volume* 72A(2): 272, 1990 | 211 | 7.03 | 2 |
| 46   | Salvati EA, Robinson RP, Zeno SM, Kostin BL, Brause BD, Wilson PD. Infection-rates after 3175 total hip and total knee replacements preformed with and without a horizontal unidirectional filtered air-flow system. *Journal of Bone and Joint Surgery-American Volume* 64(4): 525, 1982 | 211 | 5.55 | 6 |
| 47   | Engesaeter LB, Lie SA, Espehaug B, Furnes O, Vollset SE, Havelin LI. Antibiotic prophylaxis in total hip arthroplasty—effects of antibiotic prophylaxis systemically and in bone cement on the revision rate of 22,170 primary hip replacements followed 0-14 years in the Norwegian Arthroplasty Register. *Acta Orthopaedica Scandinavica* 74(6): 644, 2003 | 210 | 12.35 | 9 |
| 48   | Crockarell JR, Hanssen AD, Osmon DR, Morrey BF. Treatment of infection with debridement and retention of the components following hip arthroplasty. *Journal of Bone and Joint Surgery-American Volume* 80A(9): 1306, 1998 | 196 | 8.91 | 5 |
| 49   | Namba RS, Inacio MCS, Paxton EW. Risk Factors Associated with Deep Surgical Site Infections After Primary Total Knee Arthroplasty. *Journal of Bone and Joint Surgery-American Volume* 95A(9): 775, 2013 | 192 | 27.43 | 40 |
| 50   | Espehaug B, Engesaeter LB, Vollset SE, Havelin LI, Langeland N. Antibiotic prophylaxis in total hip arthroplasty—review of 10 905 primary cemented total hip replacements reported to the Norwegian arthroplasty register, 1987 to 1995. *Journal of Bone and Joint Surgery-British Volume* 79B(4): 590, 1997 | 191 | 8.3 | 4 |
Periprosthetic Joint Infection in the United States” by Kurtz et al. (58.0 citations/year) comprised the two major contributors (Table 4).

The Journal of Bone and Joint Surgery, American Volume had the highest recorded Cite Score among all journals associated with our top 50 list and comprised over a third of the contributions (n = 17). The second most frequent journal was Clinical Infectious Diseases (n = 6), and the third most frequent journal was Clinical Orthopaedic and Related Research (n = 5) (Table 5).

Publication analysis marked 2000–2009 (n = 25) as the most prolific decade. The number of publications within our top 50 list increased with each successive decade with exception of the most recent decade 2010–2019 (n = 7) (Figure 5). The oldest article on our list was from 1969, titled “Postoperative infection in total prosthetic replacement arthroplasty of hip-joint with special reference to bacterial content of air of the operating room,” written by Charnley and Eftekhar. This article saw a decrease in infection rate in total hip arthroplasty following measures to...
decrease air contamination, which lead to the conclusion that postoperative infection primarily occurred during the operation, particularly from the air particulates.\textsuperscript{23} The most recent article, “Prosthetic joint infection” by Tande and Patel, reviews the epidemiology, pathophysiology, diagnosis, and treatment of prosthetic joint infections (PJIs) as of 2014 (Table 1).\textsuperscript{24}

**Discussion**

The focus of this study is to identify the most cited articles concerning PJI in order to provide a reference of the work that supports current research and drives clinical understanding and decision-making for the orthopaedic Surgeon and the community. The most widely cited study is written by Zimmerli et al. (1,384 citations), which describes an overall outlook of PJI’s, explaining the pathogenesis, diagnosis and treatment of PJI.\textsuperscript{19} Of all papers in our analysis, this paper also has the most citations in 2018 (136) and the most citations per year (86.5). This citation data shows the persistence in referencing the Zimmerli study, which supports this paper’s consistent relevance to PJI today.

