



A decade of Australian and New Zealand orthopaedic publications: a bibliometric trend analysis from 2008 to 2018

Agesilaus W. Churchill¹ · Eva Malacova² · Simon F. Journeaux^{1,3} · Martin Richardson⁴ · Ross Crawford^{5,6} · Mark L. Vickers^{1,5} 

Received: 17 February 2019 / Accepted: 10 June 2019 / Published online: 26 June 2019
© SICOT aisbl 2019

Abstract

Purpose We aimed to apply bibliometric tools to Australian and New Zealand orthopaedic publications produced between 2008 and 2018 to identify the most highly cited publications, author and institution collaboration networks and topic trends. Analysis of the literature can highlight areas of emerging interest and knowledge gaps, and direct future research.

Methods A systematic search was conducted using Clarivate Analytics Web of Science. Citation analysis was carried out using Web of Science. Collaboration networks were constructed using chord diagrams. Trends in publication topics were analysed using simple linear regression to find the rate of change of publication volume on each topic.

Results A total of 3097 publications contributed to by 8855 individual authors met inclusion criteria. Across the study period, there was a large increase in the annual volume of publications on the topic of ACL (Anterior Cruciate Ligament) surgery. We also found that collaboration between Australian and New Zealand authors was very low with only 1% ($n = 31$) of publications including authors from both countries and 0.4% ($n = 12$) including orthopaedic surgeons or trainees from both.

Conclusions Publications on ACL surgery have increased over the past decade, likely due to the presence of competing surgical approaches and the recently recognized risk of osteoarthritis following ACL reconstruction. The overall collaboration between Australian and New Zealand authors was very low which lends itself to opportunities for future research.

Keywords Orthopaedics · Bibliometrics · Australia · New Zealand · Anterior cruciate ligament

Electronic supplementary material The online version of this article (<https://doi.org/10.1007/s00264-019-04359-1>) contains supplementary material, which is available to authorized users.

✉ Mark L. Vickers
Mark.vickers@uq.net.au

¹ Faculty of Medicine, The University of Queensland, Brisbane, Queensland, Australia

² QIMR Berghofer Medical Research Institute, Brisbane, Queensland, Australia

³ Department of Orthopaedics, Mater Health Services, Brisbane, Queensland, Australia

⁴ Department of Surgery, Epworth Clinical School, The University of Melbourne, Melbourne, Victoria, Australia

⁵ Biomedical Engineering and Clinical Sciences, Queensland University of Technology, Brisbane, Queensland, Australia

⁶ Orthopaedic Department, The Prince Charles Hospital, Brisbane, Queensland, Australia

Introduction

Australian and New Zealand orthopaedic networks evolved from a mutual medical experience in the First World War and the subsequent foundation of a common surgical college in 1926 [1, 2]. These geographic neighbours have come to largely share in their approach to domestic orthopaedic education, research and registry data capture, while co-hosting exchange fellowships and annual scientific meetings [1, 2]. Clinicians from both countries have made important contributions internationally to orthopaedic knowledge on robotics [3], autologous bone grafting techniques [4], the dangers of metal on metal joint replacement [5], surgical space suit infection risk [6], and pathologies impacting femoral fracture fixation [7]. In order to highlight significant advances and knowledge gaps, and to assist future research direction and funding, it is important to analyse the progress of recent Australian and New Zealand orthopaedic publications.

Bibliometric analysis combines metrics such as citation counts and journals' impact factors with trend analysis to

enable a surrogate quantification of the state of play within a given scientific field [8]. Outstanding metric scores can indicate a high level of scientific impact, peer interest and academic or research productivity [8, 9]. High total citation counts for instance, demonstrate strong acceptance by fellow researchers of the validity of an author's scientific findings [8]. In recent years, there have been a growing number of citation analyses on orthopaedic topics including shoulder surgery, pelvic trauma, paediatric surgery and ankle arthroplasty [9–12]. Identifying those publications and authors with the greatest impact can influence the practice of junior clinicians, direct current and future research and inform funding bodies by adding to knowledge on areas of interest, innovation and deficiency [8, 13, 14]. Exemplifying this are two recent bibliometric studies of Australian research by Hohmann et al. and Croker et al. who respectively noted that knee surgery is presently the dominant topic and that many senior clinician mentorship opportunities are frequently missed [13, 14].

To date, there have been no comprehensive bibliometric analyses of Australian and New Zealand orthopaedic research. The aim of this study was to summarize Australian and New Zealand orthopaedic literature produced during the past decade to identify firstly, the top 50 most cited publications, secondly, the characteristics of author and institution networks between Australia and New Zealand, and thirdly, topic trends.

Methods

Search strategy

A search of the literature was conducted using Clarivate Analytics Web of Science to identify all orthopaedic publications by Australian and New Zealand authors from 1 January 2008 to 10 September 2018. We searched using a combination of topic and address fields. The topic field included the terms: clavicle, scapula, shoulder, rotator cuff, tendon, humerus, elbow, radius, ulna, wrist, carpal, scaphoid, spine, vertebra, pelvis, hip, thigh, femur, knee, cruciate, meniscus, patella, tibia, fibula, ankle, tarsal, arthroscopy, arthrodesis, arthroplasty, chondroplasty, closed reduction, debridement, decompression, discectomy, laminectomy, open reduction, osteoarthritis, osteotomy, repair and replacement. The address field contained Australian and New Zealand location names including: (1) names and abbreviations of all states and territories, (2) city names with a population greater than 100,000 and (3) hospital names performing more than 1000 orthopaedic procedures per year. The full search strategy is available in Appendix A and was devised in consultation with health science librarians.

Exclusion criteria

A single author (AWC) manually reviewed publications in a three-step process that included screening by title, abstract and

address, then full text. Publications were included if they focused on an orthopaedic clinical or science topic and at least one author listed an institution or address affiliation in Australia or New Zealand. For inclusion into the top 50 most cited list and top 40 highest contributing authors list, we additionally required at least one author to be an Australian or New Zealand orthopaedic surgeon or trainee at the time of publication. We included only journal articles and review articles. No language restriction was applied. Animal research was excluded unless related to surgical training. No human or animal rights ethics approval was required for this study. Full details of the exclusion process are available in Appendix B.

Data collection and statistical analysis

The top 50 cited publications were reviewed in full. We used Web of Science tools to identify publication type, citation count, author affiliation, publishing journal and journal impact factor. We summarized the following: (1) the overall most cited publication, (2) the publication with the fastest growing citation count, and (3) the top cited randomized control trial (RCT). Calculation of citation count growth potentially corrects for citation lag and indicates that a paper may later become the highest cited publication overall [15]. We calculated this by dividing the total citations by the number of years since publication to within a one month accuracy [15].

To analyse the characteristics of author and institution networks, we exported dataset details to Endnote (Clarivate Analytics, USA) and R (R Core Team, Austria), using R packages ggplot2 [16], ggrepel [17] and Circlize [18]. For author names we used an all initials method of disambiguation, whereby authors with the same surname and first initial but different second initial were considered unique. For the highest contributing authors, we manually reviewed alternate naming conventions. Authors were only included in the top 40 list if they were Australian or New Zealand orthopaedic surgeons or trainees. To focus on Australian- and New Zealand-based research we only included publications produced by international authors if they listed an Australian or New Zealand affiliation. To describe organizations, individual affiliations were manually combined under governing umbrella groups and clustered to the state level.

For the topic trend analysis, we categorized all publications under one of 35 predefined topics, devised in consultation with senior orthopaedic surgeons. Predefined criteria for categorisation were defined in consultation with senior authors (RC, MR, SFJ) and a hierarchical allocation system was used; full details of categorisation methods are detailed in Appendix B. Trends in topic publication volume from 2008 to 2018 were identified using simple linear regressions for each topic, in which the independent variable was the year, and the dependent variable was the proportion of all publications each year devoted to that topic. Proportions were used to

correct for partial data for 2018. The relative annual change was calculated by dividing the regression coefficient of the independent variable by the proportion of all publications on a topic.

Results

Our search conducted on 10 September 2018 yielded 11,489 publications. Of these, we excluded 4672 publications based on the title review and an additional 3720 publications based on abstract, article type and author address. Our final dataset comprised 3097 publications. Our search and exclusion process is summarized using a PRISMA flowchart in Fig. 1.

Top 50 citation analysis

Of the top 50 most cited publications, most were prospective cohort studies ($n = 14$, 28%), followed by retrospective cohort studies ($n = 10$, 20%), and literature reviews ($n = 7$, 14%). The topic with the most publications was implants and materials ($n = 13$, 26%). This was followed by publications on knee arthroplasty ($n = 7$, 14%), infection ($n = 6$, 12%), sports medicine ($n = 4$, 8%) and anterior cruciate ligament (ACL) surgery

($n = 4$, 8%). The *American Journal of Sports Medicine* was the highest contributing journal ($n = 8$, 16%), followed by *Journal of Bone and Joint Surgery* (United Kingdom) ($n = 7$, 14%), *Journal of Bone and Joint Surgery* (USA) ($n = 6$, 12%) and *Journal of Arthroplasty* ($n = 4$, 8%). A total of 62 Australian or New Zealand surgeons and trainees contributed to the 50 most cited publications list and were either first or senior author of 24 (48%) and 25 (50%) publications, respectively. Choong PFM was the most represented author, contributing to eight (16%) publications, followed by Graves SE ($n = 4$, 8%), and Feller JA, Shimmin AJ, Pinczewski LA, Wood DJ and de Steiger RN, with three (6%) publications each. The most represented senior author was Choong PFM ($n = 5$, 10%), followed by Pinczewski LA ($n = 3$, 6%) and Beaver RJ ($n = 2$, 4%). Hui C ($n = 2$, 4%) was the only person who was first author of more than one publication, and was also one of only two contributing authors who were female, the other being Hang J. Table 1 lists the 50 most cited articles.

The top cited publication overall was a 2012 review published in the *Lancet* titled ‘Knee Replacement’ by Carr et al. [19]. This was cited 288 times and details knee arthroplasty epidemiology, indications for surgery, the case for partial versus total arthroplasty, cost effectiveness, survival outcomes, patient-reported measures, functional performance tests and