The second most cited article, by Trampuz et al. (641 citations), found that using sonication to dislodge prosthetic joint infections was superior to periprosthetic tissue culture in regard to sensitivity, 78.5\% to 60.8\% respectively. Specificities were found to be 98.8\% and 99.2\%, respectively. This study ultimately provided an alternative method of diagnosing PJI in a field that, at the time, lacked accurate and sensitive microbacterial diagnostic testing.\textsuperscript{20} This paper also had a relatively high number of citations in 2018 (73) and rate of citation per year (49.3), thus showing its importance in TJA through the years. The third most cited paper was done by Volker et al. in 2004 (570 citations) which explores the use of a novel component in bone cement. By using NanoSilver, rather than commercial silver powder, the new bone cement demonstrated an increased rate of antimicrobial properties in vitro.\textsuperscript{21} This paper was cited 30 times in 2018 and has averaged 35.6 citations per year.

Because papers published more recently have a smaller window of opportunity to accrue cumulative citations, a separate analysis was conducted for papers published more recently. This analysis ranked papers that were published in the last 10 years and ranked these papers by the number of citations per year instead of the cumulative number citations. In this analysis, a paper written by Osmon et al. was the highest ranked with 531 citations, 75.86 per year and 115 total citations in 2018. This paper was also fourth on our main list of the top 50 most cited overall papers. The study used both opinion and evidence-based recommendations in order to outline the guidelines of diagnosing and treating PJIs.\textsuperscript{25}

The most common decade of cited literature on PJI was 2000–2009 (50\%), followed by 1990–1999 (25\%). This reflects a trend seen across many fields that can be
Tables 4 and 5:

Table 4. Most cited publications per year from the past 10 years.

| Rank | Publication                                                                 | Total citations | Citations/year of publication until 2019 | Citations in 2018 |
|------|-----------------------------------------------------------------------------|-----------------|----------------------------------------|------------------|
| 1    | Osmon DR, Berbari EF, Berendt AR, Lew D, Zimmerli W, Steckelberg JM, Rao N, Hanssen A, Wilson WR. Diagnosis and Management of Prosthetic Joint Infection: Clinical Practice Guidelines by the Infectious Diseases Society of America. Clinical Infectious Diseases 56(1): 1, 2013 | 531             | 75.86                                  | 115              |
| 2    | Kurtz SM, Lau E, Watson H, Schmier JK, Parvizi J. Economic Burden of Periprosthetic Joint Infection in the United States. Journal of Arthroplasty 27(8): 61, 2012 | 464             | 58                                     | 120              |
| 3    | Parvizi J, Jacovides C, Zmistowski B, Jung KA. Definition of Periprosthetic Joint Infection: Is There a Consensus? Clinical Orthopaedics and Related Research 469(11): 3022, 2011 | 358             | 39.78                                  | 122              |
| 4    | Kurtz SM, Ong KL, Lau E, Bozic KJ, Berry D, Parvizi J. Prosthetic Joint Infection Risk after TKA in the Medicare Population. Clinical Orthopaedics and Related Research 468(1): 52, 2010 | 270             | 27                                     | 43               |
| 5    | Tande AJ, Patel R. Prosthetic Joint Infection, Clinical Microbiology Reviews 27(2): 302, 2014 | 264             | 44                                     | 96               |
| 6    | Parvizi J, Zmistowski B, Berbari EF, Bauer TW, Springer BD, Della Valle CJ, Garvin KL, Mont MA, Wongworawat MD, Zalavras CG. New Definition for Periprosthetic Joint Infection: From the Workgroup of the Musculoskeletal Infection Society. Clinical Orthopaedics and Related Research 469(11): 2992, 2011 | 260             | 28.89                                  | 28               |
| 7    | Namba RS, Inacio MCS, Paxton EW. Risk Factors Associated with Deep Surgical Site Infections After Primary Total Knee Arthroplasty. Journal of Bone and Joint Surgery-American Volume 95A(9): 775, 2013 | 192             | 27.43                                  | 40               |

Table 5. Source journal.

| Name of Journal | Number of articles |
|-----------------|--------------------|
| Journal of Bone and Joint Surgery, American Volume | 17 |
| Clinical Infectious Diseases | 6 |
| Clinical Orthopaedic and Related Research | 5 |
| Journal of Bone and Joint Surgery, British Volume | 4 |
| Biomaterials | 3 |
| Journal of Arthroplasty | 3 |
| New England Journal of Medicine | 3 |

Multiple institutions may be attributed to a single publication. Only institutions with three or more contributions are included.