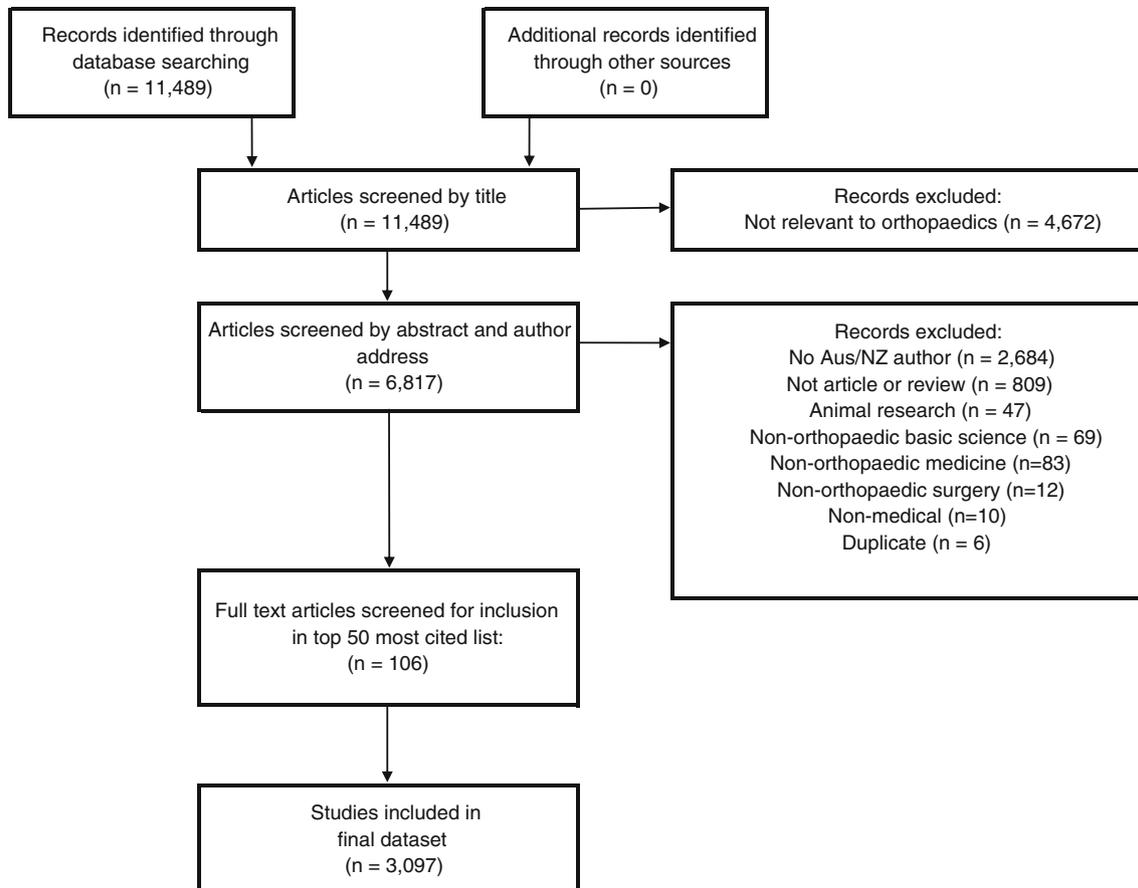


Fig. 1 PRISMA flowchart detailing the exclusion process

Table 1 Top 50 most cited articles and citation number at time of search

Rank number	Article	Citation number
1.	Carr AJ, Robertsson O, Graves S, et al. Knee replacement. <i>Lancet</i> 2012; 379(9823): 1331–40.	288
2.	Kerr DR, Kohan L. Local infiltration analgesia: a technique for the control of acute postoperative pain following knee and hip surgery - A case study of 325 patients. <i>Acta Orthopaedica</i> 2008; 79(2): 174–83.	274
3.	Arden CL, Webster KE, Taylor NF, Feller JA. Return to the Preinjury Level of Competitive Sport After Anterior Cruciate Ligament Reconstruction Surgery Two-thirds of Patients Have Not Returned by 12 Months After Surgery. <i>American Journal of Sports Medicine</i> 2011; 39(3): 538–43.	205
4.	Choong PF, Dowsey MM, Stoney JD. Does Accurate Anatomical Alignment Result in Better Function and Quality of Life? Comparing Conventional and Computer-Assisted Total Knee Arthroplasty. <i>Journal of Arthroplasty</i> 2009; 24(4): 560–9.	199
5.	Wang XJ, Xu SQ, Zhou SW, et al. Topological design and additive manufacturing of porous metals for bone scaffolds and orthopaedic implants: A review. <i>Biomaterials</i> 2016; 83: 127–41.	186
6.	Longstaff LM, Sloan K, Stamp N, Scaddan M, Beaver R. Good Alignment After Total Knee Arthroplasty Leads to Faster Rehabilitation and Better Function. <i>Journal of Arthroplasty</i> 2009; 24(4): 570–8.	165
7.	Reichert JC, Saifzadeh S, Wulschleger ME, et al. The challenge of establishing preclinical models for segmental bone defect research. <i>Biomaterials</i> 2009; 30(12): 2149–63.	162
8.	Shimmin A, Beaulé PE, Campbell P. Metal-on-metal hip resurfacing arthroplasty. <i>Journal of Bone and Joint Surgery-American Volume</i> 2008; 90A(3): 637–54.	160
9.	Chen JM, Xu JK, Wang AL, Zheng MH. Scaffolds for tendon and ligament repair: review of the efficacy of commercial products. <i>Expert Review of Medical Devices</i> 2009; 6(1): 61–73.	139
10.	Dowsey MM, Choong PFM. Obesity is a major risk factor for prosthetic infection after primary hip arthroplasty. <i>Clinical Orthopaedics and Related Research</i> 2008; 466(1): 153–8.	136
11.	Leys T, Salmon L, Waller A, Linklater J, Pinczewski L. Clinical Results and Risk Factors for Reinjury 15 Years After Anterior Cruciate Ligament Reconstruction A Prospective Study of Hamstring and Patellar Tendon Grafts. <i>American Journal of Sports Medicine</i> 2012; 40(3): 595–605.	134
11.	Gill IPS, Webb J, Sloan K, Beaver RJ. Corrosion at the neck-stem junction as a cause of metal ion release and pseudotumour formation. <i>Journal of Bone and Joint Surgery-British Volume</i> 2012; 94B(7): 895–900.	134
13.	Henkel J, Woodruff MA, Epari DR, et al. Bone Regeneration Based on Tissue Engineering Conceptions - A twenty-first Century Perspective. <i>Bone Research</i> 2013; 1: 216–48.	131
14.	Keays SL, Newcombe PA, Bullock-Saxton JE, Bullock MI, Keays AC. Factors Involved in the Development of Osteoarthritis After Anterior Cruciate Ligament Surgery. <i>American Journal of Sports Medicine</i> 2010; 38(3): 455–63.	127
15.	Little NJ, Busch CA, Gallagher JA, Rorabeck CH, Bourne RB. Acetabular Polyethylene Wear and Acetabular Inclination and Femoral Offset. <i>Clinical Orthopaedics and Related Research</i> 2009; 467(11): 2895–900.	115
16.	Dowsey MM, Choong PFM. Obese Diabetic Patients are at Substantial Risk for Deep Infection after Primary TKA. <i>Clinical Orthopaedics and Related Research</i> 2009; 467(6): 1577–81.	114
17.	Sikorski JM. Alignment in total knee replacement. <i>Journal of Bone and Joint Surgery-British Volume</i> 2008; 90B(9): 1121–7.	106
17.	Kurtz SM, Ong KL, Lau E, et al. International survey of primary and revision total knee replacement. <i>International Orthopaedics</i> 2011; 35(12): 1783–9.	106
19.	Urquhart DM, Hanna FS, Brennan SL, et al. Incidence and Risk Factors for Deep Surgical Site Infection After Primary Total Hip Arthroplasty: A Systematic Review. <i>Journal of Arthroplasty</i> 2010; 25(8): 1216–22.	102
19.	Mei-Dan O, McConkey MO, Brick M. Catastrophic Failure of Hip Arthroscopy Due to Iatrogenic Instability: Can Partial Division of the Ligamentum Teres and Iliofemoral Ligament Cause Subluxation? <i>Arthroscopy-the Journal of Arthroscopic and Related Surgery</i> 2012; 28(3): 440–5.	102
21.	Campbell P, Shimmin A, Walter L, Solomon M. Metal Sensitivity as a Cause of Groin Pain in Metal-on-Metal Hip Resurfacing. <i>Journal of Arthroplasty</i> 2008; 23(7): 1080–5.	101
22.	Zhang BGX, Myers DE, Wallace GG, Brandt M, Choong PFM. Bioactive Coatings for Orthopaedic Implants-Recent Trends in Development of Implant Coatings. <i>International Journal of Molecular Sciences</i> 2014; 15(7): 11878–921.	100
23.	Walter WL, Waters TS, Gillies M, et al. Squeaking Hips. <i>Journal of Bone and Joint Surgery-American Volume</i> 2008; 90A: 102–11.	98
23.	Hooper GJ, Rothwell AG, Frampton C, Wyatt MC. Does the use of laminar flow and space suits reduce early deep infection after total hip and knee replacement? The ten-year results of the New Zealand Joint Registry. <i>Journal of Bone and Joint Surgery-British Volume</i> 2011; 93B(1): 85–90.	98
25.	de Steiger RN, Hang JR, Miller LN, Graves SE, Davidson DC. Five-Year Results of the ASR XL Acetabular System and the ASR Hip Resurfacing System An Analysis from the Australian Orthopaedic Association National Joint Replacement Registry. <i>Journal of Bone and Joint Surgery-American Volume</i> 2011; 93A(24): 2287–93.	97
26.	Howie DW, Holubowycz OT, Middleton R, Large Articulation Study G. Large Femoral Heads Decrease the Incidence of Dislocation After Total Hip Arthroplasty A Randomized Controlled Trial. <i>Journal of Bone and Joint Surgery-American Volume</i> 2012; 94A(12): 1095–102.	96
27.	Willis-Owen CA, Konyves A, Martin DK. Factors affecting the incidence of infection in hip and knee replacement: An analysis of 5277 cases. <i>Journal of Bone and Joint Surgery-British Volume</i> 2010; 92B(8): 1128–33.	95
27.	Mulford JS, Ceulemans LJ, Nam D, Axelrod TS. Proximal Row Carpectomy vs Four Corner Fusion for Scapholunate (SLAC) or Scaphoid Nonunion Advanced Collapse (SNAC) Wrists: A Systematic Review of Outcomes. <i>Journal of Hand Surgery-European Volume</i> 2009; 34E(2): 256–63.	95
29.	Ebert JR, Robertson WB, Woodhouse J, et al. Clinical and Magnetic Resonance Imaging-Based Outcomes to 5 Years After Matrix-Induced Autologous Chondrocyte Implantation to Address Articular Cartilage Defects in the Knee. <i>American Journal of Sports Medicine</i> 2011; 39(4): 753–63.	93

Table 1 (continued)

Rank number	Article	Citation number
30.	Arden CL, Taylor NF, Feller JA, Whitehead TS, Webster KE. Psychological Responses Matter in Returning to Preinjury Level of Sport After Anterior Cruciate Ligament Reconstruction Surgery. <i>American Journal of Sports Medicine</i> 2013; 41(7): 1549–58.	92
31.	Hui C, Salmon LJ, Kok A, Maeno S, Linklater J, Pinczewski LA. Fifteen-Year Outcome of Endoscopic Anterior Cruciate Ligament Reconstruction With Patellar Tendon Autograft for “Isolated” Anterior Cruciate Ligament Tear. <i>American Journal of Sports Medicine</i> 2011; 39(1): 89–98.	89
31.	Ek ETH, Neukom L, Catanzaro S, Gerber C. Reverse total shoulder arthroplasty for massive irreparable rotator cuff tears in patients younger than 65 years old: results after five to fifteen years. <i>Journal of Shoulder and Elbow Surgery</i> 2013; 22(9): 1199–208.	89
33.	Dowsey MM, Liew D, Stoney JD, Choong PF. The impact of pre-operative obesity on weight change and outcome in total knee replacement: A prospective study of 529 consecutive patients. <i>Journal of Bone and Joint Surgery-British Volume</i> 2010; 92B(4): 513–20.	86
34.	Karanicolas PJ, Bhandari M, Kreder H, et al. Evaluating Agreement: Conducting a Reliability Study. <i>Journal of Bone and Joint Surgery-American Volume</i> 2009; 91A: 99–106.	85
35.	Peel TN, Cheng AC, Buising KL, Choong PFM. Microbiological Aetiology, Epidemiology, and Clinical Profile of Prosthetic Joint Infections: Are Current Antibiotic Prophylaxis Guidelines Effective? <i>Antimicrobial Agents and Chemotherapy</i> 2012; 56(5): 2386–91.	84
36.	Griffin DR, Dickenson EJ, O’Donnell J, et al. The Warwick Agreement on femoroacetabular impingement syndrome (FAI syndrome): an international consensus statement. <i>British Journal of Sports Medicine</i> 2016; 50(19): 1169–76.	82
37.	Young AA, Maia R, Berhouet J, Walch G. Open Latarjet procedure for management of bone loss in anterior instability of the glenohumeral joint. <i>Journal of Shoulder and Elbow Surgery</i> 2011; 20(2): S61-S9.	81
38.	Lloyd BD, Williamson DA, Singh NA, et al. Recurrent and Injurious Falls in the Year Following Hip Fracture: A Prospective Study of Incidence and Risk Factors From the Sarcopenia and Hip Fracture Study. <i>Journals of Gerontology Series a-Biological Sciences and Medical Sciences</i> 2009; 64(5): 599–609.	80
38.	Coulter G, Young DA, Dalziel RE, Shimmin AJ. Birmingham hip resurfacing at a mean of ten years: Results from an independent centre. <i>Journal of Bone and Joint Surgery-British Volume</i> 2012; 94B(3): 315–21.	80
40.	Trantalis JN, Boorman RS, Pletsch K, Lo IKY. Medial rotator cuff failure after arthroscopic double-row rotator cuff repair. <i>Arthroscopy-the Journal of Arthroscopic and Related Surgery</i> 2008; 24(6): 727–31.	78
41.	Thomason P, Baker R, Dodd K, et al. Single-Event Multilevel Surgery in Children with Spastic Diplegia A Pilot Randomized Controlled Trial. <i>Journal of Bone and Joint Surgery-American Volume</i> 2011; 93A(5): 451–60.	76
42.	Singh PJ, O’Donnell JM. The Outcome of Hip Arthroscopy in Australian Football League Players: A Review of 27 Hips. <i>Arthroscopy-the Journal of Arthroscopic and Related Surgery</i> 2010; 26(6): 743–9.	75
42.	Ebert JR, Robertson WB, Lloyd DG, Zheng MH, Wood DJ, Ackland T. Traditional vs accelerated approaches to post-operative rehabilitation following matrix-induced autologous chondrocyte implantation (MACI): comparison of clinical, biomechanical and radiographic outcomes. <i>Osteoarthritis and Cartilage</i> 2008; 16(10): 1131–40.	75
42.	Busija L, Bridgett L, Williams SRM, et al. Osteoarthritis. <i>Best Practice & Research in Clinical Rheumatology</i> 2010; 24(6): 757–68.	75
42.	Biau DJ, Katsahian S, Kartus J, et al. Patellar Tendon Versus Hamstring Tendon Autografts for Reconstructing the Anterior Cruciate Ligament A Meta-Analysis Based on Individual Patient Data. <i>American Journal of Sports Medicine</i> 2009; 37(12): 2470–8.	75
46.	Prosser GH, Yates PJ, Wood DJ, Graves SE, de Steiger RN, Miller LN. Outcome of primary resurfacing hip replacement: evaluation of risk factors for early revision 12,093 replacements from the Australian Joint Registry. <i>Acta Orthopaedica</i> 2010; 81(1): 66–71.	74
47.	Panteli M, Papakostidis C, Dahabreh Z, Giannoudis PV. Topical tranexamic acid in total knee replacement: A systematic review and meta-analysis. <i>Knee</i> 2013; 20(5): 300–9.	73
47.	Boyle MJ, Youn SM, Frampton CMA, Ball CM. Functional outcomes of reverse shoulder arthroplasty compared with hemiarthroplasty for acute proximal humeral fractures. <i>Journal of Shoulder and Elbow Surgery</i> 2013; 22(1): 32–7.	73
49.	Pearse AJ, Hooper GJ, Rothwell A, Frampton C. Survival and functional outcome after revision of a unicompartmental to a total knee replacement: The New Zealand National Joint Registry. <i>Journal of Bone and Joint Surgery-British Volume</i> 2010; 92B(4): 508–12.	72
49.	Hui C, Salmon LJ, Kok A, et al. Long-Term Survival of High Tibial Osteotomy for Medial Compartment Osteoarthritis of the Knee. <i>American Journal of Sports Medicine</i> 2011; 39(1): 64–70.	72

costing. The publication with the fastest growing citation count was ‘Topological design and additive manufacturing of porous metals for bone scaffolds and orthopaedic implants: A review’ by Wang et al. which also ranked fifth overall with 186 citations. This received 70 citations per year compared to the next fastest growing citation count by Carr et al. with 44 citations per year. Wang et al. describes advances in additive manufacturing, porous scaffold topologies, optimization and recommendations for this burgeoning field [20]. The top cited randomized controlled trial was ranked fourth overall with

199 citations and titled ‘Does accurate anatomical alignment result in better function and quality of life? Comparing conventional and computer-assisted total knee arthroplasty’ [21]. Published in 2009 by Choong et al., this study randomized patients undergoing total knee arthroplasty to receive either conventional jig based or computer-navigated surgery and compared the incidence of adequate mechanical alignment, as well as correlating coronal and femoral rotational alignment with knee function and quality of life. The authors identified significantly better alignment with computer assisted