The most publications are from the United States, specifically the Mayo Clinic (n = 15) and Thomas Jefferson University/Rothman Institute (n = 11). These institutes comprise 26 of 34 (76.5%) publications from the United States and are leading sources of reference, led by authors Hanssen (n = 9) and Parvizi (n = 8), respectively. These two authors also have the most citations amongst our top 50 list. These high-output institutions and authors all publish from the United States, where the gross number of TJAs performed far outpaces other countries. In terms of the reported countries of origin, there may be an English-language bias toward western nations as more published literature is written in English. Moreover, the most highly cited journal was the Journal of Bone and Joint Surgery, American Volume. It consisted of 17 out of 50 citations (34%). A number of similar bibliometric studies analyzing the classic papers in orthopedics also found this journal to be the most popular. This demonstrates the high-quality output seen from the Journal of Bone and Joint Surgery, American Volume. The next most highly cited journal was Clinical Infectious Diseases with 6 citations (12%) and Clinical Orthopedic and Related Research with 5 citations (10%). Our search criteria were not limited to specific journals, thus maximizing the breadth of our analysis. In addition, we found that the most likely type of article to be cited was clinical outcomes (n = 19), review articles (n = 9) and clinical guidelines (n = 8). Clinical outcomes are often most cited because of the relative ease in citing these papers when bolstering or opposing statements. The most cited clinical article is a review article by Zimmerli et al., showing that these types of articles are particularly impactful because they synthesize expansive...
information on a topic into one source. Lastly, the fourth
most cited paper, by Osmon, is a clinical guideline paper,
which is widely cited due to its widespread use as a model
in providing guidelines for diagnosing and treating PJIs.25

There are limitations to this study. Of note, the main
parameter in determining the importance of studies was the
total number of citations. This methodology allows older
and more established studies to have a greater likelihood of
accruing a greater number of citations. This methodology
can either downplay or overstate the significance of a study
depending the study was a relatively newer or relatively
older, respectively. Articles published in more reputable
journals may accrue a greater number of citations because
these articles are more widely available to authors. Con-
versely, many highly reputable journals require viewer sub-
scriptions or institutional access, which may limit the
viewership and citations of the articles published within
these journals; as such, articles available in free and elec-
tronic versions may have increased viewership and there-
fore increased total citations.

Another study limitation is the breadth of literature
searched. Although Clarivate Analytics Web of Science
is regarded as a comprehensive search database, containing
articles from a wide variety of fields and over 12 million
citations, the database has notable deficits. Potential cita-
tions appearing in non-peer-reviewed sources may have
been missed. Cite Scores can fluctuate over the years and
can be inflated or deflated based on the editorial policy of
each journal, which may further blur the relative impact of
various journals and journal articles. As such, many schol-
ars have suggested eliminating journal-based metrics as
objective indicators of the value of research. Another dis-
advantage of Web of Science is that the database queries
the citation, abstract, and keyword identifiers and does not
query the full text of the articles.32,33 Future bibliometric
studies can aim to conduct more thorough reviews using
multiple search databases to create a comprehensive list of
articles for bibliometric analysis using additional author-
level metrics as well as citation reports.

Despite these limitations, this study is useful in identi-
fying the most cited articles concerning PJI in order to pro-
vide a framework of the literature that has supported
current research and driven clinical understanding and
decision-making.

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