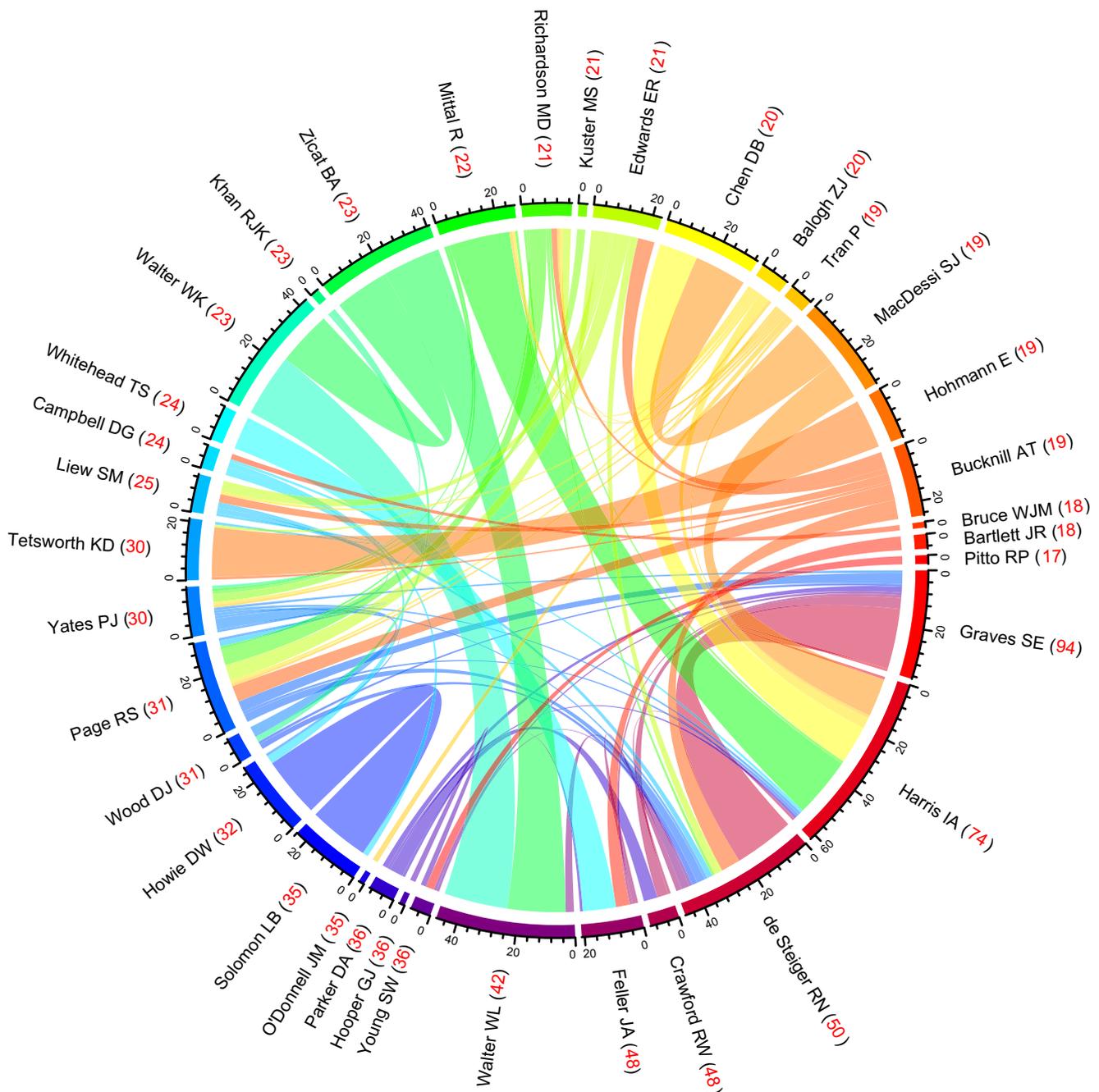


Fig. 2 Collaboration network of the top 40 highest contributing Australian or New Zealand orthopaedic surgeons or trainees who collaborated with other surgeons or trainees in the top 40. The outer rim represents the number of collaborations each individual has made with

other authors and the width of each chord is proportional to the number of collaborations between the two authors. Total number of publications in brackets. Two authors tied for fortieth place, so 41 authors were included in total. Only 35 authors are shown as six did not collaborate at all

procedures over conventional techniques, especially in obese patients [21].

Author and institution collaboration networks

From a total dataset of 3097 articles, we identified 8855 individual authors and 501 publishing journals. The journal with the most publications was *Journal of Arthroplasty* with 208

publications (2017 Journal Impact Factor 3.339), followed by *ANZ Journal of Surgery* with 131 publications (2017 JIF 1.586). A total of 2772 (89.5%) publications included an Australian author, while 356 (11.5%) publications included a New Zealand author. The highest contributing Australian orthopaedic surgeon or trainee was Graves SE with 94 publications, followed by Choong PFM ($n=92$) and Harris IA ($n=74$). The highest contributing New Zealand orthopaedic

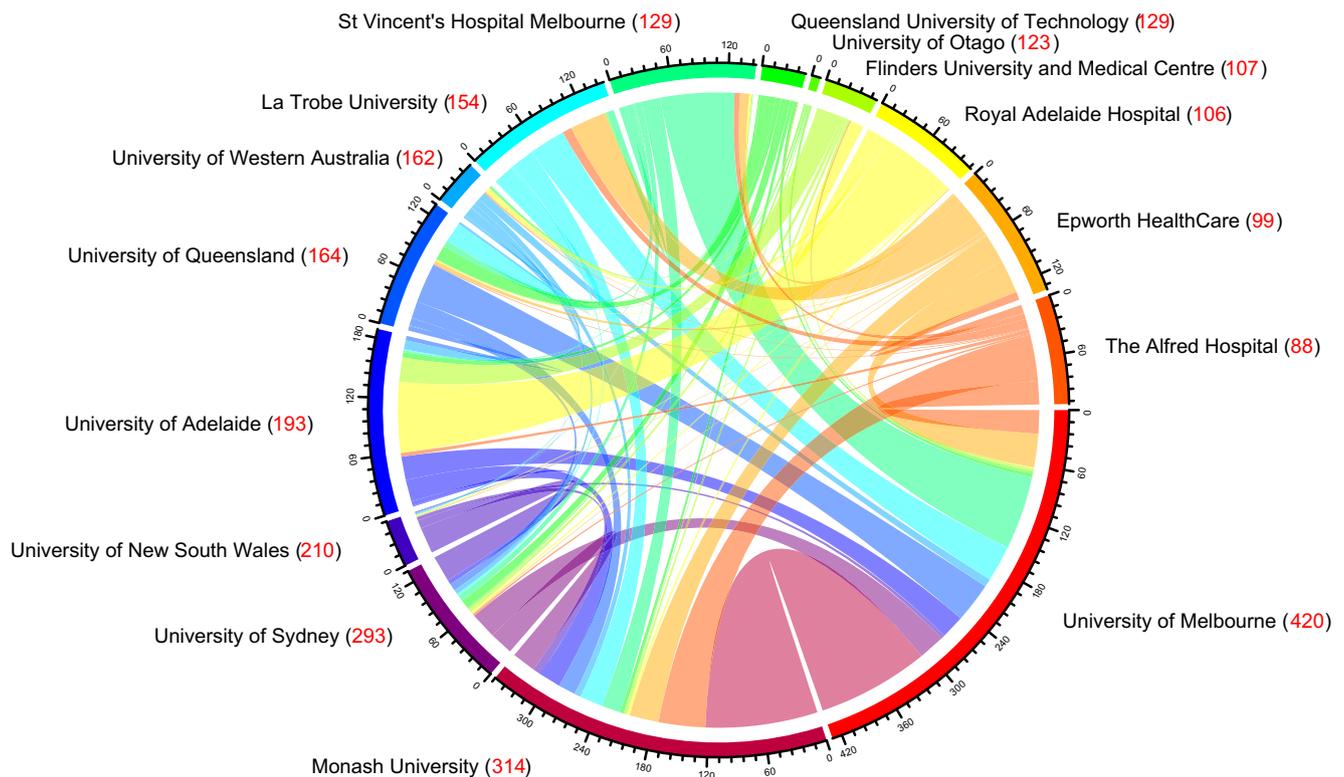


Fig. 3 Collaboration network between the top 15 highest contributing Australian or New Zealand institutions. The outer rim represents the number of collaborations individual organizations made with other

organizations in the top 15, and the width of each chord is proportional to the number of collaborations between the two organizations. Total number of publications in brackets

surgeons or trainees were Young SW and Hooper GJ with 36 publications each. Of the total dataset, only 31 (1%) publications included an author from both Australia and New Zealand, and only 12 (0.4%) publications included an orthopaedic surgeon or trainee from both countries. Of the surgeons or trainees contributing to these 12 publications only Page RS (Australian) collaborated more than once with a surgeon or trainee from the other country, with two collaborations. Of the top 40 highest contributing orthopaedic surgeons or trainees, six never collaborated with any of the others. This included Choong PFM, the second most published Australian orthopaedic surgeon. Of those who did collaborate, the two collaborating most frequently were father and son, Walter WL and Walter WK with 23 collaborations. Author collaboration networks are shown in Fig. 2.

There were 611 unique institutions which contributed to our dataset, comprising 524 Australian and 87 New Zealand institutions. The institution with the highest number of contributions was the University of Melbourne, with 420 publications. This was followed by Monash University ($n = 314$) and the University of Sydney ($n = 293$). The hospital with the highest number of contributions was St Vincent's Hospital Melbourne ($n = 129$). The most prolific New Zealand institution was the University of Otago ($n = 123$). The greatest number of collaborations between institutions occurred between the University of Melbourne and Monash University with

123 collaborations. This was followed by the University of Melbourne and St Vincent's Hospital Melbourne with 81 collaborations. Institution collaboration networks are shown in Fig. 3.

Topic trends analysis

Of the 35 discrete topics, the most common was orthopaedic basic science with 438 publications (14.1%), followed by implants and materials ($n = 338$, 10.9%), peri-operative care ($n = 214$, 6.9%) and non-surgical management ($n = 174$, 5.6%). Overall publication output showed a strong linearly increasing trend by year (R -squared 0.97). Linear regressions by year for each topic demonstrated 20 topics increasing, and 15 topics decreasing as a proportion of total publications across the study period. ACL (anterior cruciate ligament) surgery demonstrated the greatest relative change in the annual proportion of publications devoted to it, with proportional publication volume increasing annually by 17.5% of the total proportional volume over the study period. The next fastest growing topics were hip arthroscopy (10.2%), foot and ankle surgery (9.3%) and spine surgery (9.0%). Radiology (12.8%) and anaesthesia and analgesia (11.5%) showed the greatest relative decrease in proportional publication volume, and were the only topics demonstrating an absolute decrease in annual publication numbers. Figure 4 displays the absolute and

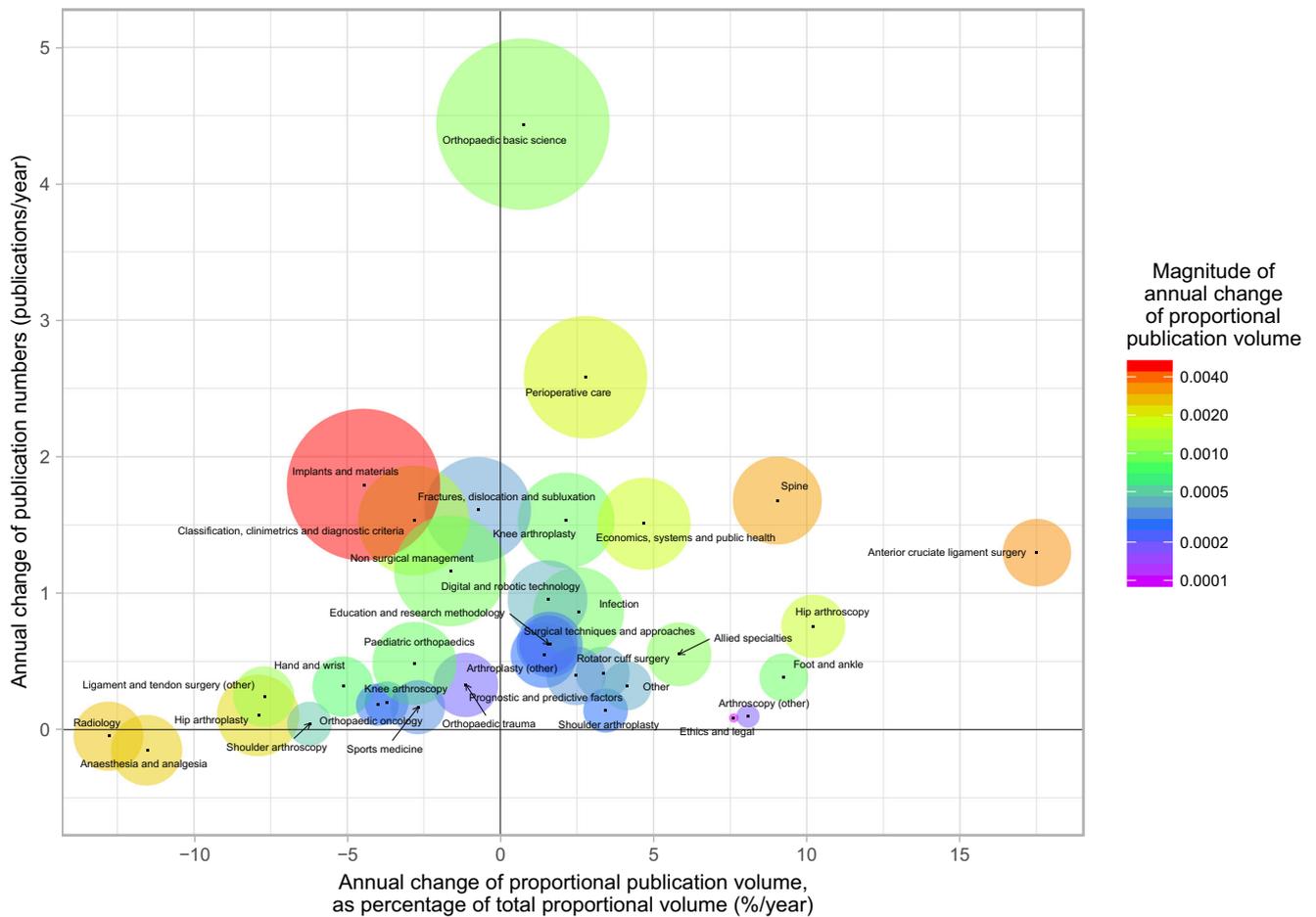


Fig. 4 Absolute and relative rates of change in publication volume on each topic across the study period. Each disc represents a topic, with size proportional to the total number of papers on that topic. Disc colour represents the annual rate of change of the proportion of publications on

each topic between 2008 and 2018. The horizontal axis represents this rate as a fraction of the total proportion of papers devoted to each topic, and the vertical axis shows the absolute rate of change of annual publication numbers on each topic over all complete years

relative trends in topic volume for all topics, and Fig. 5 shows detailed trends across the study period for the topics for which the relative change in the annual

proportion of publications on that topic exceeded 10%. The volume of publications per topic is presented in Table 2.

Fig. 5 Topics with greatest increase or decrease in annual publication volume. The figure shows proportion of articles published each year for all topics with an annual rate of change from linear regression analysis greater than 10% of the proportion of all publications on that topic from 2008 to 2018

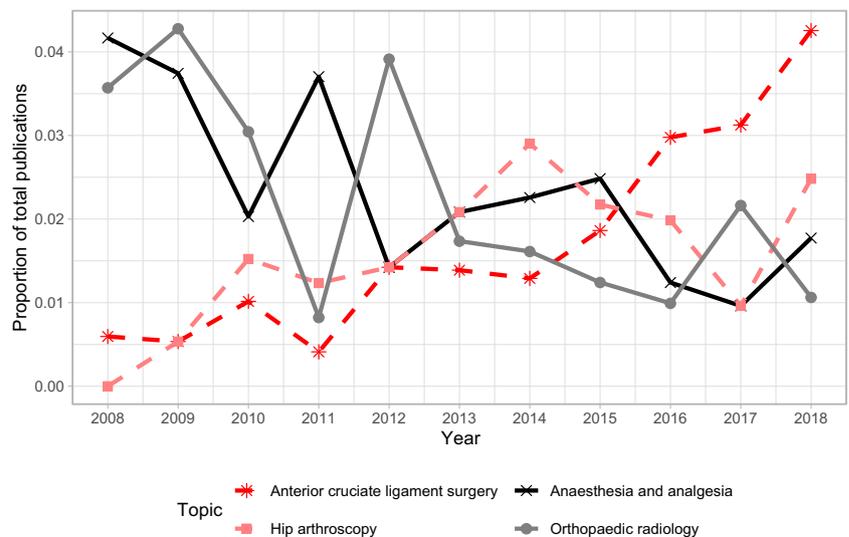


Table 2 Number and percentage of publications per orthopaedic topic ($n = 3097$)

Orthopaedic topics	Number	Percentage
Orthopaedic basic science ^a	438	14.1
Implants and materials	338	10.9
Peri-operative care	214	6.9
Non-surgical management	174	5.6
Classification, clinimetrics and diagnostic criteria	171	5.5
Fractures, dislocation and subluxation	156	5
Knee arthroplasty	127	4.1
Economics, systems and public health	117	3.8
Infection	111	3.6
Spine	106	3.4
Paediatric orthopaedics	94	3
Hip arthroplasty	90	2.9
Digital and robotic technology	84	2.7
Anaesthesia and analgesia	66	2.1
Radiology	63	2
Anterior cruciate ligament surgery	60	1.9
Arthroplasty (other) ^b	56	1.8
Surgical techniques and approaches	56	1.8
Orthopaedic trauma	54	1.7
Allied specialties	53	1.7
Hip arthroscopy	52	1.7
Hand and wrist	47	1.5
Ligament and tendon surgery (other) ^c	47	1.5
Prognostic and predictive factors	44	1.4
Education and research methodology	43	1.4
Sports medicine	37	1.2
Rotator cuff surgery	36	1.2
Other	30	1
Foot and ankle	29	0.9
Shoulder arthroplasty	24	0.8
Shoulder arthroscopy	24	0.8
Knee arthroscopy	23	0.7
Orthopaedic oncology	22	0.7
Arthroscopy (other) ^d	7	0.2
Ethics and legal	4	0.1

^a Non-clinical research with an orthopaedic focus including biochemical, biomechanical and cadaveric studies but excluding animal research

^b Any arthroplasty not of the hip, knee or shoulder

^c Any ligament or tendon surgery not of the rotator cuff or anterior cruciate ligament

^d Any arthroscopy not of the hip, knee or shoulder

Discussion

The aim of this study was to conduct a bibliometric analysis of orthopaedic publications produced by Australian and New

Zealand authors over the past decade to identify the top 50 most cited publications in the field, collaboration networks and topic trends.

Our search strategy and exclusion criteria produced a final dataset of 3097 publications. Using linear regression, we identified a large annual increase in the proportion of publications on ACL surgery as a percentage of the total proportion of publications on that topic (17.5%). We also found very low collaboration between Australian and New Zealand authors with just 0.4% ($n = 12$) of publications including an orthopaedic surgeon or trainee from both countries. Our finding regarding ACL surgery reflects publication output following an increase in research activity. This follows a recent period where the patellofemoral graft approach competed with a hamstring graft approach for superiority [22, 23]. Other factors influencing interest in ACL surgery include the recent recognition of increased early patellofemoral osteoarthritis following ACL reconstruction [24], and a growing tendency to perform ACL procedures in younger patients [25]. We cannot explain our finding regarding the observed low levels of collaboration between Australian and New Zealand authors, surgeons and trainees. Croker et al. noted that improving collaboration between orthopaedic clinicians may enhance research quality and productivity by building research networks, expediting data collection and providing fertile ground for high-level prospective multicentre clinical trials [13]. Our finding points to potential opportunities for future research direction and funding between Australia and New Zealand.

There are a number of limitations to our study. Firstly, because we used author affiliation as a proxy for author country of origin it is possible that we missed important publications by Australian or New Zealand authors where those authors listed a foreign institution. Secondly, many authors in this study produced other publications which were not included in our dataset and so our analysis may not be reflective of an author's full research impact. Thirdly, only one author screened all articles by title and abstract during the exclusion and categorisation stages which increases the risk of bias though we attempted to mitigate this through the use of clear predefined exclusion and category criteria. Finally, finer detail in publication trends on each topic from 2008 to 2018 may have been overlooked by performing only linear regressions.

Conclusion

During the past decade, the annual volume of publications from Australian and New Zealand authors on the topic of ACL surgery has increased. In addition, the level of collaboration between Australian and New Zealand orthopaedic surgeons and trainees was very low with just 0.4% of publications including a surgeon or trainee from both countries.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

- New Zealand Orthopaedic Association (2014) A brief history of orthopaedics in New Zealand. New Zealand Orthopaedic Association. <http://www.nzoa.org.nz/brief-history-orthopaedics-new-zealand>. Accessed 11 November 2018
- Williams PF (1992) Orthopaedic surgery in Australia: an international perspective. *Aust N Z J Surg* 62(1):3–6
- Karunaratne S, Duan M, Pappas E, Fritsch B, Boyle R, Gupta S, Stalley P, Horsley M, Steffens D (2018) The effectiveness of robotic hip and knee arthroplasty on patient-reported outcomes: a systematic review and meta-analysis. *Int Orthop*. <https://doi.org/10.1007/s00264-018-4140-3>
- Rutherford M, Khan RJK, Fick DP, Haebich S, Nivbrant O, Kozak T (2019) Randomised clinical trial assessing migration of uncemented primary total hip replacement stems, with and without autologous impaction bone grafting. *Int Orthop*. <https://doi.org/10.1007/s00264-019-04290-5>
- de Steiger RN, Hang JR, Miller LN, Graves SE, Davidson DC (2011) Five-year results of the ASR XL acetabular system and the ASR hip resurfacing system: an analysis from the Australian Orthopaedic Association National Joint Replacement Registry. *J Bone Joint Surg Am* 93(24):2287–2293. <https://doi.org/10.2106/JBJS.J.01727>
- Vijayasegaran P, Knibbs LD, Morawska L, Crawford RW (2018) Surgical space suits increase particle and microbiological emission rates in a simulated surgical environment. *J Arthroplast* 33(5):1524–1529. <https://doi.org/10.1016/j.arth.2017.12.009>
- Gallagher CA, Jones CW, Kimmel L, Wylde C, Osbrough A, Bulsara M, Hird K, Yates P (2019) Osteoarthritis is associated with increased failure of proximal femoral fracture fixation. *Int Orthop* 43(5):1223–1230. <https://doi.org/10.1007/s00264-018-4014-8>
- Wallin JA (2005) Bibliometric methods: pitfalls and possibilities. *Basic Clin Pharmacol Toxicol* 97(5):261–275. https://doi.org/10.1111/j.1742-7843.2005.pto_139.x
- Namdari S, Baldwin K, Kovatch K, Huffman GR, Glaser D (2012) Fifty most cited articles in orthopedic shoulder surgery. *J Shoulder Elb Surg* 21(12):1796–1802. <https://doi.org/10.1016/j.jse.2011.11.040>
- Malik AT, Noordin S (2018) The top 50 most-cited articles on total ankle arthroplasty: a bibliometric analysis. *Orthop Rev (Pavia)* 10(1):7498. <https://doi.org/10.4081/or.2018.7498>
- Mehlman CT, Wenger DR (2006) The top 25 at 25: citation classics in the journal of pediatric orthopaedics. *J Pediatr Orthop* 26(5):691–694. <https://doi.org/10.1097/01.bpo.0000235229.53163.de>
- White-Gibson A, O'Neill B, Cooper D, Leonard M, O'Daly B (2018) Levels of evidence in pelvic trauma: a bibliometric analysis of the top 50 cited papers. *Ir J Med Sci*. <https://doi.org/10.1007/s11845-018-1818-x>
- Croker N, Lobo A, Croker A, Balogh ZJ, Dewar D (2017) Who, where, what and where to now? A snapshot of publishing patterns in Australian orthopaedic surgery. *ANZ J Surg* 87(12):1044–1047. <https://doi.org/10.1111/ans.14177>
- Hohmann E, Glatt V, Tetsworth K (2017) Orthopaedic research in Australia: a bibliographic analysis of the publication rates in the top 15 journals. *ANZ J Surg* 87(9):709–713. <https://doi.org/10.1111/ans.13932>
- Ahmad SS, Evangelopoulos DS, Abbasian M, Roder C, Kohl S (2014) The hundred most-cited publications in orthopaedic knee research. *J Bone Joint Surg Am* 96(22):e190. <https://doi.org/10.2106/JBJS.N.00029>
- Wickham H (2009) *ggplot2: elegant graphics for data analysis*. Springer, New York
- Slowikowski K, Irissou J (2016) Repulsive text and label geoms for ‘ggplot2’. <https://cran.microsoft.com/snapshot/2017-02-03/web/packages/ggrepel/ggrepel.pdf>. Accessed 16 February 2019
- Gu Z, Gu L, Eils R, Schlesner M, Brors B (2014) Circlize implements and enhances circular visualization in R. *Bioinformatics* 30(19):2811–2812. <https://doi.org/10.1093/bioinformatics/btu393>
- Carr AJ, Robertsson O, Graves S, Price AJ, Arden NK, Judge A, Beard DJ (2012) Knee replacement. *Lancet* 379(9823):1331–1340. [https://doi.org/10.1016/S0140-6736\(11\)60752-6](https://doi.org/10.1016/S0140-6736(11)60752-6)
- Wang XJ, Xu SQ, Zhou SW, Xu W, Leary M, Choong P, Qian M, Brandt M, Xie YM (2016) Topological design and additive manufacturing of porous metals for bone scaffolds and orthopaedic implants: a review. *Biomaterials* 83:127–141. <https://doi.org/10.1016/j.biomaterials.2016.01.012>
- Choong PF, Dowsey MM, Stoney JD (2009) Does accurate anatomical alignment result in better function and quality of life? Comparing conventional and computer-assisted Total knee arthroplasty. *J Arthroplast* 24(4):560–569. <https://doi.org/10.1016/j.arth.2008.02.018>
- Leys T, Salmon L, Waller A, Linklater J, Pinczewski L (2012) Clinical results and risk factors for reinjury 15 years after anterior cruciate ligament reconstruction: a prospective study of hamstring and patellar tendon grafts. *Am J Sports Med* 40(3):595–605. <https://doi.org/10.1177/0363546511430375>
- Webster KE, Feller JA, Hartnett N, Leigh WB, Richmond AK (2016) Comparison of patellar tendon and hamstring tendon anterior cruciate ligament reconstruction: a 15-year follow-up of a randomized controlled trial. *Am J Sports Med* 44(1):83–90. <https://doi.org/10.1177/0363546515611886>
- Culvenor AG, Collins NJ, Guermazi A, Cook JL, Vicenzino B, Whitehead TS, Morris HG, Crossley KM (2016) Early patellofemoral osteoarthritis features one year after anterior cruciate ligament reconstruction: symptoms and quality of life at three years. *Arthritis Care Res* 68(6):784–792. <https://doi.org/10.1002/acr.22761>
- Zbrojkiewicz D, Vertullo C, Grayson JE (2018) Increasing rates of anterior cruciate ligament reconstruction in young Australians, 2000–2015. *Med J Aust* 208(8):354–358

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.